RESEARCH ARTICLE

Evidentiality, modality and probability

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Abstract We show in this paper that some expressions indicating source of evidence are part of propositional content and are best analyzed as a special kind of epistemic modal. Our evidence comes from the Japanese evidential system. We consider six evidentials in Japanese, showing that they can be embedded in conditionals and under modals and that their properties with respect to modal subordination are similar to those of ordinary modals. We show that these facts are difficult for existing theories of evidentials, which assign evidentials necessarily widest scope, to explain. We then provide an analysis using a logical system designed to account for evidential reasoning; this logic is the first developed system of probabilistic dynamic predicate logic. This analysis is shown to account for the data we provide that is problematic for other theories.

Keywords Evidentials · Japanese · Dynamic semantics · Modal subordination · Probability · Anaphora · Speech acts

1 Introduction

Until recently, evidential expressions have not received much attention in the (formal) semantic literature. This situation has changed in the last few years;

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influential work by Izvorski (1997) and Faller (2002), for instance, has in-spired a good deal of research. Evidentials in most languages examined in formal work so far seem have at least one characteristic in common: they must take widest scope. Even if they appear at the surface to be embedded under negation or modal operators, for instance, they cannot scope under them. In this paper we show that there are languages in which this charac-terization does not hold, and in which the semantic contribution of expres-sions with evidential content is best analyzed as a special kind of epistemic modality. The same conclusion was independently drawn by Faller (to appear) and Matthewson et al. (2006): taken together, the evidence is strong that evidentials need not take widest scope.

Many other semantic questions remain unanswered by the literature on evi-dentials. Consider, for instance, hearsay evidentials. For instance, is it enough just to overhear some information, or must one be told directly? Can inference play a role? More generally, since most of the literature on evidentials is oriented to functional and descriptive approaches (with some notable exceptions such as the above-cited works), a number of questions of interest to semanticists in the formalization of evidential facts are left unaddressed. How does evidential content affect anaphoric relations? Do evidentials block anaphora in a way similar to modals (Roberts 1989), or not? We will address some of these questions using data from Japanese. The conclusion will be that evidentials are similar to modals in this language in terms of their semantic behavior with respect to other operators and anaphors. They differ enough, however, that it is not obvious how to analyze them using traditional semantics for modals. The essential difficulty, as we will show, is that they explicitly indicate evidence source.

We start by laying out some general background on evidentiality and the difference between evidentials and epistemic modals, in Sect. 2. We consider some definitions of evidentiality that have been proposed in the literature and show that they apply to the Japanese system, with the result that these expressions must be considered to be truly evidentials, rather than simply epi-stemic modals. In Sect. 3, we move to the Japanese data that is the focus of the paper. Japanese has a large number of evidential and modal expressions. This paper considers two types of evidential expressions, the inferential and hearsay evidentials. We look at four distinct inferential evidentials—*mitai, (INF+)soo-da, yoo-da*, and *rashii*, which also can be used as a hearsay evidential—and one pure hearsay evidential, *(S+)soo-da*. After looking at the basic meanings and empirical facts about the evidentials, we provide new data about them in Sect. 4; the data relates to modal subordination and to the embeddability of the evi-dential content within conditional clauses and elsewhere. Section 5 discusses some existing formal accounts of evidentiality in conjunction with data from other languages, with an eye to determining whether any existing analysis is capable of accounting for the Japanese facts. Our conclusion is negative. Section 6 presents a new analysis in terms of a probabilistic dynamic semantics. The proposed logic is a version of dynamic predicate logic (Groenendijk and Stokhof 1991) augmented with probabilities, the first such logic proposed in the litera-ture. On our analysis, evidential operators are treated as a special type of

(probabilistic) modal dependent on particular evidence sources. This analysis is shown to capture the new data we present in Sect. 3. Section 7 sums up and discusses prospects for future research and implications for the crosslinguistic semantics of evidential constructions.

2 Defining evidentials and evidential modality

In this section we briefly survey some of the literature on evidentials, focusing on ways to define the class of evidential expressions. We then show that the Japanese expressions we are concerned with fall into this class. Without this discussion, it might be thought that the evidentials are simply epistemic modals (at least in the case of inferential evidentials), given the data we will be presenting;[1] but this supposition would not, ultimately, be correct, at least on a standard understanding of epistemic modality. Since we have not yet introduced these expressions in detail, we simply show what is required for a given expression to be classified as an evidential; in the next section, when the data is introduced in detail, it will become clear that the Japanese forms we consider satisfy the relevant criteria, though we will provide some argumentation to this effect in the current section as well.

An early work on evidentiality is Chafe and Nichols (1986a). In the introduction to the volume (Chafe and Nichols 1986b), Chafe and Nichols write the following (we omit most of their discussion of specific languages):

> ... the ways in which such awareness [human awareness that truth is relative (M&O)] is expressed in language. There are some things people are sure of, either because they have reliable evidence for them, ... Other languages [than English (M&O)] express these and other attitudes toward knowledge in sometimes similar, sometimes quite different ways. ... The data and analyses ... show us much about ... the ways in which ordinary people ... naturally regard *the source and reliability of their knowledge* [our italics (M&O)]. ... The term EVIDENTIAL has come to be used for such a device (Chafe and Nichols 1986b, p. vii).

Evidentials, then, serve to indicate where a given piece of knowledge came from, and the degree of reliability the speaker assigns to it, according to Chafe and Nichols. Note the difference with epistemic modals like *might*, which do not explicitly say anything about evidence source. Although speakers do not make epistemic claims (truly) without evidence—an assertion of *mightϕ* without any evidence for the claim is a deviant use—what that evidence might be is not indicated in any way by the modal.

Another recent typological work of importance is Aikhenvald and Dixon (2003). Aikhenvald (2003) writes the following, again in the context of an introduction to the papers in the volume:

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[1] This conclusion was suggested by a reviewer.

EVIDENTIALITY proper is understood as stating that there is some evidence for some information; this includes stating that there is some evidence, and also specifying what type of evidence there is. ... A number of grammatical categories, such as conditional mood or perfective aspect, can each acquire a secondary evidential-like meaning without directly relating to source of information. Such extensions of grammatical categories to evidential-like meanings will be referred to as 'evidential strategies'. ...

We take the above quote as crucial in understanding what the general class of evidential expressions is. An evidential expression is one that states that there is some evidence for some information and specifies the evidence type. Evidential systems can broadly be separated into two types based on whether they merely existentially quantify over evidence or also specify its type: systems that do only the first are called type I systems, and those that also indicate evidence type are called systems of type II. The reader is referred to Aikhenvald (2003) for details and examples of these types of system.[2]

Aikhenvald (2004) provides a slightly different definition of evidentiality. Summarizing her discussion, an expression should fulfill the following criteria to be classified as evidential in nature.[3] She notes, however, that the individual elements of the definition are not absolute, but vary somewhat across languages.

1. Evidentials indicate the source of justification for factual claims;
2. Indication of evidence source is the primary meaning of evidentials (i.e. it does not follow pragmatically);
3. Evidentials are usually not used when the fact in question is known directly to both speaker and hearer (and, if used, have a special pragmatic significance).

Generalizing from the above discussion, we can take it safely that expressions that indicate evidence source are evidentials. Note though that Aikhenvald (in 1) takes evidentials to simply indicate evidence source of *factual* claims. This is indeed a characteristic of many evidential systems, as noted in Sect. 1; and it is this characteristic that has led to the claim that they always take wide scope. Note however that any claim that all evidentials, when attached to a sentence denoting ϕ, indicate the source of evidence for ϕ would be inaccurate. Faller (2002) discusses extensively the inferential evidential *-chá* in Quechua, which, when attached to ϕ, indicates that the speaker believes that ϕ is possible ($\diamond\phi$), and that this conclusion of the speaker was obtained by inference. Thus it is not the case that evidentials cannot have modal meanings *along with* their evidential content. The same point is made by Marianne Mithun in a paper in Chafe and Nichols (1986a) (Mithun 1986); her conclusions are summed up by Chafe and Nichols (1986b) as follows:

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[2] Palmer (2001) is also a useful source of typological discussion.

[3] She provides additional criteria, which prove to be irrelevant to the Japanese case for various, largely morphosyntactic reasons; we do not consider these here.

> Marianne Mithun … extends the range of evidential phenomena to include not only 'evidence' but also *precision, probability, and expectations, noting that the same markers may be used for several of these functions, and furthermore that there are shifts among these functions over time*. [our italics (M&O)] (Chafe and Nichols 1986b)

Here we see again that evidentials need not involve only assertion, but can also include an element relating to the speaker's judgement of probabilities and expectation—in other words, a modal element.

What then is the relation of evidentiality to modality? We take our cue from de Haan (1999), who writes

> The hypothesis … is that evidentials are in fact *a priori* unmarked with respect to a commitment to the truth of the speech utterance on the part of the speaker. Evidentials merely assert that there is evidence to back up the speaker's utterance. Any conection between the two [evidentiality and modality (M&O)] … is secondary in nature. They encode different things (source of information vs. attitude toward that information). Although they are closely enough related to cause overlap in some languages, this overlap is not universal (de Haan 1999).

Thus modality and evidentiality are different; but there is nothing that says that a single form cannot encode both types of meaning. This, we argue, is what the Japanese inferential evidentials we consider—*mitai, yoo-da, inf+soo-da,* and *rashii*—are doing.

What is the difference between evidentials and 'true' modals, in the Japanese case? Epistemic modals such as *may* or *might* (Japanese *kamoshirenai* or *daroo*) can be used on the basis of available evidence; in fact, they ordinarily are, for it would be peculiar for a speaker to assert the possibility or likelihood of something based on no evidence at all, as mentioned above. But they differ in not expressing their sources explicitly; someone processing an utterance with a true modal has no way to determine how the speaker arrived at her conclusion. What we will call 'evidential modals,' on the other hand, express their sources explicitly. In certain cases we even get a kind of 'evidential binding,' where a given evidential is used on the basis of an explicitly introduced source. This fact is supported by the usability of the adverb *akirakani* 'apparently,' as follows:

(1) a. niwa-de   oto-ga   suru.   neko-ga   iru   kamoshirenai
       garden-in   sound-Nom   is-heard   cat-Nom   exist   may
       'I'm hearing a sound from the garden. There may be a cat (there).'

   b. niwa-de   oto-ga   suru.   #akirakani   neko-ga   iru
       garden-in   sound-Nom   is-heard   apparently   cat-Nom   exist
       kamoshirenai
       may
       'I'm hearing a sound from the garden. Apparently there may be a cat (there).'

   c. niwa-de   oto-ga   suru.   akirakani   neko-ga   iru   yoo-da
       garden-in   sound-Nom   is-heard   appearently   cat-Nom   exist   Evid
       'I'm hearing a sound from the garden. Apparently there is a cat (there).'

This kind of phenomenon will play a large role in the semantics we provide in this paper.

The case is even clearer for the Japanese hearsay evidentials *rashii* and *S+soo-da*. These expressions have no modal meaning at all, and also involve no assertion on the part of the speaker, as we show in detail in the next section (this is also the case for Quechua hearsay evidentials, as Faller has shown, a point we return to below).[4] They merely indicate that the speaker has been told (or simply heard) that ϕ, for ϕ in the scope of the evidential. It would therefore be odd to analyze the Japanese evidentials as all being part of a special class of epistemic modal, for these expressions exhibit no modal content whatsoever.

Before closing this section, we should note one last point. Evidentials are often characterized as being *obligatory* in certain languages. Given this, one might ask whether the Japanese evidentials can really be considered to be evidentials, given that they are not obligatory at all (since the speaker can use other expressions that don't express evidence source, if she so chooses). The answer is yes. Empirically, the statement that 'true evidentials' are obligatory is not accurate. Although it is true that many languages that have evidentials strongly prefer their use, such use is almost never—and possibly simply *never*—obligatory. Faller (2002) clearly shows that Quechua allows for non-use of evidentials, although it is often characterized as an example of a language of this type.[5] The only language in which use of evidentials in every sentence is *completely* obligatory is Tuyuca, a Tucanoan language spoken in South America, and even this case is controversial (de Haan 1999). Thus we do not take the optionality of the Japanese evidentials as evidence that they cannot be considered to be evidential expressions.

We now turn to a detailed discussion of the subset of the Japanese evidential system we consider in this paper.

3 Japanese evidentials: the basic data

We first give some background on the Japanese evidentials. We will look at each evidential individually in terms of what information sources it can be used with. The discussion here largely follows the presentation in Ogata (2005b), which includes a (critical) survey of the theory of the Japanese evidentials of Aoki (1986) and the theory of *chookoosei*-modality (modality of indication) presented by Nitta (1989) and Moriyama et al. (2000). Although the discussion builds on the existing literature, we will present a number of new observations as well.

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[4] Matthewson et al. (2006) show that St'át'imcets is different in this respect, however. This cross-linguistic difference is interesting and suggestive for the broader semantic typology of evidentials. We will not pursue this point in the present paper.

[5] Faller notes that when no evidential is used a similar interpretation arises to that of the evidential enclitic *-mi*, which is discussed further below.

First we would like to point out some general features of the evidentials. The first is syntactic. The evidentials all appear sentence-finally, as in (2).[6] For the time being, we will give identical glosses to all the inferential evidentials. Their differences will be brought out later in this section.

(2) a. Jon-wa   konya-no   paatii   ni kuru   rashii
        John-Top   tonight-Gen party   to come   RASHII
        'It seems that John will come to the party tonight.'
   b. Jon-wa   konya-no   paatii   ni kuru   soo-da
        John-Top   tonight-Gen party   to come   SOO-Cop.pres
        'I heard that John will come to the party tonight.'
   c. Jon-wa   konya-no   paatii   ni kuru   mitai   (da)
        John-Top   tonight-Gen party   to come   MITAI   (Cop.Pres)
        'It seems that John will come to the party tonight.'
   d. Jon-wa   konya-no   paatii   ni Kuru   yoo-da
        John-Top   tonight-Gen party   to come   YOO-Cop.Pres
        'It seems that John will come to the party tonight.'
   e. Jon-wa   konya-no   paatii   ni ki-soo-da
        John-Top   tonight-Gen party   to come.Inf-SOO-Cop.Pres
        'It seems that John will come to the party tonight.'

There is another nominal-modifying use of some of these morphemes that we should be careful to exclude. McCready and Ogata (in press) call this use the *adjectival* use of the morphemes: as this coinage suggests, here the morphemes are used as nominal modifiers. Some examples are shown in (3); the morphemes used here—*mitai, yoo*, and *rashii*—are the only ones that can appear in this context. Note that the morphemes here appear between two NPs, in the configuration NP$_1$ Evid NP$_2$ (where Evid is one of the evidential morphemes). McCready and Ogata (in press) argue that these constructions involve a kind of comparative construction on which NP$_2$ is compared to NP$_1$ in terms of either the degree of resemblance of the two (in some respect) for *mitai* and *yoo*, or the degree to which NP$_1$ resembles some stereotype associated with NP$_2$, in the case of *rashii*.

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[6] It seems as if in some cases they can also modify nominals, as in the representative examples below (from a Google search (July 21, 2005)).

   i. jitensha de tabi   shiteiru rashii   hito
        bicycle   on   travel doing   RASHII   person
        'person who appears to travel by bicycle'
   ii. okot-teiru   yoo-na   hito
        be.angry-Prog YOO-Cop.Pres   person
        'a person who appears to be angry'

These examples seem to have a similar semantics to the sentence-final uses, as far as we can determine. (ii) also has a reading on which the relative clause is interpreted as an adjectival modifier of the type discussed in the main text immediately below. The grammaticality of this example has been called into question by a reviewer; the reasons behind this speaker variation are not clear to us at present.

(3) a. onna   rashii   hito
        woman   RASHII   person
        'a person who approaches the stereotype of femininity'
    b. onna   mitai-na   hito
        woman   MITAI-Cop.Pres   person
        'a feminine person'
    c. onna-no   yoo-na   hito
        woman-Gen   YOO-Cop.Pres   person
        'a feminine person'

We will exclude this use in what follows. In certain cases, a given example can be interpreted in either way (as noun-modifying evidential or adjectival); we will always intend the evidential use in cases like these.

We now continue to the basic facts about the individual evidentials.

3.1 *Rashii*

We begin with *rashii*. *Rashii* on its evidential use is ordinarily an inferential evidential: it applies to whole sentences, indicating that the speaker obtained the knowledge he bases his statement on indirectly via inference.

(4) a. Konya   Jon-ga   kuru   rashii
        tonight John-Nom   come   RASHII
        'John is coming tonight (it seems).'
    b. Koizumi-sooridaijin-wa   aitsu-o   kubi   ni   suru   rashii
        Koizumi-PM-Top   him-Acc   neck   to   do   RASHII
        'Prime Minister Koizumi is going to fire him (it seems).'

According to Aoki (1986), *rashii* is used 'when the evidence is circumstantial or gathered through sources other than one's own senses.' He provides the following example. Ogata (2005b) accordingly translates *rashii* as 'seems.'

(5)   kono   kusuri-wa   yoku   kiku   rashii
       this   medicine-Top   well   work   RASHII
       'I infer from what I heard that this medicine works well.' (Aoki 1986, p. 232)

However, as noted by Ogata (2005b), this characterization is not quite right. *Rashii* is in fact compatible with certain sorts of evidence which certainly do come from one's own senses. Ogata's examples involve indirect auditory evidence and internal sensory evidence.

(6) a. hune-ga   kita   rashii
        ship-Nom   came   RASHII
        'It seems that a ship has come.' (based on the sound of a horn) (Ogata 2005b)

b. kaze-o   hiita   rashii
   cold-Acc   took   RASHII
   'It seems that I have caught a cold.' (based on my headache)

c. nazeka   yoku wakaranai   kedo kore-wa yoku   ureru   rashii
   why-∃   well not-understand   but this-Top well   sell   RASHII
   'I don't really understand why but this thing apparently sells well.'

Ogata also notes that *rashii* can be used with evidence that comes from unknown sources—that is, evidence whose source is not clear, but which is still sufficient to make the speaker confident of the truth of the propositional content, as in (6c). And, interestingly, *rashii* is also compatible with hearsay evidence like that used for the pure hearsay evidential *soo-da*, which is discussed further below. Ogata provides the following example.[7]

(7)   rinjin-no   hanashi ni   yoru-to   koko-wa   dare-mo
      neighbor-Gen speech to   according-COMP   here-Top   who-∀
      inai   rashii
      COP.NEG RASHII
      'According to the neighbor, no one lives here.'

Rashii can even be used, it seems to us, in contexts which involve only hearsay evidence with no inferential flavor at all. Clearly this is the case in (7) as well. It seems, then, that *rashii* is compatible with multiple types of evidence, both (relatively) indirect sensory evidence and also hearsay evidence. Its semantics thus should be compatible with that of *soo-da* in the sense that both admit pure hearsay evidence. *Rashii* differs here from the other inferential evidentials, which lack this ambiguity.

There are certain other cases in which *rashii* behaves differently from the other inferential evidentials. Ogata (2005b) provides a comprehensive discussion of types of evidence with which particular evidentials can be used. *Rashii* is compatible only with certain kinds of evidence: hearsay evidence (as we have already seen), auditory evidence (6a), internal sensory evidence (6b), and evidence from unclear sources (6c). Excluding hearsay evidence, the other inferential evidentials are also compatible with all these sources. However, they also admit other sources which *rashii* does not, as we will show below.

3.2 Infinitive + *soo-da*

According to Aoki (1986), infinitive + *soo-da* is an evidential, while Teramura (1984) characterizes it as a modality denoting a prediction (*yosoo*) or a

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[7] Here and below, we modify the romanization of examples from their original sources when necessary to maintain consistency with our preferred system.

premonition (*yokan*) whose source lies in the speaker's observations. *Inf+soo-da* is actually perhaps the most 'direct' of the inferential evidentials in an intuitive sense, as noted by Teramura (1984), who takes infinitive + *soo-da* to have the least guess-like quality and the strongest flavor of a direct description of a situation among the Japanese modal and evidential auxiliaries. It is compatible with several sorts of evidence, according to Ogata: tactile, visual, auditory, internal sensory, and unknown source evidence. These possibilities are held in common with the other inferential evidentials (except for *rashii* in the case of tactile and visual evidence).

