

# Connecting perception, inference, and temporality: nominal and propositional evidentiality

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## Witnesses With Firsthand Knowledge Of Events Central To Impeachment Inquiry Testify

NPR · 3 days ago

## Impeachment: Firsthand Witnesses Voice Concerns About July 25 Call

Wall Street Journal · 3 days ago · Satire



## Evidentiary Matters

Flathead Beacon · 8 hours ago · Opinion

## Second Ukraine Whistleblower With Firsthand Knowledge of Allegations Comes Forward

Slate · Last month



## In a new book, an insider offers a firsthand look at the Beatles. Here are a few takeaways.

The Washington Post · Yesterday · Opinion



## Democrats and Republicans battle over 'hearsay' during impeachment hearings

Fox News · 7 days ago

How do human beings connect a piece of evidence to a piece of information and form core justified beliefs?

An evidential is a linguistic marker of **how** an agent came across a piece of information.

The issue of evidence for a proposition is complex:

- the **mechanism** behind evidence collection
- the **temporality** of evidence collection
- the **reliability** of the evidence source

Linguists and philosophers have written volumes about each of these.

[[mee tabori botee]-**mete-moneha**] otaaA awa-**hamaro** ama-ke  
3nsg home:f old-FPNf-REPF nsg.exc see-FPEf EXTENT-DECf  
'We were seeing this in the far past what was reported to be their old camp from far past.'

## Jawahara: three evidentials in one sentence

[[mee tabori botee]-**mete-moneha**] otaaA awa-**hamaro** ama-ke  
3nsg home:f old-FPnf-REPF nsg.exc see-FPef EXTENT-DECf  
'We were seeing this in the far past what was reported to be their old camp from far past.'

The temporal paradigm is intertwined with the evidentiality paradigm.

This richness in marking types evidence is very common across diverse language families.

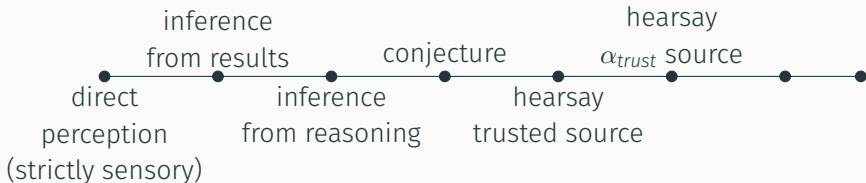
first:

evidentiality in the **propositional**  
domain

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Major accounts have focused on **propositional** evidentiality. [PE]

evidential [ proposition ]



Like Jarawara, many languages have evidential paradigms intertwined with tense and aspect paradigms.

**Three temporal relationships** play a crucial role in determining which tense/aspectual marking is reflected on the verb in the presence of what flavor of evidence.

- the time the event occurred [ET]
- the time the evidence about the event was acquired by the agent, i.e. the evidence acquisition time [EAT]
- the speech time [ST]

Korean, Bulgarian, and Matsigenka are the most well-studied of these systems.

Chung (2007), Fleck (2007), Lee (2012), Smirnova (2012), Koev (2016)



# Matses Double Tense

- (1) a. mayu-n                      bēste-wa-**ak-onda-ṣh**.  
non.Matses.Indian-ERG hut-make-REC.PAST.INF-DIST.PAST.EXP-3  
'Non-Matses Indians (had) made a hut.' [a recently made hut was  
discovered by the speaker a long time ago]

- b. mayu-n                      bēste-wa-**nēdak-o-ṣh**.  
non.Matses.Indian-ERG hut-make-DIST.PAST.INF-REC.PAST.EXP-3  
'Non-Matses Indians (had) made a hut.' [an old hut was discovered  
by the speaker a short time ago]

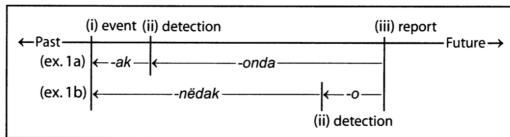


FIGURE 1. Temporal reference points for inferential and experiential suffixes.

The primary parameter in temporal PE systems is to determine is whether or not there is **temporal overlap** between ET, EAT, and ST, and consequently, the evidential overtones are deduced.

Let us call this parameter the *temporal* factor.

## the temporal factor: perfect aspect

Morphologically, across languages, the perfect aspect shows up when the proposition has been **inferred**, rather than witnessed.

Bulgarian perfect aspect:

- (1) Maria celuna-**la** Ivan  
Maria kiss-PERF Ivan  
'Maria apparently kissed Ivan.'

# inference in South Asian languages: perfect aspect

Hunza Burushaski

- (2) khuulto giłt-ulo buT-an tiS gutshari-lá qheér  
today Gilgit-in great-INDEF wind blow-PERF.3S DISC  
'There was a storm in Gilgit today' (concluded after seeing  
broken branches)

Wakhi

- (3) wudg-i mōr dyet-k  
today-3S rain give-PERF  
'It has rained today.' (concluded after seeing water on ground).

Bashir (2006)

## the temporal factor: simple past

The simple past tense contributes a DIRECT evidential flavor or a **witnessed event**.

Malayalam simple witnessed past:

- (4) Raman-te acchan i viTu nirmmiccu  
Raman-GEN father(NOM) this house build(PST)  
'Raman's father built this house.' (Speaker saw him building it).

