Computational Cognitive Morphosemantics

Modeling morphological compositionality in Hebrew verbs with Embodied Construction Grammar

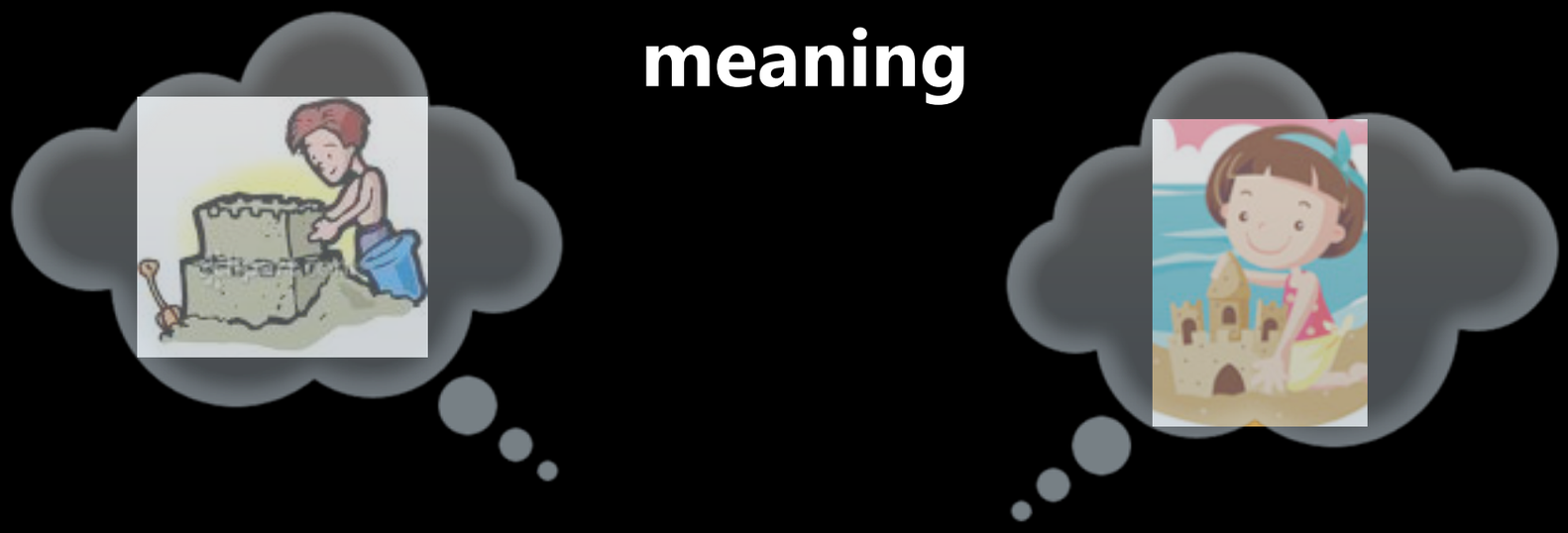
Nathan Schneider ~ BLS 36 ~ 7 February 2010

http://www.cs.cmu.edu/~nschneid/bls36-slides.pdf

Overview

- An analysis of Hebrew verbs linking cognitive semantics to complex morphological constructions
  - Must account for compositionality as well as idiosyncrasy
- Cast within the ECG formalism to facilitate computational processing
  - Previously, ECG was only used for syntax

meaning



meaning

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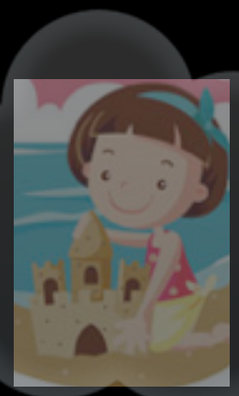
morphologically complex forms

(e.g. Hebrew verbs)

meaning



construction grammar

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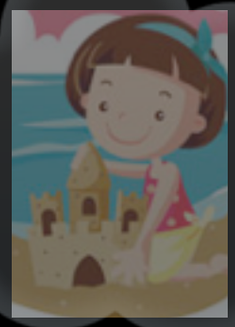