(8) a. Tactile evidence (Ogata 2005b):
         koko-ga   mushiba-ni   natteiru   yoo-da
         here-Nom   cavity-Dat   becoming   YOO-Cop.Pres
         'I seem to have a cavity here (touching tooth).'
    b. Visual evidence:
         soko-ga   mushiba-ni natteiru   yoo-da
         there-Nom   cavity-Dat   becoming   YOO-Cop.Pres
         'You seem to have a cavity there (observing blackened tooth).'

This form, however, admits some additional possiblities. It can be used with what Ogata refers to as 'experienced-event' and 'direct-visual' evidence, as in (9a) and (9b) respectively. By 'experienced-event' evidence Ogata means reasoning from patterns derived by inference on events that the speaker has experienced. None of the other inferential evidentials can be used in these cases.

(9) a. kinoo   mo daremo ko-na-katta   node kyoo mo   daremo
         yesterday   also anyone come-Neg-Pst   so   today also anyone
         ko-nasa-soo-da
         come-Neg-SOO-Cop.Pres
         'No one came yesterday, so it seems that no one will come today either.'
    b. mirukarani   kono ringo-wa   oishi-soo-da
         as-it-looks   this apple-Top   tasty-SOO-Cop.Pres
         'Based on its appearance this apple seems tasty.'

At first glance, (10) seems to be a counterexample to this characterization of *soo-da* as admitting direct-visual evidence. Here use of *inf+soo-da* is bad despite the visual nature of the evidence, which is unexpected.

(10) #mirukarani kono   ringo-wa   aka-soo-da
        as-it-looks   this   apple-Top red-SOO-Cop.Pres
        'Based on its appearance this apple seems red.'

We can conclude that *soo-da* is selective with respect to the semantic class of the adjective that it takes as complement, as have others in the literature. According to Teramura (1984), *soo-da* selects adjectives which denote *inner* properties (non-visible properties) such as *delicious* but not *outer* properties

(externally visible properties) such as *red*. Still, the sentence in (11) is acceptable.

(11)   ringo-wa   ikken   aka-soo-de-mo   te-ni   totte
        apple-Top   at-the-first-glance   red-SOO-Cop.Inf-but   hand-Loc   take
        yoku   miru-to   soo   demo   nai
        well   see-Cond.   so   be.CONC   not
        koto-ga   aru.
        case-Subj   exist
        'At first glance, an apple may seem to be red, but when you take it and look
        at it closely, sometimes it isn't so.'

(12) shows that *soo-da* can be used for expressing an inference from available facts to a conclusion that is expected given world knowledge. For example, in (12a), the ripe and attractive appearance of the watermelon coupled with knowledge about how the flesh of such melons looks licenses the statement in the second sentence. These examples also come from Google.

(12)a. rippa-na   suika-ga   aru.   naka-wa   aka-soo-da.
        fine-Cop   water-melon-Subj   exist   inside-Top   red-SOO-Cop.pres
        'There is a fine watermelon. Its inside seem as if it must be red.'
    b. shatsu   ichi-mai-no   kare-wa   samu-soo-da.
        shirt   one-sheet-Gen   he-Top   cold-SOO-Cop.pres
        'It seems that he must feel cold (because) he has only a shirt.'

Similarly, *soo-da* can attach to the objective property *atsu-i* 'hot,' even when it does not express the subjective sensation of the speaker. Note that in this example use of the evidential is impossible when the speaker has certain knowledge of the proposition that lies in its scope (see also Kekidze 2000); this is actually something quite general that holds of all the Japanese evidentials. Like the data we will see in the next section, this fact again makes this evidential look very much like a modal operator, in that modification by modals when the speaker is actually sure of the modified proposition results in pragmatic oddity, for Gricean reasons. We return to this point later.

(13)a.#Soto-ni   deta. Totemo   atsu-soo-da.
        outside-Loc   went   very   hot-SOO-Cop.pres
        'I went outside. It seemed to be very hot.'
    b. Soto-wo   mita. Totemo   atsu-soo-da.
        outside-Acc   saw   very   hot-SOO-Cop.pres
        'I looked outside. It seemed to be very hot.'

It appears, then, that *Inf+soo-da* can be used in contexts in which the available information supports an inference on the part of the speaker to the content of the infinitive (here a proposition; we abstract away from this detail here), unless that content is already known to be true. Thus the distinction

between external and internal properties is a Gricean one: properties which the speaker already knows to hold of an object, or not, are not usable with Inf + *soo-da*.

Another kind of example involves predicates that require speaker judgement. The next example does contain an 'inner' property, *kowai* 'scary,' but clearly the content in the scope of the evidential follows—for the speaker—from known facts about George Romero.

(14) Jooji   Romero-ga   eiga-wo   tsukutta.   totemo
      George   Romero-Subj   movie-Acc   produced.   very
      kowa-soo-da.
      scary-SOO-Cop.pres
      'George Romero produced a movie. It seems like it must be really scary.'

In cases like this, it seems to us, the judgement of the speaker is crucial; for other speakers, it might be that the evidence is not evidence at all. Further, use of this sort of evidence is subjective, as it is limited to predicates of personal taste and to clear instances of inference. We will use the term *judgemental evidence* for this sort of case. Among the inferential evidentials, only *soo-da* can be used with evidence of this sort.

It has also been noted that using this evidential gives the sense that the evidence present is very immediate, though it is not easy to characterize this sense exactly. Consider first the following example from Ogata (2005b).

(15) ame-ga   furi-dashi-soo-da
      rain-Nom   fall-start-SOO-Cop.Pres
      'It looks like it is going to rain (any minute).'

Here the impression is that it will rain immediately; the evidence for this would presumably be the state of the sky, rising wind, smell of ozone, etc. Substituting another inferential evidential, e.g. *mitai* or *yoo-da*, here removes the sense that rain is going to fall soon. Instead it could be the case that the speaker is talking about events a week later, say on the day his interlocutor plans to go to the beach.

One might conclude that some statement about immediate effect should be built into the semantics: e.g., that use of *infinitive + soo-da* should assert that whatever eventuality the sentence describes will happen soon. Of course this is vague, but presumably the time length here will be related pragmatically to the particular content of the sentence. But in fact even such a vague statement would be too strong. Consider (16a) and its sentence-final variant (16b).

(16)a. Taro-no   suki-soo-na   eiga   da   ne
        Taro-Gen   like-SOO-Cop.Pres   movie   Cop.Pres   NE
        'This is a movie of the kind that Taro seems like he would like (it)'
    b. Taro-wa   kono eiga-ga   suki-soo-da
        Taro-Top   this   movie-Nom   like-SOO-Cop.Pres
        'It seems that Taro would like this movie.'

Here it is not clear at all that Taro should come to like the movie immediately; in fact, it is likely that this conversation is taking place in a context where Taro is not even present. We conclude that we should not build the immediacy into the semantics, but rather that the sense of immediacy that arises is an implicature stemming from the kind of evidence needed for use of this evidential. Since the kinds of evidence that are compatible with *inf+soo-da* include evidence that is more direct than for the other evidentials, it makes sense that such an implicature would be generated.

In fact, there is a generalization here that has not yet been noted, as far as we know. Note the aspectual type of the embedded verb in (15) versus that of the predicate in (16): the first is an achievement and the second a stative. It turns out that the relevant sense of immediacy appears just in case the verb is nonstative (an activity, accomplishment, or achievement); it does not appear with statives at all. Consider the following examples. (17a) is an activity, and (17b) an accomplishment.

(17)a. Jon-ga   hashiri-soo-da
      John-Nom   run-SOO-Cop.pres
      'John looks like he is about to run.'
   b. kare-ga   biiru-o   nomi-soo-da
      he-Nom   beer-Acc drink-SOO-Cop.pres
      'He looks like he is about to start drinking his beer.'

A discussion of the reasons for this fact is beyond the scope of the present paper, though we will build a stipulative way of accounting for it into the semantics as a stopgap.

3.3 *Yoo-da* and *mitai*

Yoo-da and *mitai* behave nearly identically in terms of the sorts of evidence they can accept, according to Ogata. For this reason, we will treat them together. They are, of course, similar to *rashii* in being inferential evidentials, but differ from it and from *Inf+soo-da* in the sources of information they allows. According to Aoki (1986), *yoo-da* is used when the speaker has 'visible, tangible or audible evidence collected through his own senses' that is then used in making the inference to the content of the *yoo-da*-marked sentence. He has nothing to say about *mitai*, but it seems to be similar in this respect. There are differences, however.

Neither *yoo-da* or *mitai* can be used with what we above called *judgemental evidence*. There is a small difference in acceptability of the two with respect to strictly inferential evidence; use of *yoo* is slightly worse than use of *mitai* in examples like (9a), though both are equally bad with (9b); corresponding examples with *yoo* and *mitai* are given in (18).

(18)a. kinoo   mo   daremo ko-na-katta   node kyoo mo   daremo
        yesterday also anyone come-Neg-Pst so   today also anyone
        ko-nai   {yoo/?mitai}-da
        come-Neg {YOO/MITAI}-Cop.Pres
        'No one came yesterday, so it seems that no one will come today either.'
   b.   mirukarani kono ringo-wa   oisii {#yoo/#mitai}   da
        as-it-looks this apple-Top tasty YOO/MITAI   Cop.Pres
        'Based on its appearance this apple seems tasty.'

These evidentials differ from *rashii* in being acceptable with evidence obtained through tactile and visual sources.

3.4 *φ* + *Soo-da*

The last evidential we will consider is *soo-da*. There are two distinct types of *soo-da*, as already noted; one which embeds the infinitive form of verbs, and one which embeds full tensed sentences. The first type was discussed previously. The second is a pure hearsay evidential, differing in this respect from the ambiguous *rashii*, which, as we saw, is good with both inferential and hearsay evidence sources. The use of *S+soo-da* is exemplified by the following sentences.

(19)a. Konya   Jon-ga   kuru   soo-da
        tonight John-Nom   come   SOO-DA
        'John is coming tonight (I heard).'
   b.   Koizumi-sooridaijin-wa   aitsu-o   kubi ni suru soo-da
        Koizumi-PM-Top   him-Acc neck to do   SOO-DA
        'Prime Minister Koizumi is going to fire him (I heard).'

As we have seen, evidential *soo-da* (and also *rashii*) applies to whole sentences and indicates that the basis for the speaker's belief in the proposition the sentence expresses comes from hearsay. If the speaker has not heard the information from another person, it is peculiar—infelicitous—to use *soo-da*. Now, this requirement is clearly satisfied for a speaker if someone else explicitly tells them something—for instance, if A has been told by B that John is coming tonight, A can utter (4a) felicitously. But what if the transmission of information is less direct? It is worth exploring this issue.

One first wonders whether the information transmission must be directed at A. We can imagine a situation in which A overhears B telling C that John is coming tonight. (20a), uttered after this takes place, can be used. This indicates that A need not be told the information explicitly, but only needs to acquire the information via some act of communication. This fact may be unsurprising, given that facts acquired via, e.g., the newspaper can be used as a basis for use of *rashii* or *soo-da*, as would generally be the case for (20b); presumably the newspaper writer does not have a particular individual in mind as audience as he writes his article, and nor does the utterer of a sentence like (20b) need direct acquaintance with people connected to the political establishment.

(20)a. Konya   Jon-ga   kuru   rashii/soo-da
      tonight   John-Nom   come   RASHII/SOO-DA
      'John is coming tonight (I heard).'
  b. Koizumi-sooridaijin-wa aitsu-o   kubi ni suru rashii/soo-da
     Koizumi-PM-Top   him-Acc neck to do   RASHII/SOO-DA
     'Prime Minister Koizumi is going to fire him (I heard).'

Let us now consider a different sort of indirectness. Assume that James and John are joined at the hip, and that if James comes to a party, John always comes too. Now assume that B tells A that James will be coming to the party tonight. A of course knows of John and James' friendship. Can A utter (20a) in such a situation? After all, in some sense A has been told that John is coming; a single step of inference is enough for A to conclude that. As it turns out, (20a) cannot be used here with *soo-da* (though *rashii*, on its inferential use, is good). We can conclude that the proposition *soo-da* applies to must be communicated directly to some individual—but this need not be the case for *rashii*, showing again that *rashii* has an inferential use.

The last question we should consider is whether the speaker is responsible for the content in the scope of *soo-da*. Faller (2002), in her discussion of the Quechua evidentials (which we will come back to below), notes that reportative *-si* can be used when the informational content is known by the speaker to be false, in case the sentence is used as a correction, as in the following. Use as a correction of course entails that the speaker believe the content to be false as well.

(21)   Pay-kuna-**s** ñoqa-man-qa   qulqi-ta   muntu-ntin-pi   saqiy-wa-n,
       (s)he-PL-**si** I-Illa-Top   money-Acc   lot-Incl-Loc   leave-1o-3

       mana-má   riki riku-sqa-yki i   un
       not-Surp   right see-PP-2   not   one
       sol-ta   centavo-ta-pis saqi-sha-wa-n-chu
       Sol-Acc   cent-Acc-Add   leave-Prog-1o-3-Neg
       'They left me a lot of money (they said/it was said), but as you have seen, they didn't leave me one *sol*, not one cent.'   (Faller 2002, p. 191)

It turns out that *soo-da* is similar; the speaker need not believe the content himself for the sentence to be true and felicitous. The noncontradictory nature of the following examples (several of a large number of hits from a Google search; 5/15/2006) makes the point.

(22)a. miso-tama tte   konnyaku?!   nanka   miso-ni
      miso-ball QUOT   devil's tongue root jelly well   miso-DAT
      naru   soo-da   kedo   shinjirarenai na
      become   SOO-DA but   can't believe
     'Miso balls are devil's tongue root jelly?! Well, they say it'll become miso, but I can't believe it.'[8]

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[8] http://www.fururu.net/itudoko24/20060409085501

  b. naniyara   raishuu   kara-wa   atsuku-naru soo-desu
      for some reason   next week from-TOP   hot-become   SOO-DA.Hon
      ga   totemo shinjiraremasen
      but   really   can't believe.Hon
      'They say it's going to get hot starting next week, but I really can't believe
      it.'[9]

We can also consider a simpler constructed example.

(23)   Jon-ga   kuru soo-da   kedo, hontoo-ni   kuru-no   ka
         John-Nom come SOO-DA but   really-DAT come-NOM   Q
         totemo shinjirarenai
         really   can't believe
         '(They said) John would come, but I really don't think he will.'

This example and those in (22) clearly indicate that there is no entailment
from $\phi sooda$ to ϕ, since a speaker can state the first without believing the
second.

3.5 Other evidentials

Our discussion here has not exhausted all Japanese evidential constructions. In
fact, there are many other constructions including those in (24), which are
frequently observed in newspapers; the examples in (24) are in fact based on
examples found in *Asahi Shinbun 1989–1993*, an archive of articles from a
Japanese newspaper.

(24)a. Kaijoo-mae-de-wa   kougi-guruupu 7,8-nin-ga
      conference.hall-front-Dat-Top   protest-group   7,8-people-Nom
      taiho-sare-ta   *moyoo-da*.'
      arrest-Pass-Past   Evid
      'In the front of the conference hall, 7 or 8 people of the protesting group
      seem to have been arrested.'
  b. Taihuu   Tarimu-wa kon'ya   Fukushuu-ni jooriku-suru
      Typhoon   Tarim-Top tonight   Fuzhou-Dat   land
      mikomi-da/mitooshi-da.
      Evid
      'Typhoon Tarim seems as if it will make landfall on Fuzhou tonight.'

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[9] http://www010.upp.so-net.ne.jp/kazu-honyomi/nikki0308.html

c. Doru-wa   120-en-ni   naru   *kumoyuki-da.*
   dollar-Top   120-yen-Dat   become   Evid
   'The exchange rate of the US dollar seems as if it will become 120 yen.'
d. Hukyoo-kan-wa   sarani   hirogaru   *kehai-da.*
   Depression-mood-Top   more   spread   Evid
   'The depressed mood looks like it will spread further.'
e. Hisashiburini   konzatsu-ga   modottekita   *yoosu-da.*
   After-a-long-time   congestion-Nom   had-returned   Evid
   'After a long time, the congestion (of the town) seems to have returned.'
f. Nihon-he-no   keikaikan-ga   takamatteiru   *kanji-da.*
   Japan-Dat-Gen   precaution-Nom   getting-higher   Evid
   'The feeling of wariness toward Japan seems to be getting stronger.'

Mikomi, mitooshi, kumoyuki, kehai, keikou, yousou have a meaning similar
to that of *Inf* +soo, and can only attach to non-past forms of verbs. We will not
consider these other evidentials further in this paper.

3.6 Summary

The following table summarizes the findings of this section as to what sorts of
evidence the various Japanese evidentials can mark. We will abbreviate the
evidence types—tactile, visual, auditory, internal sensory, unknown, judge-
mental, and report—to their initial letter to make the table readable.

	T	V	A	IS	U	J	R
yoo	√	√	√	√	√	X	?
mitai	√	√	√	√	√	?	?
rashii	X	X	√	√	√	X	√
Inf+ soo-da	√	√	√	√	√	√	X
φ + soo-da	X	X	X	X	X	X	√

Here is a partial visual representation of this table, which may be more
perspicuous. We omit *mitai* in that it is, we take it to be more or less the same as
yoo. Note also that the source hierarchy on the horizontal axis of the graph is a
representation of our intuitions and has not been systematically investigated. It
is also not intended to correspond to evidential hierarchies like those discussed
by Faller (2002) and others. We allow hearsay evidence to cover the entire
vertical axis—from completely uncertain to positive—because the speaker can
have varying degrees of commitment to the content of hearsay evidence, as
shown above.
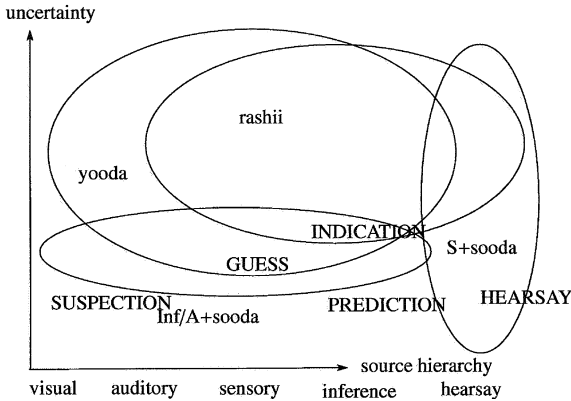
We now move to some more complex data about the evidential semantics.

4 Scope, embeddability and anaphora

This section presents new data that has implications for how the evidentials should be analyzed. The data relates to scope and anaphora. More specifically, Sect. 4.1 considers how evidentials interact with individual pronominal anaphors (the standard understanding of modal subordination) and Sect. 4.2 looks at the possibility of embedding the evidentials under other operators. The ultimate conclusions of the section will be that, first, the semantics of the evidentials must include a modal element, and second, that we need to allow for a way to let evidential content scope under other semantic operators in certain cases (so evidential content must be truth-conditional). These two considerations, with others to be presented later, lead to the particular account we will advocate in this paper.

4.1 Modal subordination

To begin with, consider (26), an evidential version of standard examples like (25) that show that modals block anaphoric dependencies (Roberts 1987, 1989).

(25) A wolf might come in. It would eat you first.

(26)a. ookami-ga   kuru   mitai   da
        wolf-Nom   come   MITAI   Cop.Pres
        'A wolf will come in, it seems.'
    b. #anta-o   taberu
        you-Acc   eat
        'It will eat you.'