Bashir (2006) for Malayalam, Telugu, Kannada, Marathi, Wakhi

# simple witnessed past in South Asian languages

## Tamil

- (5) viran inta viṭaik kaTT-**in**-an  
Viran this house-ACC build-PAST-3SG  
'Viran built this house.' (personally witnessed or known as verified fact)

## Telugu

- (6) salim vaḷḷ-a nanna i illu kaTT-inc-**a**-Du  
Salim ones-OBL father this house build-CS-PAST-3SG  
'Salim's father built this house.' (personally witnessed)

## Marathi

- (7) majhy-ā bhāvā-nī salīm-lā patra lihi-**lā**  
my-OBL brother-AG salim-DAT letter write-PAST.INDEF(m.s.)  
'My brother wrote a letter to Salim' (personally witnessed)

## the temporal factor

### TENSE

**past** = witnessed/DIRECT

### ASPECT

**perfective/resultative** = inference  
from results

**imperfective** = DIRECT

next:

evidentiality in the **nominal**  
domain

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## compare: nominal evidentiality

Somali is a language with **nominal tense**, within which the evidentiality paradigm is housed.

Context: Both the speaker and the hearer know that the girl is present in the next room.

(8) Inantaa-**dii**    uur                  bay                  leedahay  
girl-F.POSS2S-DEFF.PAST[+NOM] pregnancy C/F.3FS has.3FS  
Doctor to Mother: ‘Your daughter is pregnant.’

By the use of past tense, the speaker signals that the girl is absent from the immediate visual context.

Crucially then, the past tense signals: the referent is ‘*epistemically present/visible but **evidentially** past/hidden/distant*’

Lecarme (2008)

when evidentials scope over nominals in nominal tense languages:  
the crucial parameter appears to be **visibility** of the referent.

- when the nominal past tense is used, then the implication is that the referent is **not visible** to the speaker at utterance time.
- when the nominal present tense is used, then the implication is that the referent is **visible** to the speaker at utterance time.

## nominal evidentiality in the determiner system

Lillooet marks degrees of sensory evidentiality in the determiner system.

- (9) Lillooet **visual** sensory  
pun-lkan **ti**=n-lk'wal'us=a  
find-1SG.A DET:VIS=1SG.POSS-basket=ASSERTION.OF.EXISTENCE  
'I found my basket.' (the referent is visible to the speaker at utterance time)
- (10) Lillooet **non-visual** sensory  
ctas lakwta llakwu **kwu**=s?'alalam=a  
come NON.VIS there:NON.VIS DET:NON.VIS.SENS=grizzly=EXIST  
'There is a grizzly coming from there.' (speakers hear a grizzly but does not see it)

van Eijk (1997)

# nominal evidentiality in South Asian languages

Till date, I have not found any mention of a nominal tense system in South Asia.

However, we do know of a few dem/det systems that mark evidential contrasts!

Enter: the Shina languages (Dardic; Indo-Aryan) of Pakistan

<i>aae/paár</i>	proximal det/deictic	visual/visible to sp. or addr.
<i>asá/pér</i>	distal det/deictic	hearsay/not visible to sp. or addr.

- (11) **pér** bo waá  
away [invisible] go.IMP EMPH  
'Go away!'
- (12) mō **paár-aae** váari bój-m-as  
I over.there (close, seen) direction go-IMPV-1SG  
'I am going over there (a short distance in the speaker's line of sight).'

a pronominal system with four third person pronouns/deictic elements:

- visible or known
- invisible or unknown
- close visible
- remote visible

Evidentiality is encoded into this system:

**first-hand knowledge** is mapped onto **visibility** (*zo*)

**second-hand knowledge** (hearsay) or inference is mapped onto **invisibility** (*so*)

So, what do we notice in common within languages with non-propositional evidentiality?

The **visibility** of the referent is the crucial factor in determining the appropriate tense/DET presence.

A paradigmatic connection between visual perception and the 'known/unknown'.

**Visual evidence is privileged over other forms of sensory evidence.**

Let us call this the **spatial factor**.

## the spatial factor

### NOMINAL TENSE

**past** = not visible at speech time

**present** = visible at speech time

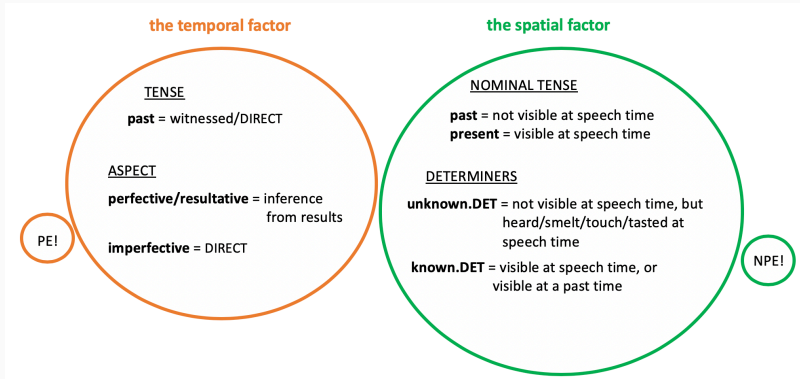
### DETERMINERS

**unknown.DET** = not visible at speech time, but  
heard/smelt/touch/tasted at  
speech time

**known.DET** = visible at speech time, or  
visible at a past time



# comparing PE and NPE systems



We see a **clear opposition** across PE and NPE systems with respect to the evidential status of past/non-past.

Also note that overwhelmingly, **NPE systems are restricted to just sensory/DIRECT evidence.**

## the temporal factor

### TENSE

**past** = witnessed/DIRECT

### ASPECT

**perfective/resultative** = inference  
from results

**imperfective** = DIRECT

PE!

## the spatial factor

### NOMINAL TENSE

**past** = not visible at speech time

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### DETERMINERS

**unknown.DET** = not visible at speech time, but  
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**known.DET** = visible at speech time, or  
visible at a past time

NPE!