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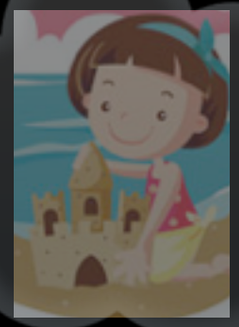

formal representation

construction grammar

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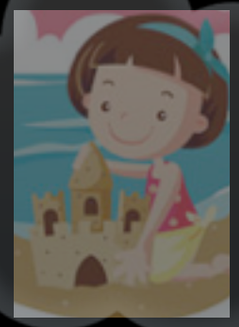

formal representation

construction grammar

bonɛ

bona

automatic analysis procedure

morphologically complex forms

(e.g. Hebrew verbs)

Construction Grammar for Hebrew Verb Morphology

- Challenges:
  - Nonconcatenative morphology
  - Semantics of roots, paradigms, and verbs (whether compositional or idiosyncratic)
- I will use Embodied Construction Grammar, a formalism designed to support computational analysis and simulation of sentences

Construction Grammar

- In the family of cognitive theories known as Construction Grammar, there is no separation between lexicon and grammar
- Words, lexical categories, multiword expressions, syntactic phrases, idioms all form-meaning pairs: constructions, albeit with different levels of generality
- Usage-based theories of grammar: constructions may be stored redundantly in memory ("constructicon"); sensitive to factors such as frequency

e.g.: [Fillmore et al. 1988] [Kay & Fillmore 1999] [Goldberg 1995, 2006] [Langacker 1990] [Croft 2001] [Tomasello 2003]

Other Related Work

Formal Approaches to Semitic/Nonconcatenative Morphology

[McCarthy 1979] proposed an autosegmental analysis for the root-pattern morphology of Arabic. [Finkel & Stump 2002] used inheritance in the KATR formalism to describe Hebrew verb forms. For other approaches to nonconcatenative morphology, see [Orgun 1996] [Rubba 2001] [Roark & Sproat 2007].

Morphology in Construction Grammar

Previous work has described composition of morphological constructions [Riehemann 1998] [Booij 2005, 2007] [Gurevich 2006]. Several mechanisms for adding morphology to ECG were entertained in [Bergen 2003], but none were implemented. [Rubba 1993] (synopsis in [Rubba 2001]) takes a Cognitive Grammar approach to nonconcatenative morphology, situating words in a network (cf. [Bybee 1985, 2001]). Two other relevant approaches to phonology are found in [Inkelas 2008] and [Nathan 2007]. [Mandelblit 1997] offers an extensive semantic account of Hebrew verb paradigms.

There has been a great deal of formal work on Semitic morphology using a variety of approaches, including rules, autosegmental phonology, and unification grammars. There has also been some work on morphology in Construction Grammar and related theories. To my knowledge, this is the first work to explicitly combine detailed semantic representations from cognitive linguistics in a formal description of morphological constructions.

e.g. [Berman 1978]

Key claim: The grammar has morphological constructio
at multiple levels, all of which contribute to the form ar
meaning of the composite word.

ROOT

e.g. [Berman 1978]

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STEM

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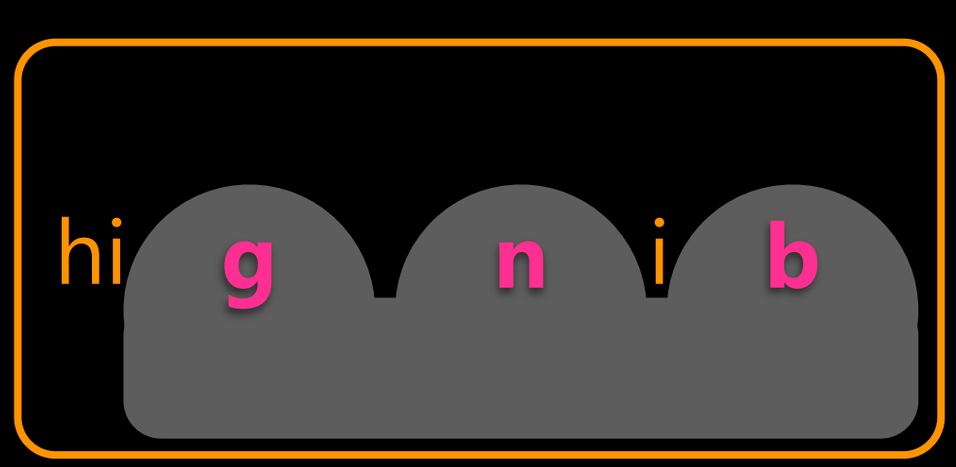