Here the anaphoric dependence needed for the second sentence is impossible; just as in cases with modals, the evidential seems to block anaphoric depen-

dency on *ookami* 'wolf.' And, just as in other cases of modal subordination, adding a modal to the second sentence improves anaphora dramatically. Japanese modal subordination will be discussed in more detail later in the paper (see also McCready and Asher 2006).[10]

(27)a. ookami-ga   kuru   mitai   da
       wolf-Nom   come   MITAI   Cop.Pres
       'A wolf will come in, it seems.'
   b. anta-o   taberu   kamoshirenai
      you-Acc   eat   might
      'It might eat you.'

The situation is similar with the other inferential evidentials, though we will not present the examples for reasons of space. We conclude, based on examples like these, that the 'subordinate context' created by an inferential evidential is one that can be picked up by a modal.

The situation is different for hearsay *soo-da*, as one might expect. As we've seen propositions in the scope of *soo-da* need not be believed to any degree by the speaker. Thus, intuitively, it is not surprising that anaphora is not supported by adding a later modal; there is no prior modal context for it to pick up. To sharpen the judgement, assume that the speaker of these sentences does not believe the content in the scope of *soo-da*.

(28)a. ookami-ga   kuru   soo   da
       wolf-Nom   come   SOO   Cop.Pres
       'A wolf will come in, it seems.'
   b. #anta-o   taberu   kamoshirenai
      you-Acc   eat   might
      'It might eat you.'

In certain cases, adding an evidential to the second sentence of a discourse like this also licenses modal subordination, as in the following example. Here the context is one in which one hears the sound of an engine; this is the evidence for the coming of the bus.

(29)a. basu-ga   kiteiru   yoo   da
       bus-Nom   coming   YOO   Cop.Pres
       'It seems that a bus is here.'
   b. enjin-ga   okashii   mitai   da
      engine-Nom   strange   MITAI   Cop.Pres
      'It sounds like it has engine problems.'

The classic modal subordination examples also can appear with evidentials that pick up an earlier subordinate context. The context here is one in which we

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[10] It is worth noting that speakers exhibit a great deal of variation on examples like these. Some are very permissive and some extremely severe in their judgements. We return to this point below in Sect. 5.2.

are in a cabin in the woods, with no window, listening to a howling noise outside. We think that we are hearing a wolf, or wolves; but in fact the north wind is just strong tonight.

(30)a. ookami-ga   kita   mitai/yoo   da
      wolf-Nom   came   MITAI/YOO   Cop.Pres
      'A wolf/Some wolves has/have come, it seems.'[11]
   b. yatsu(ra)-wa   totemo   onaka-o   sukaseteiru   mitai/yoo
      it(they)-Top   very   stomach-Acc   emptied   MITAI/YOO
      da
      Cop.Pres
      'It/they seems/seem to be very hungry.'

Interestingly, similar examples with *rashii* in second position are impossible.[12]

(31)a. ookami-ga   kita   mitai/yoo   da
      wolf-Nom   came   MITAI/YOO   Cop.Pres
      'A wolf/Some wolves has/have come, it seems.'
   b. #yatsu(ra)-wa   totemo   onaka-o   sukaseteiru   rashii
      it(they)-Top   very   stomach-Acc   emptied   RASHII
      'It/they seems/seem to be very hungry.'

Examples like this one indicate something important about the sort of information source that *rashii* takes as evidence: *rashii* allows evidence inferred directly from sensory or observed evidence, but not evidence obtained by inferential processes *from the content of other inferences*. In this example, the speaker has no direct evidence for the wolves being hungry; the speaker guesses this based on the amount of noise she perceives the wolves to be making. This sort of evidence cannot be antecedent to *rashii*. The system we present below will obey this constraint.

The full body of constraints on when it is possible to modally subordinate with one evidential or another are nontrivial—even more so, perhaps, than the situation in English modal subordination with modals, where the constraints are still not fully understood after nearly 20 years of research (Roberts 1987, 1989; Heim 1992; Frank 1997; Geurts 1999; Asher and McCready 2007, and many others). In many cases speaker judgements are inconsistent, meaning that experimental work and/or statistical work on survey data is essential (as is also the case for other instances of modal subordination in Japanese and elsewhere). Working out all constraints on the evidential case is far beyond the scope of this paper.[13] It is enough for our purposes—determining what a semantics for Japanese evidentials should look like—to observe that modal subordination

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[11] The subject here can be interpreted as either singular or plural, as usual with bare nominals.

[12] Again, some variation is found with judgements here. Some people find this discourse fine.

[13] We note only that there seem to be distinctions between null pronouns and (bindable) demonstratives in terms of when modal subordination is allowed. We leave a detailed discussion for future work.

phenomena arise with the evidentials. The conclusion that we draw from this fact is that the inferential evidentials must include a modal component.

4.2 Embedding the evidentials

One characteristic of many evidentials, cross-linguistically, that has been noted by a number of authors is that they cannot be semantically embedded; in other words, the evidential content always takes wide scope. This fact has been taken to show that evidential content cannot be truth-conditional (though see Higginbotham 2005 for a more nuanced view). We will discuss this cross-linguistic data further in Sect. 5.1 below, but for the present we would like to concentrate on some Japanese examples in order to show that these observations do not universally hold for expressions with evidential content.

We begin with conditionals. Consider first the following Cuzco Quechua conditional example from Faller (2002), which involves the hearsay evidential enclitic -*si*; this will give us a feel for the issue. Here, the material in the conditional antecedent does not serve to satisfy the requirements of the evidential; the evidential content invariably projects out from the conditional.

(32)   Sichus   ni-wa-rqa-n   Juan   hamu-na-n-ta   chay-qa,   Juan-qa
       if   say-1o-Pst1-3   Juan   come-Nm-3-Acc   this-Top,   Juan-Top
       hamu-nqa-**s**
       come-3Fut-**si**
       '(I heard that Juan will come and) if I was told that Juan will come, then Juan will come.'

Japanese does not behave this way. It is the case, quite generally, that—given the right context—evidential content does not need to scope out. Consider first some examples involving inferential evidentials.

(33)a.   Taro-ga   kuru   yoo   da-ttara   osiete   kudasai
         Taro-Nom   come   YOO   Cop.Pres-COND   teach   please
         'If it looks like Taro will come, please tell me.'
   b.   Taro-ga   ki-soo-da-ttara   osiete   kudasai
         Taro-Nom   come-SOO-Cop.Pres-COND   teach   please
         'If it looks like Taro will come, please tell me.'
   c.   Taro-ga   kuru   mitai   da-ttara   osiete   kudasai
         Taro-Nom   come   MITAI   Cop.Pres-COND   teach   please
         'If it looks like (Taro) will come, please tell me.'

Further, in Japanese, evidential content can embed even with hearsay evidentials, quite generally, although it is easier given the right context. (34) is ambiguous between a reading in which the evidential content scopes out—so the speaker has in fact heard that Taro will come—and one on which it

doesn't—so the speaker is making his going conditional on his hearing Taro will come.

(34)a. Taro-ga   kuru   soo   da-ttara   osiete   kudasai
       Taro-Nom   come   SOO   Cop.Pres-COND   teach   please
       'If you hear that Taro will come, please tell me.'
   b. Taro-ga   kuru   soo   nara   osiete   kudasai
       Taro-Nom   come   SOO   Cop COND   teach   please
       'If you hear that Taro will come, please tell me.'

Here use of this sentence is quite neutral and does not presuppose that there is any evidence (at present) that Taro will come.[14] It should be noted that some speakers find examples like these quite unnatural, and in fact cannot embed either hearsay *soo-da* or *rashii* in sentences like these. The reason for this difference is not clear to us at present. Perhaps for such speakers *soo-da* and *rashii* are in fact evidentials of the Quechua type; this would explain why they pattern with Quechua and Tibetan in this respect. We turn to these cases now.

It is not clear whether this case works in Quechua; Faller does not provide examples like this one. In general, though, in that language evidentials can appear in the consequent or on the 'connecting element' *chay* 'this,' but not in the antecedent, so cases like this may not appear at all. Examples can be found in Faller (2002, pp. 267–268), who notes that preliminary investigation suggests that the evidentials scope over the consequent and the conditional relation itself; clearly, this is different from Japanese. Another case of a Quechua-like language is Tibetan, as reported on by Garrett (2001). Here, evidentials can appear in assertive environments only, according to Garrett, although he notes that they can also be used in questions, which are obviously not assertive in general (though biased questions may in fact be; see, e.g., Gunlogson 2003). Since conditional antecedents are unasserted, evidentials cannot be used there.

(35)a. *kho   'gro-gired-na   ...
        he   go-ind.fut-if
        'If he'll go ...'
   b. *kho   na-pared-na   ...
        he   sick-ind.pst-if
        'If he was sick ...'   (Garrett 2001)

In any case, Japanese allows all its evidentials to appear in conditional antecedents, so its evidentials are clearly semantically different from Quechua and Tibetan. Examples like these suggest that building a requirement for wide scope directly into the semantics would be a mistake for Japanese. And this conclusion is only strengthened by looking at examples that involve negation.

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[14] It seems that the ambiguity mentioned in the main text has its source in the conditional itself, which, like English conditionals, can be interpreted as an acknowledgement, as in *If John's coming, then I'll go too*. Presumably the existence of this reading has nothing to do with the semantics of the evidential.

Cross-linguistically, evidentials have been shown not to scope under negation either. Consider, for instance, the following Cuzco Quechua example from Faller (2002). Here, the evidential content associated with the the evidential clitics -n, -chá and -s scope over the negation; the sentence can never mean that the speaker lacks evidence for the propositional content of the sentence. This feature is typical of evidentials in many languages, according to most authors (to the extent that data of this sort has been looked at).

(36) Ines-qa   **mana-n/-chá/-s** qaynunchaw   ñaña-n-ta-chu
      Ines-Top   not-MI/CHÁ/SI   yesterday   sister-3-Acc-CHU
      watuku-rqa-n
      visit-Pst1-3
      'Ines didn't visit her sister yesterday.' (and speaker has evidence for this)
      NOT 'Ines visited her sister yesterday' (and speaker doesn't have evidence
      for this)

Unfortunately it is difficult to test this situation for the Japanese case. In Japanese, negation is suffixal and scopes over the content associated with the verb or adjective it attaches to. Clausal negation, however, cannot apply to sentence-final modal expressions or to evidentials, as shown by the following representative examples. The actual content of the evidential is suppressed here.[15]

(37)a. Satoshi-ga   paatii ni   kuru   kamosirenai
        Satoshi-Nom   party   to   come   might
        'Satoshi might come to the party.'
    b. *Satoshi-ga   paatii ni   kuru   kamosirena-kunai
        Satoshi-Nom   party   to   come   might-Neg
        Intended: 'Satoshi might not come to the party.'
(38)a. Satoshi-ga   paatii ni   kuru   rashii
        Satoshi-Nom   party   to   come   RASHII
        '(I have evidence that) Satoshi might come to the party.'
    b. *Satoshi-ga   paatii ni   kuru   rashi-kunai
        Satoshi-Nom   party   to   come   RASHII-Neg
        Intended: '(I don't have evidence that) Satoshi might come to the party.'

The reason for this fact may lie in the order of projections proposed by Cinque (1999). According to Cinque, evidential content is located in a projection (EvidP) that dominates the projection containing negation (NegP). If so, negation would not be able to appear on evidentials for morphological or syntactic reasons.

As we showed above, ordinary morphological negation doesn't apply to the evidentials. There is another kind of negation, however, that *can* be used with

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[15] Yasutada Sudo (p.c.) reports to us that examples like (37b) are in fact good in a dialect of Japanese spoken by (some segment of) people under 25. In this dialect the examples in (40) are also good. We will not consider this dialect further in the present paper.

certain of the evidentials; it will turn out that they can in fact be embedded semantically in these cases. It is necessary to use a kind of 'external negation' (cf. Horn 1989) for negation to be grammatical; once we do, however, the evidential content embeds very easily in at least the case of *inf+soo-da*, as in (39).

(39) konya   ame-ga   furi-soo   janai
      tonight   rain-Nom   fall(inf)-SOO   Cop.Neg.Pres
      'It doesn't look like it will rain tonight.'

Other evidentials, however, do not allow this sort of embedding. Examples like the following are fairly bad.

(40)a. *konya   ame-ga   furu   mitai   janai
       tonight   rain-Nom   fall   MITAI   Cop.Neg.Pres
       'It doesn't look like it will rain tonight.'
   b. *konya   ame-ga   furu   rashii   to   iu   koto-wa
       tonight   rain-Nom   fall   RASHII   thing-Top   Comp   say
       nai
       Cop.Neg.Pres
       'It doesn't look like it will rain tonight.'

For some speakers, it does seem to be possible to embed using constructions like the above, if (and, we think, only if) the embedded evidential is presented as expressing someone else's evidence—that is, if the evidential presents information that was heard by someone else.[16] Semantically we can find similarities to quotative constructions, and perhaps to shifted indexicals as well (Schlenker 2003; Anand and Nevins 2004). We do not know just what causes this restriction and leave it at present as an open research question.

   We finally note that 'indirect' negations such as the following are very natural with all evidentials we consider. Although here negation does not apply directly to the evidential, the negated attitude does scope over it, indicating again that evidentials need not take widest scope. We gave similar examples above for the hearsay evidential *(S)soo-da*; we repeat one of these here as well.[17]

(41)a. ame-ga   furu   yoo-ni-wa   omoenai
       rain-Nom   fall   YOO-Dat-Top   can't think
       'It doesn't look to me like it's going to rain.'

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[16] We have found considerable variation among speakers on examples like these, which indicates that more research is needed here, just as in the case of modal subordination discussed above.

[17] Similar examples can be found in Dutch involving the auxiliary verb *moeten* 'must', which is said to indicate that the speaker has only indirect evidence available for her claim (de Haan 1999):

i. Het moet een geode film   zijn, maar ik heb   er   mijn twijfels over
   it   must a   good movie   be   but I have   there   my   doubts   about
   'It is said to be a good movie, but I have my doubts about that' (de Haan 1999)

    b. ame-ga   furu mitai   da   to-wa   omoenai
       rain-Nom fall MITAI Cop.Pres Comp-Top can't think
       'It doesn't look to me like it's going to rain.'
    c. naniyara   raishuu   kara-wa   atsuku-naru soo-desu
       for some reason next week from-TOP hot-become SOO-DA.Hon
       ga   totemo   shinjiraremasen
       but   really   can't believe.Hon
       'They say it's going to get hot starting next week, but I really can't believe it.'[18]

4.3 Summary

We can summarize the data as follows.

1. Japanese (inferential) evidentials can enable modal subordination.
2. They can be embedded in conditionals and under certain sorts of negation.

We believe that (1) indicates that we need to include a modal element in the semantics of the evidentials, and (2) that the content of Japanese evidentials must be truth-conditional.[19]

    In the following section we will examine some available analyses of evidentiality to see whether they can handle these facts, and, if so, how.

5 Some possibilities

We will look at three main analyses. We start with the speech act-based analysis of Faller (2002), touching on Garrett (2001) along the way. The conclusion is that Faller's analysis, since it's designed to deal with the Quechua evidential system (in which evidential content does not embed) is not flexible enough to handle the Japanese embeddability facts. Next we consider the analysis of Japanese modals of McCready and Asher (2006) and the related independent work of Izvorski (1997). This line of analysis, as it turns out, runs into serious difficulties with embeddability. Finally, we turn (in the next section) to the dynamic multimodal analysis of Ogata (2005b). This analysis proves to be the best in handling the data we have seen, though it is insufficient; we use it as a base for our own implementation.

5.1 Speech acts

Let's first look at the theory of Faller (2002), who did extensive work on the evidential system of Cuzco Quechua. Cuzco Quechua has several enclitic

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[18] http://www010.upp.so-net.ne.jp/kazu-honyomi/nikki0308.html

[19] In the phrase of Higginbotham (2005), these evidentials introduce singulary propositions.

suffixes that mark evidentiality or the nature of the speaker's justification for making the claim. Faller analyzes three suffixes in detail:

– *-Mi*: indicates that the speaker has direct (usually perceptual) evidence for the claim.
– *-Si*: indicates that the speaker heard the information expressed in the claim from someone else.
– *-Chá*: indicates that the speaker's background knowledge, plus inferencing, leads him to believe the information in the claim true.

Some examples follow (from Faller 2002).[20]

(42) a. Para-sha-n-mi
      rain-PROG-3-MI
      'It is raining. + speaker sees that it is raining'
    b. para-sha-n-si
      rain-PROG-3-SI
      'It is raining. + speaker was told that it is raining'
    c. para-sha-n-chá
      rain-PROG-3-CHÁ
      'It may/must be raining. + speaker conjectures that it is raining based on some sort of inferential evidence'

Faller uses Vanderveken's (1990) speech act theory for her analysis. Vanderveken's theory assigns speech acts preconditions for successful performance. Faller takes evidentials to introduce additional content into the set of preconditions. Vanderveken's basic conditions are the following (for the assertive cases under consideration).

(43) a. Propositional content: restricted in instances such as promises.
    b. ILL: Illocutionary force (*assertion* for all examples we consider).
    c. SINC: sincerity conditions on successful performance of the SA. For assertions, that $Bel(s, p)$ holds—that the speaker believes the content of the assertion.

In large part, the focus of Faller's analysis of *-mi* and *chá* is on the sincerity conditions for the assertion. Essentially, *-mi* adds an additional sincerity

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[20] Faller glosses (42c) in two distinct ways in her dissertation. The first is what we have provided above (found on e.g. p.3 of her work). The second gloss is "'It is raining' and the speaker conjectures that it is raining." (on, e.g., p. 170). This translation seems to us infelicitous, in a similar way to the well-known Veltman example (i)

i. It is not raining. It might be raining.   (Veltman 1996)

It is peculiar to assert that it is raining and at the same time conjecture that it might be true that it is raining. (We thus assume the translation in the main text is the intended one.) This infelicity suggests that making a conjecture about the truth of φ is incompatible with knowing that it is true, which makes sense, given that assertions require that their agent be certain about the truth of their propositional content, and that modal statements are weaker than non-modal ones. We will return to this observation later in our motivation of our specific analysis.

condition to the assertion, that $Bpg(s, p)$. The formula $Bpg(s, p)$ means that the speaker has the best possible grounds for believing p. Faller does not attempt to make this notion completely precise, noting only that it is dependent on the content in the scope of *-mi*: for externally visible events Bpg will ordinarily be sensory evidence, while for reports of people's intentions or attitudes even hearsay evidence will often be enough.

Faller analyzes *-chá* as being simultaneously modal and evidential. As a result, the asserted propositional content p is mapped to $\diamond p$, as is the corresponding belief object $Bel(s, p)$ in SINC. The condition $Rea(s, Bel(s, \diamond p))$ is also added to SINC. $Rea(s, Bel(s, \diamond p))$ indicates that the speaker's belief in the possibility of p follows from his own reasoning/inference. *-Si* is also complex; the propositional content p is not asserted when this hearsay evidential is used (as is also the case in Japanese), as we saw, which means that the propositional content of the utterance cannot be asserted. Faller posits a special speech act PRESENT for this situation, on which the speaker simply presents a proposition without making claims about its truth. Therefore $Bel(s, p)$ is eliminated from SINC, and the condition $\exists s_2[Assert(s_2, p) \wedge s_2 \notin \{h, s\}]$ is added to the set of sincerity conditions (where s is the speaker and h the hearer).