**Goals:** a comparison of PE & NPE systems along this space-time continuum; a unified formal semantic analysis

Through the comparison of PE & NPE systems along the space-time continuum, I want to weigh in on the well-debated question:

**What is at the semantic core of an evidential?**

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propositions (mostly)  
individuals/entities

Why is there a **strict divide** between flavors of evidence when associated with nominals vs. propositions?

What is a unified approach that captures interactions with **temporal** categories like tense/aspect, and **spatial** categories like demonstratives/determiners?

Through the comparison of PE & NPE systems along the space-time continuum, I want to weigh in on the well-debated question:

What is at the semantic core of an evidential?

using tools from Modal Logic:

*a spatio-temporal accessibility relation*

propositions (mostly)  
individuals/entities

Why is there a **strict divide** between flavors of evidence when associated with nominals vs. propositions?

What is a unified approach that captures interactions with **temporal** categories like tense/aspect, and **spatial** categories like demonstratives/determiners?

## Analysis: Perception

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Perception is crucial to intelligent agents:

- in forming a coherent mental picture of the physical space surrounding them, encompassing objects, events, individuals.
- **underlies the formation of beliefs** (like reasoning and hearsay) and yet enjoys a more privileged status in terms of **reliability**

However, the nature of perception is inherently complex:

- accounting for how connections are built between sensing the *appearance* of an entity and *reality*

This has long been recognized as a problem for any theory of perceiving by philosophers and cognitive scientists alike<sup>1</sup>.

<sup>1</sup>Musto & Konolige (1993)

Perception has been argued to be *causal* in nature:

– perceiving an occurrence in the physical world leads us to acquire a logical belief of what the truth/reality looks like.

**Perception has an epistemic component.**

(Dretske's (1969, 1990) pioneering work on the philosophy of perception)

What we are seeing at any given point of time is always evaluated against an existing body of knowledge he calls *proto-knowledge*.



# epistemic seeing

Our knowledge is incremented directly by visual perception, in a process Dretske calls *epistemic seeing*.

- (13) A: I have put some water on for tea; can you see whether it is boiling or not?  
B (perfunctorily): Yes, it is.  
A (suspiciously): Are you sure?

B cannot have known that the object on the stove is indeed water without visually experiencing it and confirming it himself.

We have to be careful to not confuse the following: (i) *seeing that the water is boiling*, versus (ii) *seeing that something is boiling water*.

Dretske (1969)

# epistemic perception

(i) *seeing that the water is boiling*

– the fact that it is water is asserted based on B's proto-knowledge

(ii) *seeing that something is boiling water*

– the fact that it is boiling is accessed by vision

(and thus added to the agent's knowledge)

What is termed as the process of perception is **epistemic perception**: objects of perception are both evaluated against an agent's existent knowledge

AND

help add to that knowledge new justified true beliefs causally formed via perception.

**All perception is epistemic perception.**

# cross-categorical epistemic perception

One main goal: is to provide a view of evidentiality that encompasses both PE and NPE systems.

I want to build a notion of epistemic perception in formal semantic terms.

We will need tools that allow for “perceiving” both nominals as well as propositions.

How can we then build a cross-categorical model of epistemic perception that encodes both the **spatio-temporal coordinates of physical reality** and convey **the (almost) absolute confidence** that an agent places on the beliefs caused by perceptual processes?

The answer lies in *historical modality*.<sup>2</sup>

A historical accessibility relation grants an agent a special kind of access:

(14) **Historical accessibility relation**<sup>3</sup>

R is a historical accessibility relation iff for some time  $t$ , R = the relation which holds between two worlds  $w$  and  $w'$  iff  $w$  and  $w'$  are identical at all times up to and including  $t$ .

<sup>2</sup>Kamp 1979, Thomason 2002

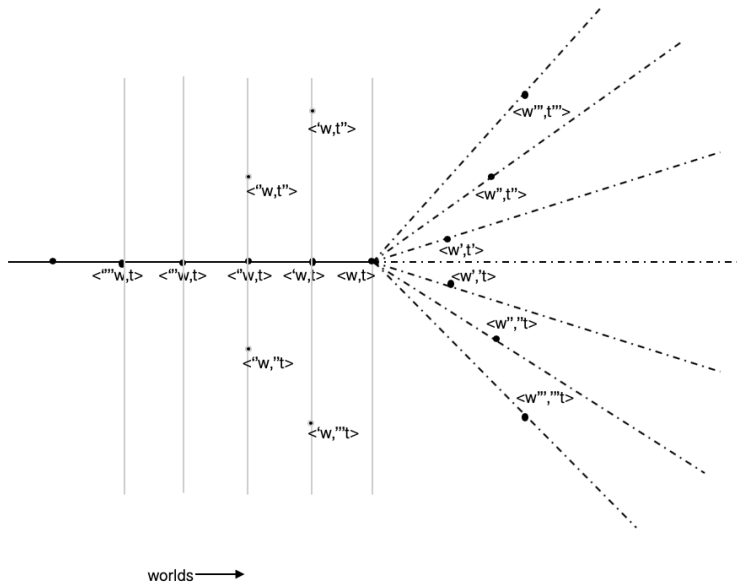
<sup>3</sup>Portner 2009

There is an asymmetry between a fixed past and an open future (based on a notion of “branching time”).

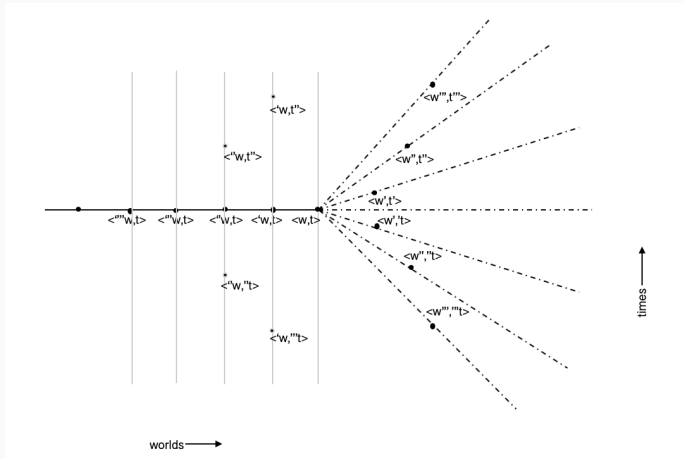
- time is not a line but a tree with a fixed root (for past time) and many branching leaves (for possible future times)

A historical accessibility relation is a special modal relation whose role is to identify *historical alternatives*

- i.e. given the world-time pair of evaluation  $\langle w, t \rangle$ , its historical alternatives are worlds that are identical to  $w$  up to and including  $t$ 
  - are allowed to differ from  $w$  at times later than  $t$



# historical alternatives



At times later than  $t$ , the worlds start being different:

$$\text{(after } t) w \neq w' \neq w'' \neq w'''$$

$$\text{(before } t) '''w = ''w = 'w = w$$

The **historical accessibility relation** ( $\approx$ ) is an equivalence relation in that it is reflexive, symmetric and transitive.

The crucial properties of the relation  $\approx$  ('being a historical alternative to'):

- (15) Properties of  $\approx$  (assuming  $>$  and  $<$  to be temporal precedence and succession relations, respectively)
- a.  $\approx$  is modal
  - b.  $\approx$  is an equivalence relation
  - c. If  $\langle w, t \rangle \approx \langle w', t' \rangle$  and  $t' < t$ , then  $\langle w, t' \rangle \approx \langle w', t' \rangle$
  - d. If  $\langle w, t \rangle \approx \langle w', t' \rangle$ , then for all atomic sentences  $p$ ,  $V_{\langle w, t \rangle}(p) = V_{\langle w', t' \rangle}(p)$



If  $\langle w, t \rangle \approx \langle w', t \rangle$  and  $t' < t$ , then  $\langle w, t' \rangle \approx \langle w', t' \rangle$

– two worlds that are each other's historical alternatives at some time  $t$  have been historical alternatives at *all* times up to  $t$ , ensuring

**a hard-wired shared past**

– accessibility of a world from the world of evaluation  $w$  at a given time is extended to all earlier times

If  $\langle w, t \rangle \approx \langle w', t \rangle$ , then for all atomic sentences  $p$ ,

$$V_{\langle w, t \rangle}(p) = V_{\langle w', t \rangle}(p)$$

– the truth assignment function assigns the same truth value to all atomic sentences that are evaluated at  $w$  and a historical alternative 'just like  $w'$ ', i.e.  $w'$

(given that they are identical worlds at a given time)

## settledness/historical necessity

- (16) Properties of  $\approx$  (assuming  $>$  and  $<$  to be temporal precedence and succession relations, respectively)
- $\approx$  is modal
  - $\approx$  is an equivalence relation
  - If  $\langle w, t \rangle \approx \langle w', t \rangle$  and  $t' < t$ , then  $\langle w, t' \rangle \approx \langle w', t' \rangle$
  - If  $\langle w, t \rangle \approx \langle w', t \rangle$ , then for all atomic sentences  $p$ ,  $V_{\langle w, t \rangle}(p) = V_{\langle w', t \rangle}(p)$

This formulation thus underlies the idea of **settledness** or **historical necessity**.

- because by design, truth at all historical alternatives results in necessity with respect to  $\approx$ .
- The past is thus incommutable in this design of metaphysical necessity (and the future non-deterministically open)

# historical necessity

Thus, we are modeling the past as incommutable in the design of metaphysical necessity.

An agent bases their certainty in their knowledge on the settledness arising out of **universal access to all historical alternatives**.

Denoted by  $\Box_{\approx}$ .

Access to all prior (identical) worlds at a given time seems necessary in modeling epistemic perception.

Crucially however, **we also need temporal accessibility**, whereby we have access to prior times as well

– given that we are exploring the fundamental involvement of temporality in evidentiality in a large number of languages.

Let's add a **temporal dimension** to possible worlds, by introducing an ordered set  $(T, <)$ .

$<$  (the *earlier than* relation) has the following properties (which are preserved by its inverse operator  $>$  (the *later than* relation) as well:

- (17) Properties of temporal accessibility:
- irreflexivity*: not  $(t < t)$
  - transitivity*: if  $t < t'$  and  $t' < t''$ , then  $t < t''$
  - linearity*:  $t < t'$  or  $t' < t$  or  $t = t'$

- (18) Properties of temporal accessibility:
- a. *irreflexivity*: not  $(t < t)$
  - b. *transitivity*: if  $t < t'$  and  $t' < t''$ , then  $t < t''$
  - c. *linearity*:  $t < t'$  or  $t' < t$  or  $t = t'$

$>_{\langle w,t \rangle}$  then gives us the set of all world-time pairs  $\langle w,t' \rangle$  that **precede**  $\langle w,t \rangle$  in time (given  $t > t'$ ).

The relationship holds in the opposite direction with  $<_{\langle w,t \rangle}$  as well.

Additionally we have the sets  $\leq_{\langle w,t \rangle}$  and  $\geq_{\langle w,t \rangle}$  which include the current world-time pair  $\langle w,t \rangle$ .