The reason for using a speech act-based analysis is that the Cuzco Quechua evidentials do not embed semantically, as already mentioned above. Even if they appear under negation or in a conditional consequent, their content cannot be 'bound' by some content in the antecedent; this shows that they are not standard presuppositions. Faller provides examples with negation for each of the three evidentials:

(44)   Ines-qa   **mana-n/-chá/-s**   qaynunchaw   ñaña-n-ta-chu
        Ines-Top   not-MI/CHÁ/SI   yesterday   sister-3-Acc-CHU
        watuku-rqa-n
        visit-Pst1-3
        'Ines didn't visit her sister yesterday.' (and speaker has evidence for this)
        NOT 'Ines visited her sister yesterday' (and speaker doesn't have evidence
        for this)

How could we apply a Faller-type analysis to the Japanese inferential and hearsay evidentials? It is rather straightforward. 'Hearsay' *soo-da* is essentially the same as Cuzco Quechua *-si*. *Soo-da* therefore can be given a similar semantics. So *soo-da* will just introduce an additional condition into the set of preconditions: that the speaker heard the information from some other individual before making the utterance. Similarly, the inferential evidentials can be modeled along the lines of Faller's analysis of *-chá*, though some additional conditions about evidence types will be needed.

This solution certainly gets the basic meaning right. But it doesn't allow for embedding of evidentials, which makes sense given that it is designed precisely to account for evidentials in a language which disallows such embeddings. But, as we have seen, making this possibility available is necessary for Japanese. So, although Faller's analysis may be right for Quechua, it doesn't extend easily to

the Japanese case. This is not something we should take as a shortcoming of the Faller system: languages clearly differ in how their evidentials work semantically, and in fact the typology seems to be a good deal more complex than indicated by the semantic literature on the topic so far.[21]

The same point applies to another possible analysis of evidentials, one in terms of expressive content (Potts 2003, 2005). Potts explicates the content of expressives and appositives, among other constructions, in terms of conventional implicature: pragmatic aspects of meaning that never embed semantically, and are associated with particular lexical items. The Quechua evidentials seem to be prime examples of such forms, and, although to our knowledge no analysis of them in terms of conventional implicature has been attempted, it seems to be a fruitful avenue. But, for the same reasons as the Faller speech act-based analysis, such an approach seems to be too rigid to work out for the Japanese case. The analysis we will consider next was prompted by precisely this fact, although for a different empirical domain.

5.2 Presupposition

A different way of thinking about evidentiality is provided by McCready (2005) and McCready and Asher (2006). These authors treat evidentials as presuppositional in nature, an approach proposed indepedently by Izvorski (1997). The reason for this move is that, in the case of certain Japanese modals that seem to have evidential content, this content can in fact be bound in a conditional antecedent. The particular modal for which this seems to hold is *nichigainai*. Consider the following examples from McCready (2005). The first translates the famous Roberts modal subordination example in (45) already discussed above.

(45)   A wolf might come in. It would eat you first.   (Roberts 1989)

(46)   ookami-ga kuru   kamoshirenai. # ∅ anta-o   taberu   nichigainai.
        wolf- NOM   come   might   ∅   you-ACC   eat   surely
        'A wolf$_i$ might come in. It$_i$ would eat you first.'

As we see here, the Japanese translation is infelictious. McCready (2005) argues that the reason for this is that the necessity modal *nichigainai* has evidential content that is not satisfied in this context. In particular, φ in the scope of *nichigainai* must follow by inference from contextually supplied evidence (see the above-cited works for arguments to this effect). However, as it turns out, the evidential can be satisfied in other contexts, specifically those provided by the addition of discourse particles to the second sentence or by putting the second sentence in a conditional (as consequent).

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[21] Some discussion of this point can be found in McCready (2007).

(47)a. ookami-ga   kuru   kamoshirenai.   soshite ∅   anta-o   taberu
       wolf-NOM   come   might   then   ∅   you-ACC   eat
       nichigainai.
       surely
       'A wolf$_i$ might come in. Then it$_i$ would eat you.'
    b. ookami-ga   kuru   kamoshirenai.   moshi   ∅   kitara   ∅
       wolf-NOM   come   might   if   ∅   came-COND   ∅
       anta-o   taberu nichiigainai.
       you-ACC   eat   surely
       'A wolf$_i$ might come in. If (one) did, it$_i$ would eat you.'

What the above examples show is that, given the right context, the evidential content of *nichigainai* can in fact be satisfied. And what that means is that the speech act theory is too strong, if it is indeed correct that the content of *nichigainai* is partly evidential (which it does seem to be). Presupposition seems an ideal tool for explaining these facts. If content in a conditional antecedent is sufficient to satisfy a given presupposition, the presupposed content does not project, which is precisely what is needed here. But it is wrong for the pure evidentials.

However, we also see cases of evidentiality in which the evidential content does, necessarily, project. The particular case considered in the works above was that of *hazu*, another Japanese modal which McCready and Asher argued to have evidential content (a viewpoint also espoused by Masuoka and Takubo 1989 (pp. 127–129)). The examples in (48) show that the evidential meaning of *hazu* cannot be satisfied in conditionals or by the presence of a discourse particle.[22]

(48)a. ookami-ga   kuru   kamoshirenai.   # soshite ∅   anta-o
       wolf-NOM   come   might   then   ∅   you-ACC
       taberu   hazu   da.
       eat   surely COP
       'A wolf$_i$ might come in. Then it$_i$ would eat you.'
    b. ookami-ga   kuru   kamoshirenai.   # moshi ∅   kitara   ∅
       wolf-NOM   come   might   if   ∅   came-COND   ∅
       anta-o   taberu hazu   da.
       you-ACC   eat   surely COP
       'A wolf$_i$ might come in. If (one) did, it$_i$ would eat you.'

As it turns out, the content of *soo-da* cannot be bound either. Consider the following example involving a conditional, in which the antecedent makes the event of communicating the propositional content in the scope of *rashii* explicit.
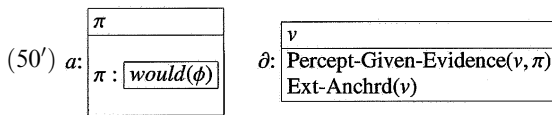
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[22] Again, we note that there is a great deal of speaker variation on examples like these. Most people find them all terrible, but some allow them (at least marginally), and a few find them fully acceptable. Some speculations as to why this may be so can be found in McCready (2005) and McCready and Asher (2006).

(49)a. # moshi   dare-ka-ga   [konya   Jon-ga   kuru]   to
    if   who-∃-Nom   [tonight   John-Nom   come]   COMP
    osiete-kure-tara   konya   Jon-ga   kuru   soo-da
    tell-give-COND   tonight John-Nom   come   SOO-DA
    'If someone tells me John will come tonight, then John will come tonight
    (I heard).'

This means that *soo-da* must be formalized using the same mechanisms used for *hazu*, if an analysis like this is adopted for the pure evidentials.
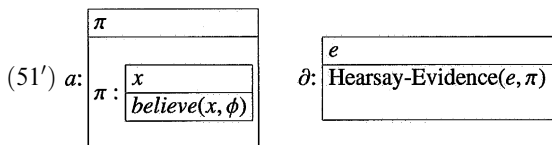
  The previous work mentioned assumed the binding theory of presupposition (van der Sandt 1992; Geurts 1999), in particular the version used in the theory of discourse structure SDRT (Asher and Lascarides 2003; see Kamp and Reyle 1993 for the basics of DRT, on which SDRT is based). Within this framework, the meanings of *nichigainai* and *hazu* were handled by separating them into asserted (modal) and presupposed (evidential) content. For *hazu*, this procedure yields the following representation (slightly modified from the original formulation). Here the modal content is written as $would(\varphi)$ (where φ is the propositional content of the sentence), and the presuppositional content (annotated by the ∂ symbol) is some piece of perceptually given evidence. Crucially, the evidence is required to be *externally anchored*; this is a DRT term indicating that the variable corresponding to the evidence must map to an object in the actual world (i.e., not simply a mental object, which the theory allows for in certain cases such as conditionals and objects in the scope of universal quantifiers). We abstract away in our discussion from the SDRT elements (the πs) in these representations.

(50) *hazuϕ*

(50′) a: π : $\boxed{would(\phi)}$ ∂: $\begin{array}{l} v \\ \text{Percept-Given-Evidence}(v, \pi) \\ \text{Ext-Anchrd}(v) \end{array}$

  Clearly, for the case of hearsay evidential *rashii* and *soo-da*, it is not necessary to make use of a modal component. We need a more direct sort of assertion. What we want is to presuppose an externally anchored event of communication. We also need to ensure that ϕ is not asserted, since the speaker need not subscribe to any beliefs concerning the proposition. So we might use the following representation for *soo-daφ*:

(51) *soo-daϕ*

(51′) a: π : $\boxed{\begin{array}{l} x \\ believe(x, \phi) \end{array}}$ ∂: $\begin{array}{l} e \\ \text{Hearsay-Evidence}(e, \pi) \end{array}$

There are two parts to this semantics. First, the asserted content states that there is some individual x who believes ϕ. This condition is very weak, but it comes close to the content proposed by Faller for *-si* when taken in conjunction with the presupposed content *Hearsay − Evidence*(v, φ).[23] The upshot of this conjunction is the same as Faller's analysis given the following semantics for this formula. τ is the temporal trace function (cf., e.g., Krifka 1992).

(52) $\forall e[Hearsay - Evidence(e, \varphi)$
  $\longleftrightarrow \exists x[\tau(e) < n \wedge Comm(e, x, s, \varphi) \wedge Ext - Anchrd(e) \wedge x \neq h]]]$

In words, for there to be hearsay evidence for a proposition, there must be an event of communication (*Comm*) that took place at a past time. Any sort of communication is possible: speaking, writing, even overhearing a conversation with some other individual. The speaker of the *soo-da* sentence need be involved only insofar as she absorbs information from this communication. Further, this event must be externally anchored. This last move captures the fact that *soo-da* cannot be bound within, e.g., a conditional. The hearsay evidential use of *rashii* can be given the same semantics as one subpart of its meaning.

Faller presents several arguments against the related analysis of Izvorski (1997), who provides the following semantics for indirect (inferential or hearsay) evidentials (her (8)). Here □ is a standard Kratzer-style universal epistemic modal (Kratzer 1981).

(53) The Interpretation of EV*p*:
  a. Assertion: □*p* in view of the speaker's knowledge state
  b. Presupposition: Speaker has indirect evidence for *p*

Most of Faller's arguments do not apply to the analysis we sketched within the McCready–Asher system. Since we ultimately will not adopt this analysis, we will not go through the details here. Instead, we concentrate on Faller's main reason for not adopting an epistemic modal analysis for the inferential evidential *chá*, which is in her conclusion that a speech act-based analysis is necessary for the other evidentials. However, this conclusion is somewhat hasty. It is in fact possible to analyze the other evidentials in a way similar to what an epistemic modal, plus presupposition, analysis would have for *chá*. A different sort of presupposition is needed, but the same form can be given to the various types. The presupposition simply needs to include some externally anchored content: that there is evidence of the right sort for the modal statement. Quechua *chá* would look like this but with the addition of the condition *Ext-Anchrd(v)* to ensure projection.

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[23] Here, again, we have ignored the SDRT notation; φ in this formula should be identified with the asserted content above.

(54)   *Inf-Evidϕ*

$$
(54')\ a: \begin{array}{|c|} \hline \pi \\ \hline \pi : \boxed{would(\phi)} \\ \hline \end{array} \qquad \partial: \begin{array}{|l|} \hline v, R \\ \hline R(v, \pi) \\ v = ? \\ R_{evid} = ? \\ \hline \end{array}
$$
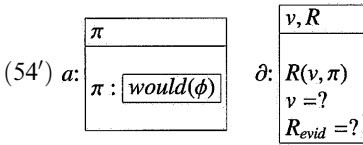
Now, given an analysis like this, are the facts discussed in the previous section accounted for, and, if so, how? The modal subordination facts fall out directly from the analysis of the evidentials as containing a possibility operator in their asserted content. This is good. The embedding facts are more problematic, however. If our evidentials presuppose the presence of some sort of evidence, how can it be that they are neutral with respect to the presence of such evidence when embedded in a conditional antecedent?

There seems to be some hope for a solution in the analysis of van der Sandt (1992). van der Sandt discusses instances of local accommodation caused by a need to avoid making assertions redundant. Thus, in (55), an example from Beaver (2002), the existence of a husband of Jane would entail that she is married; so this presupposition gets trapped in the conditional antecedent. Geurts (1999) reanalyzes cases like these as instances of interpretative mechanisms functioning so as to avoid violation of Gricean maxims and we will couch our discussion in these terms as well.

(55)   If Jane is married, then her husband is on holiday.

It seems possible to try to extend this sort of analysis to our evidential cases. The idea would be that exporting the presupposition that some kind of evidence exists would make the conditional antecedent true, and so make the conditional irrelevant, since a simple assertion could have been used instead. Consider (56a), and the simplified version of its logical form in (56b).

(56)a. Taro-ga   kuru   yoo   da-ttara   osiete   kudasai
        Taro-Nom   come   YOO   Cop.Pres-COND   teach   please
        'If it looks like Taro will come, please tell me.'
    b. $[C(t) \land \partial(\exists e[Evid(e, C(t))])] \Rightarrow [Imp(tell\_me)]$

There are two possible resolutions of the presupposition, corresponding to the two logical forms below. If the presupposition is projected outside the conditional, we get (57a); if it is not, we get (57b). The Gricean story we are exploring would have it that (57b) is preferred, since projecting the evidence outside the conditional would make it uninformative.

(57)a. $\exists e[Evid(e, C(t))] \land [[C(t)] \Rightarrow [Imp(tell\_me)]]$
    b. $[[C(t) \land \exists e[Evid(e, C(t))]] \Rightarrow [Imp(tell\_me)]]$

We do not think that this can be right. This analysis hinges on the assumption that the existence of evidence for some conclusion implies that the conclusion must be true. Without this condition, there is nothing wrong (in Gricean terms) with projection of the evidential content. Intuitively, however, this certainly need not be the case. It is easy to find cases where all available evidence in a situation points to one conclusion, but to a conclusion which is in fact false. And the fact that embedding under negation is possible is, if anything, even more problematic. The upshot is that the embedding facts look quite bad for the presuppositional analysis.

All in all, the presuppositional analysis does not seem to be a good candidate for explaining the evidential data. One would like a more elegant solution. It is worth noting, though, that although the McCready–Asher approach does not work well for true evidentials, it appears to account correctly for the restrictions on Japanese modals discussed above and in McCready and Asher (2006).

5.3 Conclusion

The upshot of this discussion is that analyses based on speech act modification or presupposition do not perform well when faced with data related to the Japanese evidential system. The perhaps surprising conclusion is that the Japanese evidentials act differently from evidentials in those languages for which semantic analyses have been developed; in fact, they are semantically very close to modal operators, differing only in also specifying a source of information. Still, because they specify an information source, they satisfy the standard definitions of evidentials to be found in the literature. This finding is interesting, in that the relationship between (epistemic) modality and evidentiality is still controversial; the conclusion of Faller (2002) and Aikhenvald (2004), among others, is that the two notions must be kept distinct. Our findings show that, for Japanese at least, this is not (completely) the case.

6 Dynamic semantics of evidential modalities

At this point we have established that the Japanese evidentials need a modal component. But what should this look like? We begin this section with a discussion of the analysis of Ogata (2005b), which serves as a point of departure for the system we will present. We then adduce some additional data that clarify where the Ogata system is insufficient and what the correct analysis should look like, after which we turn to an informal sketch of the analysis we propose. We then present the full logic in Sect. 6.2. Since this section formalizes the insights we will present in Sect. 6.1, the more technical parts of it can be ignored by those readers uninterested in the details of the formal machinery. However, there we also show how to give logical forms for a variety of examples, which should be of interest even to those who want to skip the logical definitions. The

final subsection shows how our analysis accounts for the data on modal subordination and embedding presented above.

Our starting point is the work of Ogata (2005b). This is in fact the only full formal semantic analysis of the Japanese evidential system that is on the market now.[24] Ogata uses a multimodal dynamic predicate logic in his analysis, which is interpreted within Kripke–Moss models for modal logic augmented with probabilitic information. We cannot present the full logical system here but limit ourselves to the basic ideas.

In Ogata's system, *Evid* φ is translated as $\triangle_{source}\varphi$ (changing Ogata's notation slightly). Here $\triangle$ is a modal operator subscripted by a particular bit of content which corresponds to some source of evidence. For individual modals, these subscripts can be quite complex in that each possible information source for a particular evidential must be listed (cf. the table at the end of Sect. 2). The idea is that evidential expressions are translated as modals of a particular sort—those that express having a particular information source.

For a formula like this to be judged true in a model, the model must support three things. First, φ must be true at some accessible state, as in standard modal logic; this accessibility will be dictated by information sources. Second, the speaker's information state must be such that it would not support the truth of φ without this evidence; and, third, with the evidence, it must support φ (in some accessible state).

Like the other analyses we looked at, the truth conditions for the evidentials it provides are right in simple sentences. And, also like the other analyses, it handles the modal subordination facts without difficulty, for the evidentials here are simply a special type of modal. Unlike the other two analyses, though, it correctly models the behavior of the evidentials with respect to embeddability. It is no surprise that the multimodal analysis can get the facts right in this area; since, on this analysis, the evidentials are just modals, nothing prevents them from being embedded within conditionals or under negation or modals at all. In this sense, it is arguably the case that the analysis is a more natural treatment than the others.

However, Ogata's analysis leaves room for improvement. First, he treats inferential *soo-da* and the other inferential evidentials identically, which is undesirable; his treatment also is not right for the hearsay evidentials in that it models them as making claims about the speaker's belief in the content in the scope of the evidentials. His logic also does not fully capture intuitions about what evidentials do in discourse, which we will discuss in the next section. Still, the basic picture seems right. Accordingly, the analysis we present in the next section can be viewed as an extended and modified version of the original Ogata system.

6.1 A rough sketch of our semantics of the Japanese evidentials

As we have already seen, the Japanese inferential evidentials express a degree of conviction on the part of the speaker toward the proposition in their scope. But

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[24] Takubo (2005) is another relevant recent work that examines Japanese evidentials from a different perspective, but the analysis he provides is not formalized.

this should not be confused with actual assertion of that content. Here we show several facts showing that the evidentials actually indicate *uncertainty*: first, that they do not appear with certain adverbials denoting certainty and, second, that they are incompatible with *direct* evidence. We show then that evidentials are *source-bounded* in that they indicate the presence of some fact—the relevant evidence—of a certain sort, the truth of which increases the likelihood of φ being true. This observation, in conjunction with the modal subordination facts discussed above, will motivate a dynamic treatment.

For us, inferential evidentials in Japanese are modal: they indicate that φ in their scope is probably true. But they also indicate that some source of evidence has caused the speaker to reevaluate the likelihood of φ at some past time. This source can be indicated in previous discourse, as some examples we presented already showed; we make this more explicit below. As a result, a dynamic treatment in which *changes in (subjective) probability* can be modeled is needed.[25] The intuition here is that evidentials are acting in a way comparable to anaphors in discourse. In the case of anaphors, an antecedent is introduced, which changes the information state and can then be referred to by pronouns; in the evidential case, a piece of evidence can be introduced, changing the information state in a way that licenses the use of an expression that 'checks for' the presence of evidence of a certain kind. We will therefore propose a probabilistic dynamic logic for the evidentials. This logic—$L_{E,\triangle,F}$—incorporates insights from research on evidential reasoning in AI, and is the first probabilistic version of dynamic predicate logic (Groenendijk and Stokhof 1991).

As our first piece of additional data, consider the sentences in (58). As these examples show, the Japanese evidentials are incompatible with adverbs denoting certainty such as *kitto* and *zettai-ni*. We take this to indicate that we should assign the evidentials a denotation that presumes that the speaker retains uncertainty about whether the proposition in the scope of the evidential is true: thus, we should not use a simple necessity modal, much less tie the evidential to assertion of the embedded proposition.[26]

(58)a. *kitto   ame-ga   futteiru   yoo   da
      surely   rain-Nom falling   YOO   Cop.Pres
      'Surely it seems that it is raining now.'
  b. *ame-ga   zettai-ni futteiru   mitai   da
      rain-Nom   certainly falling   MITAI   Cop.Pres
      'Surely it seems that it is raining now.'

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[25] A reviewer asks: whose probability is involved? Clearly it must be subjective probability, since it relates to speaker information and attitudes. This question is quite hard, as can be seen by the debate in the philosophical literature on who should be taken as the judge of epistemic modal sentences. We will not attempt to answer it here; for present purposes we just assume that it is the speaker.

[26] Yasutada Sudo (p.c.) asks why we never get scope interactions between evidential and adverbial. We do not know the answer to this question, but speculate that it might have something to do with the kind of constraints discussed by von Fintel and Iatridou (2003).

Second, we show that if the evidence for a proposition is *too* strong, the evidentials can no longer be used. (59) shows that if we have actual proof of the proposition's truth we cannot apply an evidential to it: in (59a), we know that a cat exists, disallowing the evidential statement, but in (59b) more indirect evidence such as the existence of the sound of a cat meowing does support use of the evidential. Thus actual knowledge of a truth maker is too strong as an evidence source. This needs to be built into the semantics.

(59)a. Neko-ga   iru.   Tsumari,   # neko-ga   iru   yoo-da/rashii.
       cat-Subj   exist namely   cat-Subj exist   Evid
       'There is a cat (here). That is, there seems to be a cat (here).'
   b. Neko-no koe-ga   shita. Tsumari, neko-ga   iru   yoo-da/rashii.
       cat-Gen voice-Subj I-heard namely cat-Subj exist Evid
       'I heard the voice of a cat (here). That is, there seems to be a cat (here).'

So: if an agent a knows that a sentence ϕ that denotes a piece of evidence is is true, a cannot use the corresponding (inferential) evidential-marked sentence. We will write $\triangle_a \phi$ for a sentence ϕ modified by the inferential evidentials *rashii, mitai,* and *yoo* and used by a.

Note here the analogy to modal operators; if one knows ϕ, it is strange to assert *might*ϕ, as noted by Veltman and others. We take this as another reason to treat these evidentials in a modal-like manner, though this consideration doesn't apply to $\varphi + soo\text{-}da$ in that it has no modal component of the sort we have been discussing.[27] Further, $\triangle_a \phi$ requires that the agent's certainty about ϕ be less than complete, as shown by the adverbial facts and the examples in (59). In terms of standard modal semantics, however, it is too strong to say that $\Box \phi$, for the agent need not believe ϕ to be necessary. But it is also too weak to assert only that there is a possibility of ϕ's truth, as with $\Diamond \phi$. For this reason we make use of notions from probability theory, in which an intermediate treatment is possible.[28] We will say that $\triangle_a \phi$ is true with respect to a probability measure μ if and only if $0.5 < \mu(\llbracket \phi \rrbracket) < 1$, where roughly $\llbracket \phi \rrbracket = \{w \in W | \ w \models \phi\}$ and W is a set of possible worlds. That is, ϕ cannot be true in all accessible worlds.

Next, consider (60). Here the crucial point is that the evidence must be in a sense external: while hearsay can be the source of an evidential, a self-assertion cannot be.

(60)a. Jon-wa   neko-ga iru   to   itta. Tsumari, neko-ga   iru
       John-Top   cat-Subj exist Comp   said   namely   cat-Subj exist
       yoo-da/rashii.
       Evid
       'John said that there is a cat (here). That is, there seems to be a cat (here).'

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[27] This is reflected also in the semantics that Faller (2002) gives for the related Quechua *-si*, which is taken to 'present' φ, rather than asserting $\Diamond \varphi$ as sentences marked with *-chá* do.

[28] It would also have been possible to quantify over possible worlds using *many*, as is often done in linguistic semantic treatments of adverbials like, e.g., *probably*. However, we would like to have a more fine-grained structure, for reasons that will become apparent.

b. Watashi-wa   neko-ga   iru   to   itta.   Tsumari, # neko-ga
   I-Top   cat-Subj exist   Comp   said   namely   cat-Subj
   iru   yoo-da/rashii.
   exist   Evid
   'I said that there is a cat (here). That is, there seems to be a cat (here).'

Now consider the source-boundedness of evidential content. The point is made by the following examples. The inference in (61a) is good; that in (61b) is not.

(61)a. Neko-no   koe-ga   suru.   Neko-no   koe-ga
      cat-Gen   voice-Subj is-perceived   cat-Gen   voice-Subj
      sureba   neko-ga   iru.   Dakara,   neko-ga   iru   yoo-da.
      is-perceived.Cond cat-Subj exist   therefore   cat-Subj exist Evid
      'I perceive the voice of a cat (there). If I perceive the voice of a cat (there),
      there is a cat (there). Therefore, there seems to be a cat (here).'
   b. Neko-no   koe-ga   suru   kamoshirenai. Neko-no
      cat-Gen   voice-Subj is-perceived   may   cat-Gen
      koe-ga   sureba   neko-ga   iru.   Dakara, # neko-ga
      voice-Subj   is-perceived.Cond   cat-Subj   exist   therefore   cat-Subj
      iru   yoo-da.
      exist   Evid
      'I may perceive the voice of a cat (there). If I perceive the voice of a cat
      (there), there is a cat (there). Therefore, there seems to be a cat (there).'

(61a) shows that the source of an evidential can be a proposition inferred from direct evidence, since here an evidential is bound by a source which is derived from some piece of direct evidence by inference, while (61b) shows that the source cannot be a proposition derived from a possibility or hypothetical assumption, as such things are not really evidence. In this way the data from the Japanese evidentials, and the semantics we give for them, embodies a claim about what evidence can be. We can therefore formalize (61a) and (61b) schematically as (62a,b), respectively. Here $E_a^i(\varphi)$ indicates that φ is a piece of evidence acquired via means i by agent a.

(62)a. $E_a^i\varphi, \varphi \Rightarrow \psi \models \triangle_a^i \psi$
    b. $\diamond E_a^i\varphi, \varphi \Rightarrow \psi \not\models \triangle_a^i \psi$

Note that the content of the conditional premise $\varphi \Rightarrow \psi$ is given by world knowledge in general, and need not be as explicitly expressed as in the examples in (61). Evidentials therefore are partly pragmatic in nature in that the question of what counts as evidence for a particular proposition depends on world knowledge about causal relations and, generally, what facts are often true together.

Why should this inference pattern hold? We think there are several factors coming into play with (62). Clearly evidence can alter probabilities: $E^i\varphi$ updates the probability of φ, while $\diamond\varphi$ cannot update the probability of φ. Otherwise

stated, only true evidence allows for a change in probability. Again, this is similar to standard notions of modality in dynamic semantics, as expressed by scholars like Veltman and Roberts; hypothetical information cannot change the actual context. This behavior is another reason that we give the Japanese evidentials a dynamic treatment. Second, the probability of ψ is changed (dynamically updated) by the combination of the conditional $\varphi \Rightarrow \psi$ and the evidential statement $E^i\varphi$ (we suppress the agent parameter). That is, gaining the knowledge that φ is true changes the subjective probability of ψ. Thus $\triangle^i\psi$ should be verified in (62a), since the previously introduced evidence $E^i\varphi$ has altered the model so that $\triangle^i\psi$ is supported. But the (dynamic) modality in (62b) blocks this update.

This general picture seems right in terms of native speaker intuitions about the inferential evidentials. But some questions remain. How does the propositional content of evidential-marked sentences change, given the addition of evidence? We model this by introducing updates of probability measures by *conditional probabilties*. An evidence-introducing sentence $E^i\varphi$ updates the probability measure in way similar to that used in the systems of *Probabilistic Belief Revision* (Gärdenfors 1988) or *Probabilistic Dynamic Epistemic Logic (PDEL)* (Kooi 2003). To see how the story goes, it will be useful to consider an example. Let s, t be times such that $t = s + 1$, and let $\langle W, \mathcal{F}, \mu_s \rangle$ and $\langle W, \mathcal{F}, \mu_t \rangle$ be *probability spaces* (see Appendix A for a compact introduction to probability spaces). Let $[\![\varphi]\!], [\![\psi]\!] \in \mathcal{F}$, $\mu_s([\![\varphi]\!]) = \mu_s([\![\psi]\!]) = \frac{1}{3}$ and $\mu_s([\![\psi]\!] \cap [\![\varphi]\!]) = \frac{2}{9}$, and further let $E_a\varphi$ hold at t but not at s (so a has acquired φ-evidence between the times s and t). Then, μ_t is defined by

$$\mu_t([\![\phi]\!]) = \mu_s([\![\phi]\!] | [\![\varphi]\!]) = \begin{cases} \dfrac{\mu_s([\![\phi]\!] \cap [\![\varphi]\!])}{\mu_s([\![\varphi]\!])} & \text{if } \mu_s([\![\varphi]\!]) > 0 \\ 1 & \text{if } \mu_s([\![\varphi]\!]) = 0. \end{cases}$$

for each sentence ϕ, where $\mu_s([\![\phi]\!] | [\![\varphi]\!])$ denotes the probability of $[\![\phi]\!]$ given $[\![\varphi]\!]$. In particular, $\mu_t([\![\varphi]\!]) = 1$ and $\mu_t([\![\psi]\!]) = \frac{2}{3}$. So the probability of ψ has increased between times s and t due to the update $E\varphi$ between those two times.

On the other hand, the probability of conditionals of the form $\varphi \Rightarrow \phi$ for some ϕ needs to be stable even when the probability measure is updated by $E^i\varphi$.[29] We assume that the truth conditions of the conditional $\varphi \Rightarrow \psi$ are defined by conditional probability as in Halpern (2003): $\varphi \Rightarrow \psi$ is true at s with respect to probability measure μ_s if and only if $\mu_s([\![\varphi]\!]) = 0$ or $\mu_s([\![\psi]\!] | [\![\varphi]\!]) > \frac{1}{2}$. For example, suppose the above example. That is,

$$\mu_s([\![\psi]\!] | [\![\varphi]\!]) = \frac{\mu_s([\![\psi]\!] \cap [\![\varphi]\!])}{\mu_s([\![\varphi]\!])} = \frac{2}{3} > \frac{1}{2}.$$

Therefore, $\varphi \Rightarrow \psi$ holds at s. Similarly

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[29] The same thing is noted in a different context by Jeffrey (1983). See also Merin (1997) for another use of this sort of idea in a linguistic context.

$$\mu_t([\![\psi]\!] \mid [\![\varphi]\!]) = \frac{\dfrac{\mu_s([\![\psi]\!] \cap [\![\varphi]\!])}{\mu_s([\![\varphi]\!])}}{\dfrac{\mu_s([\![\varphi]\!])}{\mu_s([\![\varphi]\!])}} = \frac{\mu_s([\![\psi]\!] \cap [\![\varphi]\!])}{\mu_s([\![\varphi]\!])} = \frac{2}{3} > \frac{1}{2}.$$

Therefore, $\varphi \Rightarrow \psi$ holds at t, too.

Thus, we take our operator corresponding to (inferential) $Evid\phi$, $\triangle^i\phi$, to denote a test of the existence of an update of the probability measure by the source i. We accordingly propose the following semantics for $\triangle^i\phi$, the operator which models *yoo, mitai,* and inferential *rashii,* as follows:[30]

(63) $\triangle^i\phi$ is true at w with respect to s and μ iff for some $t < s$ such that $\mu_t(i)(w)([\![\phi]\!]) < \mu_s(i)(w)([\![\phi]\!])$, $\frac{1}{2} < \mu_s(i)(w)([\![\phi]\!]) < 1$, and for all $t', t'' : s \leq t' < t'' \leq t.[\mu_{t'}((i,a))(w)([\![\varphi]\!]) \leq \mu_{t''}((i,a))(w')([\![\varphi]\!])]$.

This definition can be informally unpacked as follows.

(64) $\triangle^i\phi$ is true given a world w, time s, and probability function μ iff:

a. ϕ was less likely at some time preceding s (before introduction of some piece of evidence i);
b. ϕ is probable, but still not completely certain at s (given i);
c. the probability of ϕ never decreased between the time the speaker became aware of the evidence i and s as a result of the same piece of evidence i (i.e., the probability of ϕ given i is upward monotonic).

This definition gives what we think is the right characterization of the modal-like inferential evidentials *rashii, mitai* and *yoo.*

As discussed in Sect. 2, the inferential evidentials are limited in what sorts of evidence they can take as sources, however. Thus it is not enough to simply translate them as $\triangle$. The evidential sources need to be restricted in some way. In the fragment in Appendix B, we show one way to do this. The basic idea is that the evidentials are translated as instances of $\triangle^i_a$ in which the index i is restricted to certain types of evidence, in a way corresponding to the table at the end of Sect. 2. Since it seems to us that the restrictions on source types peculiar to each evidential are more or less accidental, we do not think that a more theoretically interesting way of accounting for this data is available.

Verbal infinitive and adjectival *soo-da* are modeled somewhat differently, by making use of a construction based on $\triangle$. This accounts for their different behavior in terms of immediacy and directness, as discussed in Sect. 2.

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[30] We assume the slightly more complex version of the probability function μ to be defined in the next section. This version simply makes the assigned probability dependent on a time and world index.

(65)a. '$\phi(inf)$-*soo-da*' means that it seems that it will be the case that ϕ, i.e. $\triangle^i F\phi$, where $\phi(inf)$ is an activity, accomplishment, or activity (i.e. non-stative),

   b. '$\phi(adj)$-*soo-da*' and $\phi(inf)$-*soo-da* (where $\phi(inf)$ is stative) means that there seems to be a piece of evidence indirectly supporting ϕ; so there seems to be some direct evidence ψ which implies ϕ in the context. We formalize this as $\triangle^i\phi$, where there is a set of contextually salient propositions related to source i in the context, written $\mathcal{O}(i)$, including ψ implying ϕ.

Informally, this can be stated as follows.

(66)a. '$\phi(inf)$-*soo-da*' indicates that it seems that ϕ will be the case, where ϕ is eventive.

   b. '$\phi(inf-adj)$-*soo-da*' and '$\phi(inf)$-*soo-da*' for stative ϕ indicate that it seems that some piece of evidence along with some contextually given facts taken as a whole imply that ϕ. (Recall that this is meant to formalize the watermelon case, where independent knowledge is needed to infer anything about the quality of the inside of the watermelon.)

Note that this definition accounts for the aspectual differences found with *soo-da* and discussed in Sect. 2, but that this analysis is rather stipulative. But, as we indicated before, a detailed analysis of what aspect contributes to the evidential semantics is beyond the scope of this paper.[31]

    The hearsay evidentials *S-soo-da* and hearsay *rashii* are represented differently. This is necessary since the speaker need not have any beliefs about the likelihood of φ in their scope, a property shared with the Quechua hearsay evidential enclitic -*si*, as we showed. As a result, it would be a mistake to analyze them also as having a true modal component.[32] We accordingly treat these evidentials as simple tests for the existence of a past event of acquiring hearsay evidence for φ, by introducing a new operator H_a, which is understood as follows.

(67) $H_a\varphi$ indicates that a has experienced an event of acquiring hearsay knowledge $E_a^h\varphi$, at some past time.

    We now proceed to a formal definition of the full language and its interpretation, together with some examples.

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[31] See, e.g., Chung (2005) for more on this issue.

[32] And, as we pointed out, there is no way that these elements could be thought to be epistemic modals, unlike the other evidentials discussed immediately above.

6.2 Definition of language $L_{\mathsf{E},\triangle,F}$ and its dynamic semantics

We first define the syntax of the language and then give some examples of how this syntax applies to sentences that express evidence and sentences that contain evidentials (a fuller class is generated by the fragment in Appendix B). We then define the class of $L_{\mathsf{E},\triangle,F}$-models and the dynamic interpretation of the language.

The formal language $L_{\mathsf{E},\triangle,F}$ is defined as follows:

Definition 1 (*Syntax*). Let $R \in Rel$ be a *n*-ary relation symbol, $c \in Con$ an individual constant, $x \in Var$ an individual variable, E an evidence-introducing modality operator, $a \in Ag$ an agent symbol, $\mathcal{I}$ a non-empty set called a set of source indices $i \in \mathcal{I}$, $\Sigma = \{$tactile, auditory, internal_sensory, hearsay, visual, judgemental, unknown$\}$ a set of source sorts, and $Sort : \mathcal{I} \to \Sigma$ is a function assigning to each source index its source sort.

The set of *WFF*s $\varphi \in L_{\mathsf{E},\triangle,F}$ is defined by the following BNF grammar:

$$\varphi ::= (t_1 = t_2)|R(t_1, \ldots, t_n)|\exists x.\varphi|\mathsf{E}_a^i\varphi|\triangle_a^i\varphi|\mathsf{H}_a^i\varphi|F\varphi|\neg\varphi|\varphi_1 \wedge \varphi_2|\varphi_1 \vee \varphi_2|\varphi_1 \Rightarrow \varphi_2$$

where for each *k* such that $1 \leq k \leq n$, $t_k \in Var \cup Con$.

$\mathsf{E}_a^i\varphi$ indicates that according to agent a, there is a piece of evidence which is indexed by i and described by ϕ. When $Sort(i) \in \{tactile, auditory, internal\_sensory, visual\}$, E_a^i is an *occasion sentence* in the sense of Quine (1960), i.e., a direct description of a situation directly observed or perceived by agent a.

$\triangle_a^i\varphi$ is a sentence marked with an inferential evidential, meaning that φ is supported by the evidence indexed by i with uncertainty according to agent a. Finally, $\mathsf{H}_a^i\varphi$ indicates that φ is modified by a hearsay evidential according to agent a, based on source i.

$\varphi_1 \Rightarrow \varphi_2$ is a conditional whose denotation is defined as a conditional probability in a way described by Halpern (2003).

As previously mentioned, we define a simple fragment $\mathcal{J}$ of Japanese sentences which includes occasion sentences and evidential sentences and its translation into $L_{\mathsf{E},\triangle,F}$ in Appendix B. Here we present several examples produced by the fragment. In all cases the agent of the utterance is a. We start with examples of simple sentences: occasion sentences in Quine's sense. (68) is an occasion sentence from the agent's perspective—that is, something directly experienced by the agent (so a actually saw the cat in question).

(68) a. niwa-ni$_1$ neko-ga$_2$ iru$_3$.
     garden-in   cat-Nom   Cop.Pres
     'There is a cat in the garden.'
   b. $\mathsf{E}_a^{i_3}(\exists x_1.(garden\ x_1) \wedge \exists x_2.(cat\ x_2) \wedge (exist\ x_2\ x_1))$, where a is the speaker.

The next three examples consist of multiple sentences; here, the first sentence is an occasion sentence, and the second is an evidential statement whose evidential source is reported by the first sentence. Note that the two sentences

make use of the same source indices. This is why use of the evidential is supported. Note also the clear analogy to dynamic binding of pronouns.

(69)a. niwa-de$_1$ oto-ga$_2$ suru$_3$.
        garden-in   sound-Nom   do
        'I hear a sound in the garden.

   b. $\emptyset_1$ neko-ga$_5$ iru   yoo-da$_3$.
        emptyPRO   cat-Nom   Cop.Pres   YOO-Cop.Pres
        'There seems to be a cat in the garden.

   c. $\mathsf{E}_a^{i_3}(\exists x_1.(garden\ x_1) \wedge \exists x_2.(sound\ x_2) \wedge (exist\ x_2\ x_1)) \wedge \triangle_a^{i_3}$
        $(\exists x_5.(cat\ x_5) \wedge (exists\ x_5\ x_1))$

(70)a. niwa-de$_1$ oto-ga$_2$ suru$_4$.
        garden-in   sound-Nom   do
        'I hear a sound in the garden.'

   b. $\emptyset_1$ neko-ga$_6$ i-soo-da$_4$.
        emptyPRO   cat-Nom   be(inf)-SOO-Cop.Pres
        'There seems to be a cat in the garden.'

   c. $\mathsf{E}_a^{i_4}(\exists x_1.(garden\ x_1) \wedge \exists x_2.(sound\ x_2) \wedge (exist\ x_2, x_1)) \wedge \triangle_a^{i_4}(\exists x_6.(cat\ x_6) \wedge$
        $(exist\ x_6\ x_1))$

(71)a. kaminari-ga$_1$ natteiru$_2$.
        thunder-Nom   is-rolling-Pres
        'The thunder is rolling.'

   b. ame-ga$_3$ huri-soo-da$_2$.
        rain-Nom   fall(inf)-SOO-Cop.Pres
        'It looks like it's going to rain.'

   c. $\mathsf{E}_a^{i_2}(\exists x_1.(thunder\ x_1) \wedge (is\_rolling\ x_1)) \wedge \triangle_a^{i_2} F(\exists x_3.(rain\ x_3) \wedge (fall\ x_3))$

The next two examples we provide involve external and internal adjectives. Note that both examples make use of the construction discussed above for infinitival *soo-da*; note also that the use made of the two constructions is slightly different for internal and external adjectives, due to the different type of evidence needed.