We can quantify over these sets with the operators  $\Diamond_{>/<}$  and  $\Box_{>/<}$  (Prior 1967)

– and evaluate  $V_{\langle w,t \rangle}(\Diamond_{>} p)$  as 1 iff  $V_{\langle w,t \rangle}(p)$  is 1 for some  $\langle w,t' \rangle$  in the  $>$  relation accessed from  $\langle w,t \rangle$ , i.e.  $>_{w,t}$ .

We can now perceptual evidence by **combining both historical accessibility and temporal accessibility**.

I am going to use the symbol  $\mathbb{K}$  to denote the combination of the operators  $\square_{\approx} \diamond_{\geq}$  (the historical necessity relation and the *earlier than* temporal accessibility relation including the present time).

## Applying the analysis to nominal evidentiality

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(19) Visual nominal: present

$$R_{\text{visual-nominal}}(\langle wt \rangle, \langle e, w', t' \rangle) =_{\text{def}} \{ \langle e, w, t \rangle \mid \exists \langle w', t' \rangle \in \mathbb{K}_{\langle w, t \rangle} \\ \text{SEE}(sp, e, w', t') \wedge t = t' \}$$

The predicate SEE is true iff the speaker saw (**in the pure sense of perceived via vision**) the entity  $e$  at world  $w'$  and time  $t'$ .

The **explicit restriction of equivalence** between  $t$  and  $t'$  states that the seeing has be happening at the current time only.

The output of this accessibility relation:

- a set of tuples with each tuple consisting of an entity, world, and time
- a specification that the speaker is seeing that entity currently.

The morphological representation of this accessibility relation  $R_{V-N}$  is the use of the nominal present in Somali, Navicle, and Nambikwara.



In contrast, the **visual past** has the same temporal accessibility relation that grants access to all of the times preceding  $t$  (including of course the historical alternatives as before)

– but with an explicit restriction that the seeing is not happening at speech time.

Thus, we can represent the fact that at some point in all the world-time pairs before speech time, the speaker saw the referent as:

(20) Visual nominal: past

$$R_{V-N}(\langle wt \rangle, \langle e, w', t' \rangle) =_{\text{def}} \{ \langle e, w, t \rangle \mid \exists \langle w', t' \rangle \in \mathbb{K}_{\langle w, t \rangle} \text{ SEE} \\ (sp, e, w', t') \wedge t \neq t' \}$$

(21) Visual nominal: past

$$R_{V-N}(\langle wt \rangle, \langle e, w', t' \rangle) =_{\text{def}} \{ \langle e, w, t \rangle \mid \exists \langle w', t' \rangle \in \mathbb{K}_{\langle w, t \rangle} \text{ SEE} \\ (sp, e, w', t') \wedge t \neq t' \}$$

The output of this relation:

– a set of tuples with each tuple consisting of an entity, world, and time such that that entity was seen at that corresponding world and time.

Crucially, **the speech time cannot be any of these times.**

The **nominal past tense** shows up as the representation of this accessibility relation  $R_{V-N}$  in the same languages.

The paradigm (Lillooet, Tsou, Kohistani Shina, Tileli Shina):

'unknown'.DET = not visible at speech time, but  
heard/smelt/touch/tasted at speech time

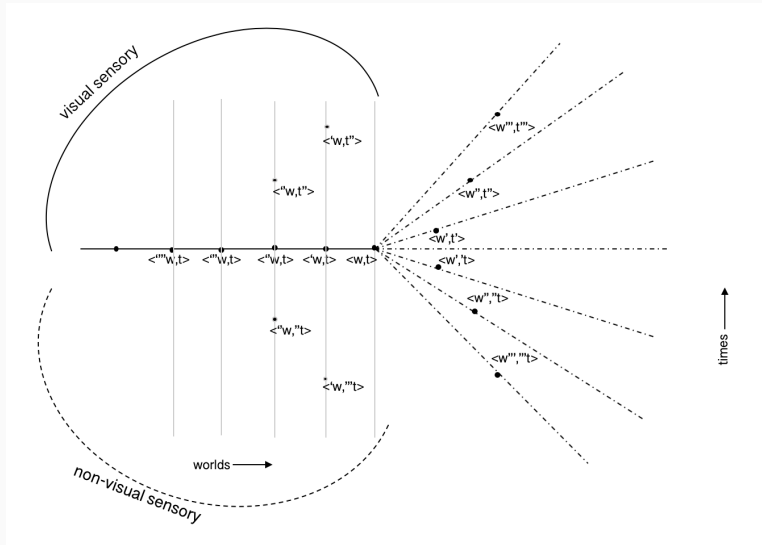
'known'.DET = visible at speech time, or visible at a past time

The vital divide is between visual and non-visual (but still sensory!)  
evidence.

Again highlights the privilege that visual input enjoys in linguistic  
encoding.

My claim: we can use the same tools from **modal logic** to represent  
these distinctive systems.

What we are seeing in DEM systems: distinctions in accessing **the same historical alternatives through different sensory devices.**



With the same historical and temporal accessibility relation, now we can locate the difference in which sensory relationship holds between **the speaker and an entity at some historically accessible world-time pair**:

$$(22) \quad R_{\text{visual-dem}}(\langle w,t \rangle, \langle e,w',t' \rangle) \stackrel{\text{def}}{=} \{ \langle e,w,t \rangle \mid \exists \langle w',t' \rangle \in \mathbb{K}_{\langle w,t \rangle} \text{ SEE } (sp,e,w',t') \}$$

$$(23) \quad R_{\text{non-visual-dem}}(\langle w,t \rangle, \langle e,w',t' \rangle) \stackrel{\text{def}}{=} \{ \langle e,w,t \rangle \mid \exists \langle w',t' \rangle \in \mathbb{K}_{\langle w,t \rangle} \text{ SMELL / HEAR / TASTE / TOUCH } (sp,e,w',t') \}$$

The 'known' DET/DEM is the lexical manifestation of (22).