In (72), the set of salient propositions selected by $\mathcal{O}$ applied to (w, t, a, i) is null, i.e., $\bigcap \mathcal{O}(w, t, a, i) = W_{(i,a),w}$ (all possible worlds accessible from possible world w at the context (w, t), where t is a time instant).[33] This makes the interpretation of $\triangle_a^i$ *direct evidential*, i.e., one that doesn't require an inference based on contextual information. On the other hand, in (73), the set of contextually salient propositions includes the propositions that the watermelon has an inside and that the look of the watermelon implies that its inside is red. Here one can get a picture of the action of the set of propositions made salient by context: essentially, it is a part of the speaker's world knowledge relevant as evidence for the question at issue.[34]

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[33] This part of the definition is introduced later.

[34] The presence of these additional propositions will not cause problems for verification of inferential evidentials formalized as $\triangle$ due to additivity of probabilities. See the end of this section for a proof sketch.

(72)a. heya-ni$_1$ suika-ga$_2$ aru$_3$.
     room-in   watermelon-Nom   Cop.Pres
     'There is a watermelon in the room.'
  b. $\emptyset_2$ oishi-soo-da$_3$.
     (it)   delicious(inf)-SOO-Cop.Pres
     'It looks delicious.'
  c. $E_a^{i_3}(\exists x_1.(room\ x_1) \wedge \exists x_2.(waterMelon\ x_2) \wedge (exist\ x_2\ x_1)) \wedge \triangle_a^{i_3}(delicious\ x_2)$
(73)a. heya-ni$_1$ suika-ga$_2$ aru$_3$.
     room-in   watermelon-Nom   exist.Pres
     'There is a watermelon in the room.'
  b. naka$_2$-ga$_4$ aka-soo-da$_3$.
     inside-Nom   red(inf)-SOO-Cop.Pres
     'It looks like it must be red inside.'
  c. $E_a^{i_3}(\exists x_1.(room\ x_1) \wedge \exists x_2.(waterMelon\ x_2)$
     $\wedge(exist\ x_2\ x_1)) \wedge \triangle_a^{i_3}(\exists x_4.(inside\ x_2\ x_4) \wedge (red\ x_4))$

Now an example with a hearsay evidential (ignoring the contribution of *dakara* 'therefore'). Here, *Sort* assigns *hearsay* to *i*, licensing the use of H_a^i.

(74)a. Taroo-ga$_1$ niwa-ni$_2$ neko-ga$_3$ iru   to   itta$_3$
     Taro-Nom   garden-in   cat-NOM   exists   COMP   said
     'Taro said there is a cat in the garden.'
  b. $\exists x_1.x_1 = Taroo \wedge E_{x_1}^{i_3} \exists x_2.(garden\ x_2) \wedge \exists x_3.(cat\ x_3) \wedge (exist\ x_3\ x_2))$
  c. dakara   niwa-ni$_2$ neko-ga$_3$ iru   soo-da$_3$
     therefore   garden-in   cat-Nom   exists   SOO-DA
     'Therefore (I heard) there is a cat in the garden.'
  d. $H_{x_1}^{i_3}(\exists x_2.(garden)\ x_2) \wedge \exists x_3.(cat\ x_3) \wedge (exist\ x_3\ x_2))$

Finally, we show the contrast between reporting the judgement of another source and one's own judgement. In the following example, the speaker is reporting the judgement of a newspaper about the upcoming political situation. The speaker is simply reporting this. She need not herself believe that a war will start. Thus the source index on the evidential operator is associated with the newspaper, not the speaker.

(75)a. shinbun$_1$-niyoruto$_1$ sensou-ga$_2$ hajimaru   yoo-da$_1$.
     newspaper-according.to   war-Nom   begin   YOO.Cop.Pres
     'According to the newspaper, it seems that a war will begin.'
  b. $\exists i_1.(newspaper\ i_1) \wedge \triangle_a^{i_1}(\exists x_2.(war\ x_2) \wedge (begin\ x_2))$

In the next example, however, the judgement is the speaker's own, and so is the evidence; this means that the indices are related.

(76)a. yoosu$_1$ karasuruto$_1$ sensou-ga$_2$ hajimaru
     scene   by-inference-based-on   war-Nom   begin
     yoo-da$_1$.
     YOO.Cop.Pres

'I infer from that situation that a war will begin.'

b. $\exists i_1.(\text{scene } i_1) \wedge \triangle_a^{i_1}(\exists x_2.(\text{war } x_2) \wedge (\text{begin } x_2))$

We now proceed to our definition of the semantics of the language. We begin by defining the class of probability spaces in which the language is interpreted.

Definition 2 $L_{\mathsf{E},\triangle,F}$ *Probability Spaces.* Let $\imath \in \mathcal{I} \times Ag$, W be a non-empty set of possible worlds, D a non-empty set of possible individuals, T a set of times with a discrete total order $<$, $t \in T$, R_E a binary relation over W, $g : Var \to W \to D$ a variable assignment, and $[\![\cdot]\!] : L_{\mathsf{E},\triangle,F} \to pow(W)$ (defined in definition 3). Then, if $\langle W, \mathcal{F}_t^0, \mu_t^0 \rangle$ is a probability space and satisfies the following conditions, it is called a $L_{\mathsf{E},\triangle,F}$-probability space:

(i) for each $w \in W$ and $\imath \in \mathcal{I} \times Ag$,

$$W_{\imath,w} \overset{def}{=} \{u \in W|\ (w,u) \in R_\imath\} \cup \{w^\top\}$$

i.e., the set of possible worlds which are accessible from w with respect to $\imath$ if it exists; otherwise $\{w^\top\}$, where $w^\top$ is the possible world which only verifies the logically true sentences, i.e., $w^\top \in [\![\varphi]\!] \Leftrightarrow \varphi$ is logically true. In symbols, $W^\top = W \cup \{w^\top\}$,

(ii) $\mathcal{F}_t : \mathcal{I} \times Ag \to W$ to $pow(pow(W^\top))$ is a function which assigns to each $\imath$ and w a set of subset of $W_{\imath,w}$ such that:

  (a) $\mathcal{F}_t(\imath)(w)$ is a σ-algebra on $W_{\imath,w}$ such that $[\![\varphi]\!] \in \mathcal{F}_t(\imath)(w)$ for all $\varphi \in L_{\mathsf{E},\triangle,F}$ and $X \in \mathcal{F}_t^0 X \cap W_{\imath,w}$, and

  (b) $\langle W_{\imath,w}, \mathcal{F}_t(\imath)(w)\rangle$ is a measurable space.

(iii) a function $\mu_t : \mathcal{I} \times Ag \to W \to pow(W^\top) \to [0,1]$ is a function such that[35]

$$\mu_t(\imath)(w)([\![\varphi]\!]) = \mu_t^0([\![\varphi]\!]|W_{\imath,w})$$

and $\mu_t(\imath)(w)([\![\varphi]\!])$ is defined for all $\varphi \in L_{\mathsf{E},\triangle,F}$. for each $\varphi \in L_{\mathsf{E},\triangle,F}$.

(iv) $\langle W_{\imath,w}, \mathcal{F}_t(\imath)(w), \mu_t(\imath)(w)\rangle$ is a probability space.

See Appendix A for details of the notions "probability measure," "probability space," "σ-algebra," "measurable space," and "probability space."[36]

Now, the dynamic semantics of $L_{E,\triangle,F}$ is defined as follows:

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[35] In this formula the superscript 0 indicates that μ lives on the base probability space $\langle W, F_t^0, \mu_t^0\rangle$. The probability functions μ_t to be used later are generated from μ_t^0.

[36] A comment on this definition. The reader will have noticed that variable assignments g are made world-dependent (as a variable assignment is a function of type of $Var \to W \to D$ such that $g(x)(w) \in D(w)$); we do this so as to leave open one possible treatment of modal subordination to be discussed briefly in the next subsection. This move does not play a role in the semantics of the evidentials themselves, which works just as well with more standard non-world-dependent assignments. The rest of the definition simply works to define a class of probability spaces that has the necessary properties for our analysis.

Definition 3 *Interpretation.* Let Ag be a set of agents, T a set of times with discrete total order $<$, $t \in T$, $\imath \in \mathcal{I} \times Ag$, W a set of possible worlds, D a set of individuals ($D(w)$ is a non-empty subset of D denoting the individuals that live in w), $(R_\imath)_{\imath \in \mathcal{I} \times Ag}$ a sequence of binary relations over W, $\langle W, \mathcal{F}_t^0, \mu_t^0 \rangle$ a $L_{E,\triangle,F}$-probability space, $\mathcal{O}\colon W \times T \times Ag \times \mathcal{I} \to pow(pow(W))$ a function assigning a conversational background to the context, agent and source such that $\bigcap \mathcal{O}(w,t,a,i) \subseteq W_{(a,i),w}$, I an interpretation of Rel and Con, and g a variable assignment.

Then a tuple

$$\sigma = \langle (R_\imath)_{\imath \in \mathcal{I} \times Ag}, \mu_t, w, g \rangle$$

is called a state and its class is written $\mathcal{S}$.

A dynamic interpretation of $L_{E,\triangle,F}$ $[\![\varphi]\!]_{\mathcal{S}} : \mathcal{S} \to pow(\mathcal{S})$ and $[\![\varphi]\!] \subseteq W$ is defined by recursion on formulas φ as follows:

- $[\![t_1 = t_2]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma\} & \text{if } [\![t_1]\!]_{I,w,g} = [\![t_2]\!]_{I,w,g} \\ \emptyset & \text{otherwise} \end{cases}$,

  where

  $$[\![t]\!]_{w,g} = \begin{cases} g(x)(w) & \text{if } t = x \\ I(c)(w) & \text{if } t = c \end{cases}$$

- $[\![R(t_1, \ldots, t_n)]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma\} & \text{if } ([\![t_1]\!]_{I,w,g}, \ldots, [\![t_n]\!]_{I,w,g}) \in I(R)(w) \\ \emptyset & \text{otherwise} \end{cases}$,

- $[\![\exists x.\varphi]\!]_{\mathcal{S}}(\sigma) = \{\sigma[g[a/x]/g] \mid [\![\varphi]\!](\sigma[g[a/x]/g]) \neq \emptyset \, \& \, a \in D\}$,

- $[\![\neg\varphi]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma\} & \text{if } [\![\varphi]\!]_{\mathcal{S}}(\sigma) = \emptyset \\ \emptyset & \text{otherwise} \end{cases}$,

- $[\![\varphi_1 \vee \varphi_2]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma\} & \text{if } [\![\varphi_1]\!]_{\mathcal{S}}(\sigma) \neq \emptyset \text{ or } [\![\varphi_2]\!]_{\mathcal{S}}(\sigma) \neq \emptyset \\ \emptyset & \text{otherwise} \end{cases}$,

- $[\![\varphi_1 \wedge \varphi_2]\!]_{\mathcal{S}}(\sigma) = \bigcup_{\sigma' \in [\![\varphi_1]\!]_{\mathcal{S}}(\sigma)} [\![\varphi_2]\!]_{\mathcal{S}}(\sigma')$,

- $[\![\varphi_1 \Rightarrow \varphi_2]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma\} & \text{if for each } E \in \mathcal{I} \times Ag, \mu_t(E)(w)([\![\varphi_1]\!] \cap W_{E,w}) = 0 \\ & \quad \text{or } \frac{1}{2} \leq \mu_t(E)(w)([\![\varphi_2]\!] \mid [\![\varphi_1]\!] \cap W_{E,w}) \\ \emptyset & \text{otherwise} \end{cases}$,

- $[\![E_a^i \varphi]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma[\mu_{t+1}/\mu_t, R_{(i,a)} \upharpoonright [\![\varphi]\!]/R_{(i,a)}]\} & \text{if } \mu_{t+1} \text{ is defined under } (*) \text{ and} \\ & \quad \mu_t((i,a))(w)([\![\varphi]\!]) < 1 \\ \emptyset & \text{otherwise} \end{cases}$,

  For each $\psi \in L_{E,\triangle,F}$,

  $(*) \quad \mu_{t+1}(\imath')(w)([\![\psi]\!]) = \begin{cases} \mu_t(\imath)(w)([\![\psi]\!] \mid [\![\varphi]\!]) & \text{if } \imath' = \imath \\ \mu_t(\imath')(w)([\![\psi]\!]) & \text{otherwise} \end{cases}$,

- $$[\![\triangle_a^i \varphi]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma\} & \text{if } \bigcap \mathcal{O}(w, t, a, i) \subseteq [\![\varphi]\!], \\ & \exists s < t.\mu_s((i, a))(w)([\![\varphi]\!]) < \mu_t((i, a))(w)([\![\varphi]\!]), \\ & \quad \text{for all } t', t'' : s \le t' < t'' \le t. \\ & \quad [\mu_{t'}((i, a))(w)([\![\varphi]\!]) \le \mu_{t''}((i, a))(w')([\![\varphi]\!])] \\ & \text{and } \frac{1}{2} < \mu_t((i, a))(w)([\![\varphi]\!]) < 1 \\ \emptyset & \text{otherwise} \end{cases},$$

- $$[\![\mathsf{H}_a^i \varphi]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma\} & \text{if } \exists s < t.\forall u : s \le u \le t.\mu_u((i, a))(w)([\![\varphi]\!]) \le 1 \text{ at } s \\ & \text{and } Sort(i) = \text{hearsay} \\ \emptyset & \text{otherwise} \end{cases},$$

- $$[\![F\varphi]\!]_{\mathcal{S}}(\sigma) = \begin{cases} \{\sigma\} & \text{if for some } s > t.[\![\varphi]\!]_{\mathcal{S}}(\sigma[s/t]) \ne \emptyset \\ \emptyset & \text{otherwise} \end{cases},$$

- $[\![\varphi]\!] = \{u \in W | [\![\varphi]\!]_{\mathcal{S}}(\sigma[u/w]) \ne \emptyset \ \sigma \in \mathcal{S}\}.$

There are a number of points in this definition that bear a closer look. The first thing to note is that the definitions of $=, R, \exists,$ and $\wedge$ are all classically dynamic and completely standard for dynamic systems; but the definition of $\vee$ is not. It is static. The result of this move is that the logic supports all the standard axioms of propositional logic, a desirable result which does not hold for systems which use dynamic disjunction. The definition of the conditional is also standard in probabilistic systems and simply makes use of conditional probability.[37] F is just the ordinary 'future' operator over times.

The new points here are crucial to our evidential system: E_a^i, H_a^i, and $\triangle_a^i$. H is the simplest. $\mathsf{H}\varphi$ is a test over information states, that passes a state if there is a past time at which the agent a experienced a hearsay event of φ with index i. We used this operator to translate the hearsay evidentials; as will be clear, there is no need for this hearsay to transform the speaker's subjective probability about φ, or for the speaker to have any beliefs about φ at all, in that $\mathsf{H}\varphi$ merely tests for the existence of a prior hearsay event with content φ. This accounts for the intuition common to Japanese and Quechua that a speaker can assert $\mathsf{H}_a^i\varphi$ and $\neg\varphi$ without contradiction. Finally, the presence of the index on this and the other evidential operators enables dynamic binding, which we showed above to be desirable.

The definitions of E_a^i and $\triangle_a^i$ are relatively complex. Update with $\mathsf{E}_a^i\varphi$ changes the probabilities assigned to every proposition ψ (excluding φ itself) in σ by replacing them with the conditional probability of ψ given φ, if it is defined (if not, the probability is left unchanged). Then the accessibility relation is replaced with one restricted to worlds in which φ holds, which means that the accessible worlds are now required to verify the content indexed by i as well. This accounts, we think, for intuitions about what evidence does in a context; it changes the probability of other propositions that are related to it

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[37] See, e.g., Halpern (2003) for more on this sort of definition.

conditionally, and revises the set of possibilities to one that makes the content of the evidence true.[38]

The inferential operator $\triangle_a^i$ is defined in terms of this. $\triangle\varphi$ expresses that φ has a high probability, but that it remains uncertain (i.e., $\frac{1}{2} < \mu_t((i,a))$ $(w)(\llbracket\varphi\rrbracket) < 1$). It also requires that this high probability not be automatic; rather, the likelihood must be based on the existence of some piece of evidence. This is ensured by the first two conditions in the definition. The first states that there was a past time s at which the probability of φ was lower than it is now. The second is a convexity condition on probabilities, given a piece of evidence: the evidence must *monotonically* increase the probability of φ from s to t, the current time. This ensures that a given piece of evidence for φ cannot later be counterevidence for φ, which also seems to be the right intuition.

The convexity condition may look peculiar at first glance. For instance, couldn't we have a situation in which we update with $\mathsf{E}\varphi$, which raises the likelihood of ψ, and then update with $\mathsf{E}\chi$, which lowers it, but only to a point above the $\frac{1}{2}$ threshold we specified for $\triangle$? This would mean that ψ is still likely, but that the convexity condition is seemingly violated. But wouldn't we still judge $\triangle\psi$ true in this situation? Yes. We would. But this kind of objection leaves out the indexing on the evidential operator. A given instance of $\triangle$ is convex only with respect to a single source of evidence. Since we introduced two distinct pieces of evidence in this example—φ and χ—no problem arises with respect to convexity, and the example is predicted to be good, as desired.

Finally, we define generalized discourse update.

Definition 4 *Update.* Let $\mathcal{S}$ be the class of states. Then

$$\varphi_1, \ldots, \varphi_n \models \varphi \Leftrightarrow \forall \sigma \in \mathcal{S}.\sigma' \in \llbracket\varphi_1\rrbracket_{\mathcal{S}} \circ \cdots \circ \llbracket\varphi_n\rrbracket_{\mathcal{S}}(\sigma).\llbracket\varphi\rrbracket_{\mathcal{S}}(\sigma') \neq \emptyset.$$

The following basic facts follow from this semantics.

FACT 1.

1. $\models \varphi$ for all propositional tautologies $\varphi \in L_{\mathsf{E},\triangle,F}$,
2. $\mathsf{E}_a^i\varphi, \varphi \Longrightarrow \psi \models \triangle_a^i\psi$, where φ is not logically equivalent to ψ,
3. $\mathsf{E}_a^i\varphi, \varphi \Longrightarrow \psi \not\models \triangle_a^{i'}\psi$, where $i \neq i'$ and φ is not logically equivalent to ψ,
4. $\mathsf{E}_a^i\varphi, \varphi \Longrightarrow \varphi \not\models \triangle_a^i\varphi$.
5. $\mathsf{E}_a^i\varphi, \varphi \Longrightarrow \psi, \mathsf{E}_a^i\neg\varphi \not\models \triangle_a^i\psi$
6. If for all $w \in W$ and $t \in T$, $\mathcal{O}(w,t,a,i) \neq \emptyset$, $\bigcap\mathcal{O}(w,t,a,i) \cap \llbracket\varphi\rrbracket \neq \emptyset$, $\bigcap\mathcal{O}(w,t,a,i) \subseteq \llbracket\psi\rrbracket$ then $\mathsf{E}_a^i\varphi \models \triangle_a^i\psi$[39]

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[38] We do this here by manipulating accessibility relations; it is also possible to do it directly by manipulating the content of sets of epistemic states. See Asher and McCready (2007) for details.