The 'unknown' DET/DEM is the lexical manifestation of (23).

Note that **we do not need an explicit temporal restriction** whether the time satisfying the existential quantification is the speech time or not.

In general, the visual/non-visual distinction is a very integral one in the empirical landscape.

Aikhenvald (2018) reports that **no spoken languages** have a special evidential to cover just smell or taste or touch individually.

These sensory devices are often covered by a single lexical item, which is a non-visual sensory evidential or 'non-first-hand' (as opposed to 'firsthand' for visual).

The proposal here presented an **unified view** of NPE systems with the same ingredients while preserving the elevated status of vision.

## Applying the analysis to propositional eidentiality

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Now let us transition to **propositional evidentiality** while still in the realm of perceptual/sensory/DIRECT evidence.

We can use the same tools to unify the two domains.

Assuming  $V$  is the valuation function in a frame in modal logic, and  $\psi$  is a proposition in the scope of a DIRECT evidential:

$$(24) \quad \text{Visual propositional: past} \\ R_{V-P}(\langle w,t \rangle, \langle w',t' \rangle) =_{\text{def}} \{ \langle w,t \rangle \mid \forall \langle w',t' \rangle \in \mathbb{K}_{\langle w,t \rangle} \wedge t \neq t', \\ V_{\langle w',t' \rangle}(\psi) = 1 \}$$

$R_{V-P}$  = the accessibility relation  $R_{\text{visual-proposition}}$ .



(25) Visual propositional: past

$$R_{V-P}(\langle w,t \rangle, \langle w',t' \rangle) =_{def} \{ \langle w,t \rangle \mid \forall \langle w',t' \rangle \in \mathbb{K}_{\langle w,t \rangle} \wedge t \neq t', \\ V_{\langle w',t' \rangle}(\psi) = 1 \}$$

The speaker considers a proposition available to her at some point in the past via her visual sense to be a *settled* matter.

The validity of the proposition holds across *all accessible historical alternatives*.

The output of the relation is the set of world-time pairs where  $\psi$  is true.

Thus,  $\psi$  is being treated like a **known fact**, which is regarded as incommutable across (consistent) worlds and times.

The flavor of evidence (i.e. visual in this case) is not encoded in the definition per se (as opposed to the nominal cases above); *the universal quantification is a reflection of the measure of certainty*.

This proposal can account for a large array of languages, where our familiar evidential paradigm holds:

past tense = witnessed/DIRECT

(the speaker saw/perceived the event happening themselves)

(26) Malayalam simple witnessed past

Raman-re acchan i viTu nirmmiccu

Raman-GEN father(NOM) this house build(PST)

'Raman's father built this house.' (Speaker saw him building it).

The claim then is that **all of these are historical necessity statements combined with *earlier than* temporal accessibility** ( $\mathbb{K}$ ).

## strength and certainty with DIRECT

(27) Visual nominal: past

$$R_{V-N}(\langle wt \rangle, \langle e, w', t' \rangle) =_{def} \{ \langle e, w, t \rangle \mid \exists \langle w', t' \rangle \in \mathbb{K}_{\langle w, t \rangle} \text{ SEE} \\ (sp, e, w', t') \wedge t \neq t' \}$$

(28) Visual propositional: past

$$R_{V-P}(\langle w, t \rangle, \langle w', t' \rangle) =_{def} \{ \langle w, t \rangle \mid \forall \langle w', t' \rangle \in \mathbb{K}_{\langle w, t \rangle} \wedge t \neq t', \\ V_{\langle w', t' \rangle}(\psi) = 1 \}$$

The **modal component** ensures that the reliability of the information source is represented as well.

The **settledness/historical necessity operator** ensures that the speaker has access to all historical alternatives and there is no room for uncertainty about past and present.

We want this kind of strength given the **privileged status of direct perception** in natural languages.

Sentences with DIRECT evidentials cannot be followed with a contradictory continuation, unlike sentences with REPORTATIVE evidentials.

(29) #É-hótaheva-∅ Floyd naa oha é-sáa-hótahévá-he-∅  
3-win-DIR.3SG Floyd and CNTR 3-neg-win-MOD<sub>a</sub>-DIR  
Intended: 'Floyd won, I'm sure, but I'm certain he didn't.'

(30) Aya-llru-uq-gguq  
leave-PAST-3RDSG-HEARSAY  
Aya-ksaite-llru-yuka-a  
leave-NEG-PAST-think-that-3RDSG  
'It is said that she left...I don't think that she left.'

Most expansive accounts of evidentiality (Izvorki 1997, Faller 2002, Murray 2010, Anderbois 2010, Bhadra 2017, etc) have definitionally limited evidentiality to a relationship between an agent and a proposition.

This work is a departure from this tradition, and seeks to **broaden the formal semantic view of evidentiality**.

Nominal evidentiality exists, and we have modelled it as a relationship between an entity and the speaker at a world-time pair.

Overall, in arguing for **epistemic perception accompanied by historical necessity and temporal accessibility**:

– the result of obtaining perceptual evidence directly adds to an **agent's knowledge**, and not just beliefs.

## Analysis: Inference

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# the nature of inference

Making an inference is a very involved process in intelligent agents.

A basic divide exists between **two types of inferential processes** as lexically manifested in evidentials.