[39] *Proof* Suppose $\llbracket\mathsf{E}_a^i\varphi\rrbracket(\sigma)$. Then $\mu_t((a,i))(w)(\llbracket\varphi\rrbracket) < \mu_{t+1}((a,i))(w)(\llbracket\varphi\rrbracket) = 1$. By the additivity of $\mu_x((a,i))(w)(\cdot)$ for $x \in \{t, t+1\}$ and $\bigcap\mathcal{O}(w,t,a,i) \cap \llbracket\varphi\rrbracket \subseteq \llbracket\psi\rrbracket$, $\mu_t((a,i))(w)(\llbracket\psi\rrbracket) < \mu_{t+1}((a,i))$ $(w)(\llbracket\psi\rrbracket)$. $\square$

Fact 1-1 follows from our use of static disjunction. Fact 1-2 is the basic inference the logic is designed to model: an evidential can mark a proposition that follows by inference from a piece of evidence. Fact 1–3 shows that our logic models the intuition that evidentiality is source-bounded. From Fact 1–4 it follows that evidentials cannot modify propositions that are known to the hearer to be true. And Fact 1–5 shows that evidentiality is in fact dynamic in nature; despite the fact that the presence of some evidential source ϕ and the availability (from world knowledge) of an inference to ψ, if $\neg\phi$ is learned in the interim use of the evidential fails.[40] Fact 1–6 guarantees the interpretation of $\triangle$ as an indirect evidential when the conversational background is given.

It may be useful now to go through an example to show how the semantics works. We will use the simplest one, (68), repeated here as (77a), and continued by a sentence containing an inferential evidential.

(77)a. niwa-de$_1$ oto-ga$_2$ suru$_3$.
         garden-in   sound-Nom   do
         'I hear a sound in the garden.'
   b. $\emptyset_1$ neko-ga$_5$ iru   yoo-da$_3$.
         emptyPRO   cat-Nom   Cop.Pres   YOO-Cop.Pres
         'There seems to be a cat in the garden.'
   c. $\mathsf{E}_a^{i_3}(\exists x_1.(garden\ x_1) \wedge \exists x_2.(sound\ x_2)$
         $\wedge (exist\ x_2\ x_1)) \wedge \triangle_a^{i_3}(\exists x_5.(cat\ x_5) \wedge (exists\ x_5\ x_1))$

The first sentence is formalized as the 'evidence-introducing' statement $\mathsf{E}_a^{i_3}(\exists x_1.(garden\ x_1) \wedge \exists x_2.(sound\ x_2) \wedge (exist\ x_2\ x_1))$. Processing of this statement does several things. First, it affects the modal accessibility relation, limiting it to those worlds in which there is a garden and in which there is a sound audible in the garden. Second, it modifies the probability assigned to every proposition other than $\exists x_1.(garden\ x_1) \wedge \exists x_2.(sound\ x_2) \wedge (exist\ x_2\ x_1)$ by replacing the original probability assigned to them by their conditional probability given the proposition in the scope of E. The second sentence is translated as $\triangle_a^{i_3}(\exists x_5.$ $(cat\ x_5) \wedge (exists\ x_5\ x_1))$ in the logical language. This formula is a test; processing it leaves the information state unchanged if the semantics of the formula are satisfied, and gives an empty output (i.e., failure) otherwise. The test succeeds if (a) the probability of $\exists x_5.(cat\ x_5) \wedge (exists\ x_5\ x_1)$, the formula in the scope of the evidential, is greater than 0.5 but less than 1 (i.e., it is probable but not certain), and (b) if this level of probability came about as the result of update with an E-marked sentence—a piece of evidence—with the same index as $\triangle$. Here this index marks the translation of the first sentence; thus, the test succeeds if the probability of there being a cat was lower than 0.5 before processing of the first sentence and higher than 0.5 (but still lower than 1) afterward, and fails otherwise.

Something similar happens in the case of hearsay evidentials like (74), repeated below, although the situation is rather simpler.

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[40] The analogy is to Veltman's modalities: where $\diamond\varphi \models \diamond\varphi$, $\diamond\varphi; \neg\varphi \not\models \diamond\varphi$. Our evidential case, obviously, looks extremely similar.

(78)a. Taroo-ga$_1$ niwa-ni$_2$ neko-ga$_3$ iru   to   itta$_3$
       Taro-Nom   garden-in   cat-NOM   exists   COMP   said
       'Taro said there is a cat in the garden.'
   b. $\exists x_1.x_1 = Taroo \wedge \mathsf{E}^{i_3}_{x_1}\exists x_2.(garden\ x_2) \wedge \exists x_3.(cat\ x_3) \wedge (exist\ x_3\ x_2))$
   c. dakara   niwa-ni$_2$ neko-ga$_3$ iru   soo-da$_3$
       therefore   garden-in   cat-Nom   exists   SOO-DA
       'Therefore (I heard) there is a cat in the garden.'
   d. $\mathsf{H}^{i_3}_{x_1}(\exists x_2.(garden\ x_2) \wedge \exists x_3.(cat\ x_3) \wedge (exist\ x_3\ x_2))$

In this example, the first sentence introduces an evidential sentence with index type *hearsay*. The second sentence is marked with H; this operator tests for the existence of an earlier update with an E-marked sentence with *hearsay* index that shares its index with the H operator and has the same content in its scope. Since this is the case for (78), the test will succeed.

   To sum up, we have analyzed the evidentials as probabilistic modals indicating evidence sources, in the case of inferential evidentials, and as tests of the existence of past hearsay events, in the case of hearsay evidentials. This treatment directly models the analogy between introduction of evidence and the availability of the evidentials, on the one hand, and the introduction of discourse referents and the availability of pronominal anaphora, on the other. Both phenomena can be analyzed as instances of the way the introduction of new information can change the context. We take this to be a virtue of our approach. We now show that the logic also correctly models the data that was problematic for other theories.

6.3 Modal subordination and embedding in our approach

We have provided, in Sect. 4, two sets of data that must be modeled correctly for a semantics for the Japanese evidentials to be adequate: the fact that evidential content can embed in conditionals and under negation and that evidentials block anaphora and license modal subordination. Both of these facts are accounted for by our semantics.

   Consider the modal subordination facts first. The discourse in (79a) is modeled as in (79b).

(79)a. ookami-ga   kuru   mitai.   # [anta-o   taberu]
       wolf-Nom   come   MITAI   you-Acc   eat
       'It seems like a wolf will come in. # It (will) eat you.'
   b. $\triangle^i_a\exists x_1.[wolf(x_1) \wedge come(x_1)] \wedge eat(y, x_1)$

Evidentials, on our analysis, work like modals: their complements must be true at most accessible possible worlds, but not necessarily in the actual world. Therefore, like modals, they will block anaphora in the absence of additional modal operators. This is not the place to propose and defend a theory of modal subordination (though we will make some comments below); but it will be clear

that since our $\triangle$ operator is modal in nature, it will block anaphora just as (other) modals will.

The converse is true as well. The discourse in (80a) is modeled as shown in (80b). Note the presence of the modal in the second sentence. The operator *might* is provided only for illustration and not defined in the logic, since we will not give a full analysis of Japanese modality here.

(80)a. ookami-ga   kuru   mitai.   [anta-o   taberu   kamoshirenai]
        wolf-Nom   come   MITAI   you-Acc   eat   might
        'It seems like a wolf will come in. It might eat you.'

   b. $\triangle_a^i \exists x_1.[wolf(x_1) \wedge come(x_1)] \wedge might[eat(y, x_1)]$

The modal *might* scopes over the variable in the translation of the second sentence. Whatever theory of modal subordination one assumes, this situation is one that will enable modal subordination, if the antecedent is also in the scope of a modal operator; and, indeed, it is: $\triangle$. Thus it makes sense that modal subordination should be licensed.

It may seem that the situation is not so straightforward. When we use $\triangle$, we do not *directly* alter the content of particular worlds; rather, we test whether the whole set of worlds satisfies certain conditions. Thus one may wonder how we ensure that there is actually an object in each world that can serve as an anaphoric antecedent.[41] We think there are several ways to answer this question. The first thing to note is that most theories of modality also treat the content of the modal as a test on possible worlds; this is as true for dynamic theories such as Veltman's (where the modal simply tests whether an update with the existential is possible in the first sentences of the cases we are concerned with) as it is for static theories, where changing the context is not even an option. So any answer that can be given for theories like these can also be used for ours: contextually derived restriction on modals (Roberts 1989), anaphoric dependencies on the propositions in the scope of modal operators (Frank 1997), or even approaches that simply pick out the set of worlds made salient by the first operator. It seems to be relatively straightforward to adapt any of these theories to our analysis, though we will not do so here. It is worth noting though that Asher and McCready (2007) provide an analysis of epistemic modals specifically designed to unify the Veltman-style test picture with a Roberts-style distributive update, in order to account simultaneously for the contrast between $\neg\phi \wedge \diamond\phi$ and $\diamond\phi \wedge \neg\phi$, and the possibility of modal subordination. We do not see any reason why the techniques proposed there should not be applicable to the current case as well.

Another possibility is to make use of the change in accessibility relations induced by E. Something like this is in fact proposed by (Ogata 2005a); the basic idea is that modals induce changes in Kripke structures that then allows for changes in how anaphoric accessibility works. We have put the basic framework needed for this to work into the modal already in the form of variable assignments, which (in definitions 2 and 3) are functions of the type

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[41] Thanks to an anonymous reviewer for making this point.

$Var \rightarrow W \rightarrow D$ such that $g(x)(w) \in D(w)$. We cannot spell out here the details of how this analysis works; the interested reader is referred to Ogata (2005a).[42] In any case, we think that either answer is compatible with what our theory says about the evidentials themselves.

Next, consider embedding. Ordinary modals have no problem appearing in the scope of negation, or in conditional antecedents, as demonstrated (for English) in (81a,b), respectively.[43]

(81)a. It is not the case that John might come. (= $\neg \diamond C(j)$, on one reading)
  b. If John might come, I will go. (= $\diamond C(j) \rightarrow G(i)$)

This means that if we treat the evidentials as modals, there should be no reason why they cannot appear in these environments either. And, indeed, this is the case, as shown by (82) and (83), respectively. Again, we abstract away from the content of the indices.

(82)a. konya   ame-ga   furi-soo   janai
    tonight   rain-Nom   fall(inf)-SOO   Cop.Neg.Pres
    'It doesn't look like it will rain tonight.'
  b. $\neg \triangle_a^i [rain(t) \wedge tonight(t)]$
    (= There is no evidence that leads me to believe that it will rain tonight.)

(83)a. Taro-ga   kuru   mitai   da-ttara   osiete   kudasai
    Taro-Nom   come   MITAI   Cop.Pres-COND   teach   please
    'If it looks like Taro will come, please tell me.'

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[42] We will, however, give a brief exposition. Anaphoric objects participating in modal subordination must be assigned the resident of whatever world is checked. For example, if w is the actual world, w_1 and w_2 are accessible from w and $D(w_1) = \{a\}, D(w_2) = \{b\}$, and $D_e = \{a, b\}$ where a and b are wolves, come in, and eat you. Suppose that a modal subordination sentence "A wolf might come in. It would eat you." is translated into the logical form $\diamond(\exists x(wolf(x) \wedge come\_in(x))) \wedge \square(eat\_you(x))$. Let $g : Var \rightarrow D_e$ be a standard variable assignment. In its dynamic interpretation, the input is (w, g); suppose now that $\exists x$ updates g to $g[a/x]$ or $g[b/x]$. So the output is $\{(w, g[a/x]), (w, g[b/x])\}$. So the input of $\square(eat\_you(x))$ is either $(w, g[a/x])$ or $(w, g[b/x])$, or both. But neither of $\{(w, g[a/x]), (w, g[b/x])\}$ can satisfy $\square(eat\_you(x))$, because this formula requires that for every world u accessible from w one of the assignments h such that $(u, h) \models eat\_you(x)$; but $(w_1, g[b/x]) \not\models eat\_you(x)$ and $(w_2, g[a/x]) \not\models eat\_you(x)$ either. This is the difficulty with using ordinary variable assignments.

The essence of binding in modal subordination is that anaphoric objects bound across modalities are assigned the enitity which lives in the world where the antecedent is evaluated. So the assignment must remember each world where the assignment associates a variable with its value. This can be done. Let $g : Var \rightarrow W \rightarrow D_e$ such that $g(x)(w) \in D(w)$, as in the main text. Suppose $\exists x$ updates g to $g[w_1 : a/x][w_2 : b/x]$ where $h[w : a/x](x')(w') = a$ if $w' = w$ and $x' = x$, otherwise $h(x')(w)$. Then the input of $\square(eat\_you(x))$ is $(w, g[w_1 : a/x, w_2 : b/x])$ which satisfies $(w, g[w_1 : a/x, w_2 : b/x]) \models \square(eat\_you(x))$, because $(w_1, g[w_1 : a/x, w_2 : b/x]) \models eat\_you(x)$ and $(w_2, g[w_1 : a/x, w_2 : b/x]) \models eat\_you(x)$. Therefore, defining assigments as functions of type $Var \rightarrow W \rightarrow D_e$ is one way to model modal subordination.

In order to make this work, we must alter the definition of the existential quantifier. We cannot discuss this more deeply here. See Ogata (2005a) for details, and Asher and McCready (2007) for a treatment with some spiritual similarities.

[43] This is true at least for the cases we consider. See von Fintel and Iatridou (2003) for some complications.

b. $\triangle_a^i[C(t)] \Rightarrow Imp(tell(y, i))$
(= If there is some evidence for Taro coming and Taro's coming is likely,
please tell me.)

Here, there is no reason that the evidential content must scope out in either case. This is as desired, and solves the problems for presuppositional and speech-act based accounts discussed in Sect. 4.

7 Conclusion and prospects

We hope to have shown three things in this paper. First, we showed that not all evidentials have the semantic characteristics—scopelessness and non-interaction with assertions—that semantic research has shown to associate with (some) evidentials in some languages. Second, we showed that evidentials of the Japanese kind behave much like a special kind of modal operator, one that explicitly specifies the sort of evidence that the speaker's judgement is based on. And, third, we showed that evidentials of the Japanese sort, at least, can be modeled in (we think) an intuitive and natural way using a combination of dynamics and probability.

This research also suggests a number of interesting next steps for future research. On the empirical side, the immediate question is whether the Japanese system and the Quechua system represent the major types of evidential systems to be found in the world's languages. Are there other types to be found, or does this exhaust the class? The answer pretty clearly seems to be that there are a number of other types. But further, semantically oriented, fieldwork is certainly needed to confirm what sorts of systems are out there, how they relate to the systems already analyzed, and how exactly they work. Another immediate area for further research is the interaction of evidentiality and modal subordination: what constraints come into play here? Are these constraints correlated in any significant way with evidential hierarchies or perceived reliability of information sources, as seems natural? On the theoretical side, what are the metalogical properties of the logic presented in this paper? Can correlations be found with other logical systems that might give insight into the sort of reasoning involved in evidentiality of the kind exemplified by Japanese? Finally, is a unified semantic theory of evidentiality possible: is there a logical type that all evidentials can be said to fall into, as nominals can (at some level) be said to be of type $\langle e, t \rangle$? Or are the types so heterogeneous that they don't even exemplify the same *kind* of meaning, as with difference between indefinite noun phrases and definite noun phrases (only the latter of which come with presuppositions)? In a way the present paper raises more questions than it answers. We think that pursuing them is an exciting task, and hope that others will feel the same.

Appendix A: probability spaces

We define *probability spaces* and related notions based on Halmos (1950); Billingsley (1986), as follows:

Definition 5 Let W be a set and $\mathcal{F}$ be a non-empty set of subsets of W such that $\bigcup \mathcal{F} = W$. $\mathcal{F}$ is a σ-algebra of X if

(i) $\emptyset \in \mathcal{F}$,
(ii) $X_i \in \mathcal{F} \implies (X - X_i) \in \mathcal{F}$, and
(iii) $X_i \in \mathcal{F} \ (i \geq 1) \implies \bigcup_{i=1}^{\infty} X_i \in \mathcal{F}$.

Definition 6 Let $\mathcal{F}$ be a σ-algebra of a set of possible worlds W. Then, $\mu : \mathcal{F} \longrightarrow [0,1]$ is a probability distribution (or probability measure) on measurable space $\langle W, \mathcal{F} \rangle$, written $\mu \in \mathcal{D}(W)$, if it is a measurable space, i.e., pair $\langle W, \mathcal{F} \rangle$, satisfying the following conditions:

1. it is countably additive, i.e., if for every disjoint sequence $\{X_i\}_{i \in I}$ of sets such that $\bigcup_{i=0}^{\infty} X_i \in \mathcal{F}$, then $\mu(\bigcup_{i=1}^{\infty} X_i) = \sum_{i=1}^{\infty} \mu(X_i)$,
2. it is positive, i.e., $\mu(Y) \geq 0$ for all $Y \in \mathcal{F}$, and
3. $\mu(W) = 1$.

The triple $\langle W, \mathcal{F}, \mu \rangle$, is called a probability space.

Definition 7 Let W be a set and $\mathcal{F}$ a set of subsets of X. If $\sigma(\mathcal{F})$ satisfies the following conditions, $\sigma(\mathcal{F})$ is called the σ-algebra generated by $\mathcal{F}$:

– $\mathcal{F} \subseteq \sigma(\mathcal{F})$,
– $\sigma(\mathcal{F})$ is a σ-algebra, and
– if $\mathcal{F} \subseteq \mathcal{G}$ and $\mathcal{G}$ is a σ-algebra, then $\sigma(\mathcal{F}) \subseteq \mathcal{G}$.

Appendix B: fragment $\mathcal{J}$ and its translation to $L_{E,\triangle,F}$ by type logical grammar

We define a formal grammar of a fragment including the Japanese evidential modality auxiliaries of Japanese and its translation by our version of Type Logical Grammar (Morrill 1994), as follows:

B.1 λ-terms

B.1.1 Variables

1. e: $x_0, \ldots, x_n, y_0, \ldots, y_n, z_0, \ldots, z_n$
2. $e \longrightarrow t$: P_1, P_2, P_3, P_4
3. $(e \longrightarrow t) \longrightarrow t$: Q_1, Q_2, Q_3, Q_4

B.2 λ-terms of $L_{\mathsf{E},\triangle,F}$

Let $\varphi \in L_{\mathsf{E},\triangle,\mathcal{F}}$ and x be a variable. Then, the set $LTERM(L_{\mathsf{E},\triangle,F})(\ni t)$ of λ-terms of $L_{\mathsf{E},\triangle,F}$ is defined by the following BNF grammar:

$$t ::= x \mid \lambda x.t \mid \varphi \mid (t_1 \ t_2)$$

B.3 Categories

The atomic categories consist of the following categories with parameter α

1. CN_α (common noun)
2. PP_α (postposition phrase)
3. S_α (sentence)

The class of atomic categories is denoted by $AtCat$.