*Inference via reasoning* (henceforth, reasoning):

– propositions which are available to an agent through evaluating their validity relative to a consistent body of facts already known to the agent

*Inference via results* (henceforth, results)

– more contingent on perception; without knowing anything previously about an event/situation, a rational agent can perceive the results of an occurrence/events and make an inference.

(31) Reasoning context: You're sitting at home talking about going berry-picking. It's August, and the berries are usually ripe this time of year on the Suskwa (a traditional picking ground).

- a. mukw=**ima**=hl maay'  
ripe=MOD=CND berries  
'The berries might/must be ripe/Maybe the berries are ripe.'
- b. #**n'akw**=hl mukw=hl maa'y  
EVID=CND ripe=CND berries  
'The berries must be ripe/Looks like the berries are ripe.'



- (32) Results context: People are arriving home after a day of berrypicking up in the Suskwa. They're carrying buckets of berries, and their hands are all purple.
- a. mukw=**ima**=hl maay'  
ripe=MOD=CND berries  
'The berries might/must be ripe/Maybe the berries are ripe.'
- b. **n'akw**=hl mukw=hl maa'y  
EVID=CND ripe=CND berries  
'The berries must be ripe/Looks like the berries are ripe.'

# perfect aspect and inference

Wakhi

- (33) salīm pešāwar reX-**k**  
Salim Peshawar go-PERF  
'Salim went to Peshawar.' (inferred by speaker)

Kalasha

- (34) a galatí **kaiá**-am húl-a  
I mistake do.PRES PERF-1S become.PAST-3S  
'I just realized that I have made a mistake.' (speaker makes an inference)

Khowar

- (35) awá oreí-**asít**-am  
I sleep-PST PERF-1S  
'I had fallen asleep.' (speaker makes an inference)

Can we model inference with the same tools?

To begin with, every agent has a body of knowledge or a **knowledge base** by virtue of being human.

This knowledge base is traditionally represented with an epistemic accessibility relation in modal logic.

(36)  $R_{epis} = \{ \langle w, t \rangle \mid \langle w', t' \rangle \text{ is a world-time pair in which all the known facts in } \langle w, t \rangle \text{ hold} \}$

Facts are represented as propositions, and propositions are sets of world-time pairs.

Hughes & Cresswell (1986), Kratzer (1991), Portner (2009), Hacquard (2011)

(37) Inference: reasoning

$$R_{\text{reasoning}}(\langle wt \rangle, \langle w', t' \rangle) =_{\text{def}} \{ \langle w, t \rangle \mid \forall \langle w', t' \rangle [R_{\text{epist}} \langle wt \rangle \subseteq \llbracket \psi \rrbracket^{R_{\text{epist}}} \\ \rightarrow \langle w', t' \rangle \in \llbracket \psi \rrbracket^{R_{\text{epist}}} ] \}$$

Output: A set of world-time pairs where  $\psi$  holds iff  $\psi$  is entailed by the set of world-time pairs accessible via the epistemic accessibility relation.

(38) Inference: reasoning

$$R_{\text{reasoning}}(\langle w, t \rangle, \langle w', t' \rangle) =_{\text{def}} \{ \langle w, t \rangle \mid \forall \langle w', t' \rangle [R_{\text{epist}} \langle w, t \rangle \subseteq \llbracket \psi \rrbracket^{R_{\text{epist}}} \\ \rightarrow \langle w', t' \rangle \in \llbracket \psi \rrbracket^{R_{\text{epist}}} ] \}$$

This formulation makes clear two notions:

- (i) an inference has to be compatible with what is already known
- (ii) the inference is being made using only information that is epistemically accessible and nothing else.

Thus, this accessibility relation reflects inference drawn from **pure reasoning** then.

In contrast, inference from results is based on **sensorily accessed consequences/results** as evaluated against the same body of known facts.

We can take our previous accessibility relation based on visual evidence and expand it to all perceptual evidence:

(39) Sensory: proposition

$$R_{P-P}(\langle w, t \rangle, \langle w', t' \rangle) =_{\text{def}} \{ \langle w, t \rangle \mid \forall \langle w', t' \rangle \in \mathbb{K}_{\langle w, t \rangle} \wedge t \neq t', \\ V_{\langle w', t' \rangle}(\psi) = 1 \}$$

Consequently,

(40) Inference: results

$$R_{\text{results}}(\langle wt \rangle, \langle w', t' \rangle) =_{\text{def}} \{ \langle w, t \rangle \mid \forall \langle w', t' \rangle [R_{P-P} \langle wt \rangle \subseteq \llbracket \psi \rrbracket^{R_{P-P}} \\ \rightarrow \langle w', t' \rangle \in \llbracket \psi \rrbracket^{R_{\text{epis}}}] \}$$

(41) Inference: results

$$R_{results}(\langle wt \rangle, \langle w', t' \rangle) =_{def} \{ \langle w, t \rangle \mid \forall \langle w', t' \rangle [R_{P-P} \langle wt \rangle \subseteq \llbracket \psi \rrbracket^{R_{P-P}} \\ \rightarrow \langle w', t' \rangle \in \llbracket \psi \rrbracket^{R_{epis}}] \}$$

Output: a set of world-time pairs such that each world-time pair is a  $\psi$  world-time pair if  $\psi$  is entailed by the set of world-time pairs subject to historical necessity.

In this case, **the space-time continuum directly influences an agent's epistemic state.**

By definition then, **both reasoning and results have been modelled to feed knowledge**

(assuming a self-aware agent is sensitive to the consistency of her  $R_{epis.}$ )

Consequently, we predict that INFERENTIAL statements should not allow contradictory continuations either.