Let $C \in AtCat$. The class of categories $C(AtCat) \in Cat, Cat_1, Cat_2$ is defined by the following BNF grammar:

$$Cat ::= C \mid Cat_1/Cat_2 \mid Cat_2 \backslash Cat_2$$

All categories have their corresponding type defined by recursion on Cat, as follows:

1. $f(CN_\alpha) = (e \rightarrow t)$
2. $f(PP_\alpha) = ((e \rightarrow t) \rightarrow t)$
3. $f(S_\alpha) = t$
4. $f(Cat_1 \backslash Cat_2) = (f(Cat_1) \rightarrow f(Cat_2))$
5. $f(Cat_2/Cat_1) = (f(Cat_1) \rightarrow f(Cat_2))$

B.4 Lexicon

1. $\langle \emptyset_k, (\lambda P_1.P_1 x_k) \rangle : PP_\alpha$
2. $\langle \mathbf{ga}_k, \lambda P_1.\lambda P_2.\exists x_k(P_1 x_k \wedge P_2 x_k) \rangle : CN_\alpha \backslash PP_{ga,a}$
3. $\langle \mathbf{ni}_k, \lambda P_1.\lambda P_2.\exists x_k(P_1 x_k \wedge P_2 x_k) \rangle : CN_{loc} \backslash PP_{ni,loc}$
4. $\langle \mathbf{ni}_k^j, \lambda P_1.\lambda P_2.\exists x_k(P_1 x_k \wedge x_k = x_j \wedge P_2 x_k) \rangle : CN_{loc} \backslash PP_{ni,loc}$
5. $\langle \mathbf{de}_k, \lambda P_1.\lambda P_2.\exists x_k(P_1 x_k \wedge P_2 x_k) \rangle : CN_{loc} \backslash PP_{de,loc}$
6. $\langle \mathbf{to}, \lambda p_1.p_1 \rangle : S_\alpha \backslash S_{quote}$
7. $\langle \mathbf{niyoruto}_k, \lambda P_1.\lambda p_1.\exists x_k(P_1 x_k \wedge p_1) \rangle : CN_{source} \backslash (S_{txt,a,k}/S_{txt,a,k})$
8. $\langle \mathbf{karasuruto}_k, \lambda P_1.\lambda p_1.\exists x_k(P_1 x_k \wedge p_1) \rangle : CN_{source} \backslash (S_{txt,a,k}/S_{txt,a,k})$
9. $\langle \mathbf{iru}, \lambda Q_1.\lambda Q_2.Q_2(\lambda x_2.Q_1(\lambda x_1.exist \ x_1 \ x_2)) \rangle : PP_{ga,+ani} \backslash PP_{ni,loc} \backslash S_{occ}$
10. $\langle \mathbf{aru}, \lambda Q_1.\lambda Q_2.Q_2(\lambda x_2.Q_1(\lambda x_1.exist \ x_1 \ x_2)) \rangle : PP_{ga,-ani} \backslash PP_{ni,loc} \backslash S_{occ}$
11. $\langle \mathbf{suru}, \lambda Q_1.\lambda Q_2.Q_2(\lambda x_2.Q_1(\lambda x_1.exist \ x_1 \ x_2)) \rangle : PP_{ga,sense} \backslash PP_{de,loc} \backslash S_{occ}$

12. $\langle$**natteiru**, $\lambda Q_1.\lambda x_1.Q_1(is\text{-}rolling\ x_1)\rangle : PP_{ga,phe}\backslash S_{occ}$
13. $\langle$**hajimaru**, $\lambda Q_1.\lambda x_1.Q_1(begin\ x_1)\rangle : PP_{ga,event}\backslash S_{occ}$
14. $\langle$**itta**$_k$, $\lambda p_1.\lambda x_1.Sort(i_k) = hearsay \wedge E^{i_k}_{x_1}p_1\rangle : S_{quote}\backslash PP_{agent}\backslash S_{occ,a}$
15. $\langle$**huri**, $\lambda Q_1.\lambda x_1.Q_1(fall\ x)\rangle : PP_{ga,wea}\backslash S_{inf,-stat}$
16. $\langle$**oishi**, $\lambda Q_1.\lambda x.Q_1(delicious\ x)\rangle : PP_{ga,-}\backslash S_{inf,+stat}$
17. $\langle$**aka**, $\lambda Q_1.\lambda x.Q_1(red\ x)\rangle : PP_{ga,-}\backslash S_{inf,+stat}$
18. $\langle\emptyset_k, \lambda p_1.E^{i_k}_a(p_1)\rangle : S_{occ}\backslash S_{txt,a}$
19. $\langle$**yoo da**$_k$, $\lambda p_1.\triangle^{i_k}_a(p_1)\rangle : S_{occ}\backslash S_{txt,a,k}$, where $i \in \{t,v,a,is,u\}$
20. $\langle$**mitai da**$_k$, $\lambda p_1.\triangle^{i_k}_a(p_1)\rangle : S_{occ}\backslash S_{txt,a,k}$, where $i \in \{t,v,a,is,u\}$
21. $\langle$**rashi i**$_k$, $\lambda p_1.\triangle^{i_k}_a(p_1)\rangle : S_{occ}\backslash S_{txt,a,k}$, where $i \in \{a,is,u,r\}$
22. $\langle$**soo da**$_k$, $\lambda p_1.H^{i_k}_a(p_1)\rangle : S_\alpha\backslash S_{txt,a,k}$
23. $\langle$**soo da**$_k$, $\lambda p_1.{}^{i_k}_a p_1\rangle : S_{inf,+stat}\backslash S_{txt,a,k}$, where $i \in \{t,v,a,is,u,j\}$
24. $\langle$**soo da**$_k$, $\lambda p_1.\triangle^{i_k}_a F(p_1)\rangle : S_{inf,-stat}\backslash S_{txt,a,k}$, where $i \in \{t,v,a,is,u,j\}$
25. $\langle; , \lambda p_1.\lambda p_2.\lambda p_1 \wedge p_2\rangle : S_{txt,a\beta}\backslash(S_{txt,a,-}/S_{txt,a,\gamma})$
26. $\langle$**neko**, $cat\rangle : CN_{+ani}$
27. $\langle$**suika**, $waterMelon\rangle : CN_{-ani}$
28. $\langle$**niwa**, $garden\rangle : CN_{loc}$
29. $\langle$**heya**, $room\rangle : CN_{loc}$
30. $\langle$**oto**, $sound\rangle : CN_{sen}$
31. $\langle$**ame**, $rain\rangle : CN_{wea}$
32. $\langle$**kaminari**, $thunder\rangle : CN_{phe}$
33. $\langle$**sensou**, $war\rangle : CN_{event}$
34. $\langle$**naka**$_k$, $\lambda x.inside(x_k,x)\rangle : CN_{part}$
35. $\langle$**shinbun**$_k$, $\lambda x(newspaper\ x\ i_k)\rangle : CN_{source}$
36. $\langle$**yoosu**$_k$, $\lambda x(scene\ x\ i_k)\rangle : CN_{source}$
37. $\langle$**Taro**, $\lambda x(x = Taro)\rangle : CN_{agent}$

B.5 Inference rules of type logical grammar

1. $\backslash E$

n	$\langle\mathbf{a}, \lambda x.\tau_1\rangle : Cat_1\backslash Cat_2$	
$n+1$	$\langle\mathbf{b}, \tau_2\rangle : Cat_2$	
$n+2$	$\langle\mathbf{b} \bullet \mathbf{a}\ \tau_1[\tau_2/x]\rangle : Cat_2$	$\backslash E\ n, n+1$

2. $/E$

n	$\langle\mathbf{a}, \lambda x.\tau_1\rangle : Cat_2\backslash Cat_1$	
$n+1$	$\langle\mathbf{b}, \tau_2\rangle : Cat_1$	
$n+2$	$\langle\mathbf{b} \bullet \mathbf{a}\ \tau_1[\tau_2/x]\rangle : Cat_2$	$/E\ n, n+1$

3. $\backslash I$

n	$\langle\mathbf{a}, \tau_1\rangle : Cat_1$	
	$\vdots$	
$n+k$	$\langle\mathbf{a} \bullet \mathbf{b}, \tau_2\rangle : Cat_2$	$\backslash I\ n, n+k$
$n+k+1$	$\langle\mathbf{b}, \lambda x.\tau_2[\tau_1/x]\rangle : Cat_1\backslash Cat_2$	

where x's type is $Type(Cat_1)$.

4. $/I$

$$
\begin{array}{lll}
n & \langle \mathbf{a}, \tau_1 \rangle : Cat_1 \\
& \quad\quad\quad\vdots \\
n+k & \langle \mathbf{b} \bullet \mathbf{a}, \tau_2 \rangle : Cat_2 & \backslash I\ n, n+k \\
\hline
n+k+1 & \langle \mathbf{b}, \lambda x.\tau_2[\tau_1/x] \rangle : Cat_2 \backslash Cat_1
\end{array}
$$

where x's type is $Type(Cat_1)$.

B.6 Examples

(84)a. niwa-de$_6$ oto-ga$_5$ suru$_1$.
         garden-in   sound-Nom   sound
         'I hear sound in the garden.
   b. $\mathsf{E}_a^{i_1}(\exists x_6.garden\ x_6 \wedge \exists x_5.sound\ x_5 \wedge exist\ x_5\ x_6)$

1. $\langle \mathbf{suru}, \lambda Q_1.\lambda Q_2.Q_2(\lambda x_2.Q_1(\lambda x_1.exist\ x_1\ x_2)) \rangle : PP_{ga,sense} \backslash PP_{de,loc} \backslash S_{occ}$

2. $\langle Q_3, Q_3 \rangle : PP_{ga,sense}$
3. $\langle Q_3 \bullet \mathbf{suru}, \lambda Q_2.Q_2(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)) \rangle : PP_{de,loc} \backslash S_{occ}$

4. $\langle Q_4, Q_4 \rangle : PP_{de,loc}$
5. $\langle Q_4 \bullet Q_3 \bullet \mathbf{suru}, Q_4(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)) \rangle : S_{occ}$
6. $\langle \emptyset_1, \lambda p_1.\mathsf{E}_a^{i_1}(p_1) \rangle : S_{occ} \backslash S_{txt,a}$
7. $\langle Q_4 \bullet Q_3 \bullet \mathbf{suru} \bullet \emptyset_1, \mathsf{E}_a^{i_1} Q_4(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)) \rangle : S_{txt,a}$

8. $\langle Q_3 \bullet \mathbf{suru} \bullet \emptyset_1, \lambda Q_4.\mathsf{E}_a^{i_1} Q_4(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)) \rangle : PP_{de,loc} \backslash S_{txt,a}$

9. $\langle \mathbf{suru} \bullet \emptyset_1, \lambda Q_3.\lambda Q_4.\mathsf{E}_a^{i_1} Q_4(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)) \rangle : PP_{ga,sen} \backslash PP_{de,loc} \backslash S_{txt,a}$
10. $\langle \mathbf{oto}, sound \rangle : CN_{sen}$
11. $\langle \mathbf{ga}_5, \lambda P_1.\lambda P_2.\exists x_5(P_1 x_5 \wedge P_2 x_5) \rangle : CN_\alpha \backslash PP_{ga,\alpha}$
12. $\langle \mathbf{oto} \bullet \mathbf{ga}_5, \lambda P_2.\exists x_5(sound\ x_5 \wedge P_2 x_5) \rangle : PP_{ga,sen}$
13. $\langle \mathbf{oto} \bullet \mathbf{ga}_5 \bullet \mathbf{suru} \bullet \emptyset_1, \lambda Q_4.\mathsf{E}_a^{i_1} Q_4(\lambda x_2.\exists x_5(sound\ x_5 \wedge exist\ x_5\ x_2)) \rangle : PP_{de,loc} \backslash S_{txt,a}$
14. $\langle \mathbf{de}_6, \lambda P_1.\lambda P_2.\exists x_6(P_1 x_6 \wedge P_2 x_6) \rangle : CN_{loc} \backslash PP_{de,loc}$
15. $\langle \mathbf{niwa}, garden \rangle : CN_{loc}$
16. $\langle \mathbf{niwa} \bullet \mathbf{de}_6, \lambda P_2.\exists x_6(garden\ x_6 \wedge P_2 x_6) \rangle : PP_{de,loc}$
17. $\langle \mathbf{niwa} \bullet \mathbf{de}_6 \bullet \mathbf{oto} \bullet \mathbf{ga}_5 \bullet \mathbf{suru} \bullet \emptyset_1, \mathsf{E}_a^{i_1}(\exists x_6(garden\ x_6 \wedge \exists x_5(sound\ x_5 \wedge exist\ x_5\ x_6))) \rangle : S_{txt,a}$

(85)a. $\emptyset_6$ neko-ga$_5$ iru   yoo-da$_1$.
         emptyPRO   cat-Nom   Cop.Pres   YOO-Cop.Pres
         'There seems to be a cat in the garden.
   b. $\triangle_a^{i_1}(\exists x_5.cat\ x_5 \wedge exist\ x_5\ x_6)$

1. $\langle \mathbf{iru}, \lambda Q_1.\lambda Q_2.Q_2(\lambda x_2.Q_1(\lambda x_1.exist\ x_1\ x_2)))\rangle : PP_{ga,+ani}\backslash PP_{ni,loc}\backslash S_{occ}$

2. $\langle Q_3, Q_3\rangle : PP_{ga,+ani}$
3. $\langle Q_3 \bullet \mathbf{iru}, \lambda Q_2.Q_2(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)))\rangle : PP_{ni,loc}\backslash S_{occ}$

4. $\langle Q_4, Q_4\rangle : PP_{ni,loc}$
5. $\langle Q_4 \bullet Q_3 \bullet \mathbf{iru}, Q_4(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)))\rangle : S_{occ}$
6. $\langle \mathbf{yoo\ da}_1, \lambda p_1. \triangle_a^{i_1}(p_1)\rangle : S_{occ}\backslash S_{txt,a}$
7. $\langle Q_4 \bullet Q_3 \bullet \mathbf{iru} \bullet \mathbf{yoo\ da}_1, \triangle_a^{i_1}Q_4(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)))\rangle : S_{txt,a}$

8. $\langle Q_3 \bullet \mathbf{iru} \bullet \mathbf{yoo\ da}_1, \lambda Q_4. \triangle_a^{i_1}Q_4(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)))\rangle : PP_{ni,loc}\backslash S_{txt,a}$

9. $\langle \mathbf{iru} \bullet \mathbf{yoo\ da}_1, \lambda Q_3.\lambda Q_4. \triangle_a^{i_1}Q_4(\lambda x_2.Q_3(\lambda x_1.exist\ x_1\ x_2)))\rangle : PP_{ga,+ani}\backslash PP_{ni,loc}\backslash S_{txt,a}$
10. $\langle \mathbf{neko}, cat\rangle : CN_{+ani}$
11. $\langle \mathbf{ga}_5, \lambda P_1.\lambda P_2.\exists x_5(P_1 x_5 \wedge P_2 x_5)\rangle : CN_\alpha\backslash PP_{ga,\alpha}$
12. $\langle \mathbf{neko} \bullet \mathbf{ga}_5, \lambda P_2.\exists x_5(cat\ x_5 \wedge P_2 x_5)\rangle : PP_{ga,+ani}$
13. $\langle \mathbf{neko} \bullet \mathbf{ga}_5 \bullet \mathbf{iru} \bullet \mathbf{yoo\ da}_1, \lambda Q_4. \triangle_a^{i_1}Q_4(\lambda x_2.\exists x_5(cat\ x_5 \wedge exist\ x_5\ x_2)))\rangle : PP_{ni,loc}\backslash S_{txt,a}$
14. $\langle \emptyset_6, \lambda P_2.P_2 x_6\rangle : PP_\alpha$
15. $\langle \emptyset_6 \bullet \mathbf{neko} \bullet \mathbf{ga}_5 \bullet \mathbf{iru} \bullet \mathbf{yoo\ da}_1, \triangle_a^{i_1}(\exists x_5(cat\ x_5 \wedge exist\ x_5\ x_6)))\rangle : S_{txt,a}$

(86)a. naka$_6$-ga$_5$ aka-soo-da$_1$.
      inside-Nom   red(inf)-SOO-Cop.Pres
      'It looks like it must be red inside.'
   b. $\triangle_a^{i_1}(\exists x_5.inside\ x_6\ x_5 \wedge red\ x_5)$

1. $\langle \mathbf{aka}, \lambda Q_1.Q_1(\lambda x_1.red\ x_1)\rangle : PP_{ga,-}\backslash S_{inf,+stat}$

2. $\langle Q_3, Q_3\rangle : PP_{ga,-}$
3. $\langle Q_3 \bullet \mathbf{aka}, Q_3(\lambda x_1.red\ x_1)\rangle : PP_{ga,-}\backslash S_{inf,+stat}$
4. $\langle \mathbf{soo\ da}_1, \lambda p_1. \triangle_a^{i_1}p_1\rangle : S_{inf,+stat}\backslash S_{txt,a,k}$
5. $\langle Q_3 \bullet \mathbf{aka} \bullet \mathbf{soo\ da}_1, \triangle_a^{i_1}Q_3(\lambda x_1.red\ x_1)\rangle : S_{txt,a}$

6. $\langle \mathbf{aka} \bullet \mathbf{soo\ da}_1, \lambda Q_3. \triangle_a^{i_1}Q_3(\lambda x_1.red\ x_1)\rangle : PP_{ga,-}\backslash S_{txt,a}$
7. $\langle \mathbf{naka}_6, \lambda x.inside(x_6,x)\rangle : CN_{part}$
8. $\langle \mathbf{ga}_5, \lambda P_1.\lambda P_2.\exists x_5(P_1 x_5 \wedge P_2 x_5)\rangle : CN_\alpha\backslash PP_{ga,\alpha}$
9. $\langle \mathbf{naka} \bullet \mathbf{ga}_5, \lambda P_2.\exists x_5(inside(x_6,x_5) \wedge P_2 x_5)\rangle : PP_{ga,part}$
10. $\langle \mathbf{naka} \bullet \mathbf{ga}_5 \bullet \mathbf{aka} \bullet \mathbf{soo\ da}_1, \triangle_a^{i_1}\exists x_5(inside(x_6,x_5) \wedge red\ x_5)\rangle : S_{txt,a}$

(87)a. ame-ga$_5$ huri-soo-da$_1$.
      rain-Nom   fall(inf)-SOO-Cop.Pres
      'It looks like it's going to rain.'
   b. $\triangle_a^{i_1}F(\exists x_5.rain\ x_5 \wedge fall\ x_5)$

1. $\langle \mathbf{huri}, \lambda Q_1.Q_1(\lambda x_1.fall\ x_1) \rangle : PP_{ga,-}\backslash S_{inf,-stat}$

2. $\langle Q_3, Q_3 \rangle : PP_{ga,-}$
3. $\langle Q_3 \bullet \mathbf{huri}, Q_3(\lambda x_1.fall\ x_1) \rangle : PP_{ga,-}\backslash S_{inf,-stat}$
4. $\langle \mathbf{soo\ da}_1, \lambda p_1.\,\triangle_a^{i_1} Fp_1 \rangle : S_{inf,-stat}\backslash S_{txt,a,k}$
5. $\langle Q_3 \bullet \mathbf{huri} \bullet \mathbf{soo\ da}_1, \triangle_a^{i_1} FQ_3(\lambda x_1.fall\ x_1) \rangle : S_{txt,a}$

6. $\langle \mathbf{huri} \bullet \mathbf{soo\ da}_1, \lambda Q_3.\,\triangle_a^{i_1} Q_3(\lambda x_1.fall\ x_1) \rangle : PP_{ga,-}\backslash S_{txt,a}$
7. $\langle \mathbf{ame}, rain \rangle : CN_{wea}$
8. $\langle \mathbf{ga}_5, \lambda P_1.\lambda P_2.\exists x_5(P_1x_5 \wedge P_2x_5) \rangle : CN_a\backslash PP_{ga,\alpha}$
9. $\langle \mathbf{ame} \bullet \mathbf{ga}_5, \lambda P_2.\exists x_5(rain\ x_5 \wedge P_2x_5) \rangle : PP_{ga,wea}$
10. $\langle \mathbf{ame} \bullet \mathbf{ga}_5 \bullet \mathbf{huri} \bullet \mathbf{soo\ da}_1, \triangle_a^{i_1} F\exists x_5(rain\ x_5 \wedge fall\ x_5) \rangle : S_{txt,a}$

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