This prediction is empirically well supported.<sup>4</sup>

<sup>4</sup>Anderbois (2006), Murray (2010), Krawczyk (2012), Bhadra (2017), Aikhenvald (2018)



# inference does not allow contradictions

Hindi and Bangla:

- (42) **Lag-ta hain** Ram aur Ravan dost ban gay-e  
feel-HAB COP Ram and Ravan friend become go.PST-PERF  
hain, # par dost nahi ban-e hain.  
COP, but friend NEG become-PERF COP  
Intended: 'It looks like Ram and Ravan have become friends,  
but they have not become friends.'
- (43) **Mon-e hoy** Ram aar Ravan bondhutyo patieye-che,  
heart-LOC happen Ram and Ravan friendship launch-PERF  
# kintu ora ekhono bondhu hoy-ni.  
but they yet friend happen-NEG  
Intended: 'It looks like Ram and Ravan have started a  
friendship, but they are not friends yet.'

In many languages where the simple past denotes direct witnessing: inference is encoded in the **aspectual system** (especially in perfect, perfective, and resultative aspects)

Morphologically, **perfect aspect** shows up when the speaker wishes to signal that the proposition has been arrived at via inference from results (Turkic, Bulgarian, South Asian languages (like Wakhi, Hunza Burushaski, Malayalam, Kalasha, Khowar, etc), Georgian).

**What is the link between inference and perfect aspect?**

Comrie (1976), Slobin (1982), Bybee (1989), Izvorski (1997), Bashir (2006), Aikhenvald (2018)

The link is between: a completed event (assuming perfect aspect as denoting an event/process that is taken to be completed) and inference based on results.

The answer is readily available in our approach:

The propositional content deduced via the perceptual relation subject to historical necessity can only be arrived at once **a coherent picture of a past event is sensorily made accessible to an agent.**

The general concept of possessing **INFERENCE** (or REPORTATIVE) evidence entails that what is possessed is a *proposition*.  
– the most natural communicative unit is one that has an assignable truth value and explicit truth conditions.

In contrast, **perception** is often deployed in accessing objects/entities, in addition to propositional content that is accessed via sensory devices.

**Why do most NPE systems encode DIRECT (mostly visual; other senses to a lesser extent) evidence only?**

The semantics given to perception versus inference underlines this difference.

– **perception is a relation between entities and world-time pairs while inference is a relation between bodies of knowledge.**

## Conclusion

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We have explored the formal semantic underpinnings of sensory perception and inference across both propositional and non-propositional domains.

I have argued for the **combining historical necessity and temporal accessibility into single spatio-temporal accessibility relations.**

These modal relations allow us to represent quantification over world-time pairs that are made accessible only through **specific kinds of evidence:**

- sensory perception (visual/non-visual) over nominals and propositions
- inference via reasoning and inference via results over propositions

Many major accounts take the notion of **evidence to be a primitive** (see McCready 2014 for a detailed overview), with little technical clarity about the formal definition of **evidence**.

(44) Bulgarian perfect (INDIRECT)

Assuming the following:

$B = \{p: \text{a speaker considers } p \text{ indirect evidence in } w\}$

$B(w) = \{u \in W: \forall p [(p \text{ is indirect evidence in } w) \rightarrow u \in p]\}$

$g(w) = \{p: \text{a speaker believes } p \text{ with respect to the indirect evidence in } w\}$

then, an evidential statement  $Ev p$  is denoted by:

$\llbracket Ev p \rrbracket^{c,w} = 1$  iff for  $\forall w' \in O_{g(w)}(B(w))$ :  $\llbracket p(w') \rrbracket^{c,w} = 1$ .

We can make the same argument for extensional (non-modal) accounts of spatio-temporality which assumes **a monolithic notion of evidence** that is not technically defined.

Chung's (2007) *v-trace* function is as follows, that tracks spatio-temporal information relating to evidence for an event:

$$(45) \quad v\text{-trace}(e) = \{ \langle t, l \rangle \mid \exists v [\text{EVIDENCE-FOR}(v, e) \wedge \text{AT}(v, t, l)] \},$$

where  $\text{AT}(v, t, l)$  is true iff **the evidence**  $v$  for the occurrence of the eventuality  $e$  appears at a location  $l$  at time  $t$ .

In addition, modelling **certainty/reliability** as a core property of evidentials is very difficult in such extensional accounts.



# a good theory of evidentiality

I agree with McCready – we cannot have a good theory of evidentiality without defining what evidence is.

I suggest that a modal analysis along the lines of the one presented here is a better informed approach.

The kind of evidence held can be more straightforwardly correlated with the agent's evaluation of the reliability of the source.

The spatio-temporal accessibility relations in the semantics of evidentials

- are informed by the **actual nature of the evidence** (which is formally defined)
- the **measure of certainty** is manifested in quantificational force
- information about **the space and time coordinates** of the acquisition and processing of evidence that affect overt lexical choices

The analysis used as background some aspects of the cognitive underpinnings of perception.

This spatio-temporal analysis can also account for languages where we do not see the same interactions play out on the surface.

We can assume they hold, given the **language-independent processes** of perception, inference, reasoning about causality, and acquisition of justified beliefs.

**Thank You!**

The material presented here will appear as a chapter in  
D. Altshuler (ed.) *Linguistics meets Philosophy*,  
Cambridge University Press.

# Appendix

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In contrast, in these systems:

A *present imperfective* aspect would then be predicted to denote DIRECT evidentiality, and not an INDIRECT inference:

– the time of the event/process correlates directly with the speech time, or the internal temporal structure of the event is accessible during speech time.

And this is indeed what we find in many aspectual systems!  
(see Aikhenvald 2018 for an overview)