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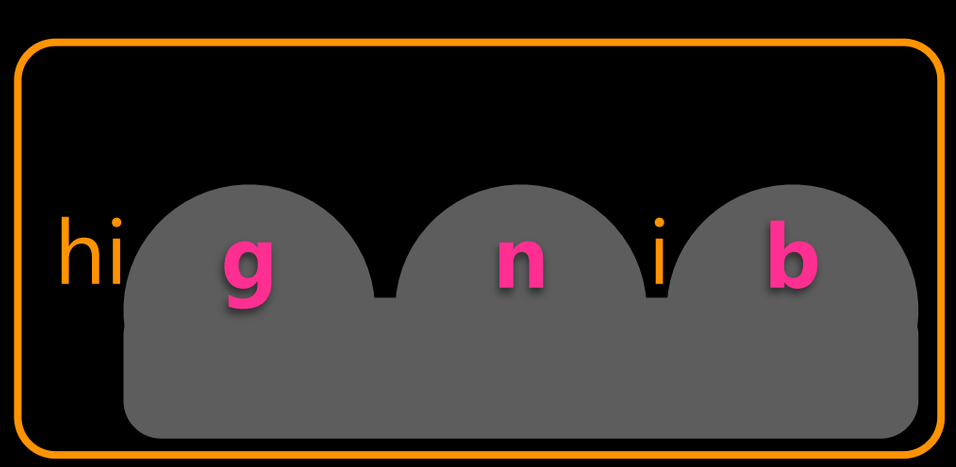
INFLECTION

u



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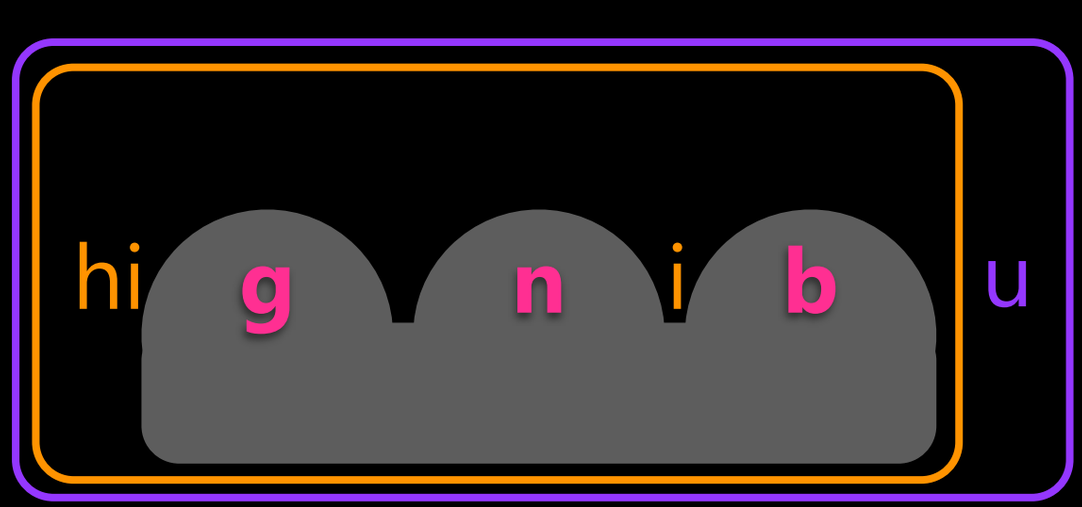

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Root	/g/▫/n/▫/b/ ~ ‘steal’		**Paradigm**	Hif’il (P5)	**Meaning**	‘smuggle in’
Tense/Num	Past m	Past f	Present m	Present f	Future m	Future f
1.sg	hignav**ti**		magniv	magniv**a**	**ʔ**agniv	
2.sg	hignav**ta**	hignav**t**			**t**agniv	**t**agniv**i**
3.sg	higniv	higniv**a**			**y**agniv	**t**agniv
1.pl	hignav**nu**		magniv**im**	magniv**ot**	**n**agniv	
2.pl	hignav**tem**	hignav**ten**			**t**agniv**u**	
3.pl	higniv**u**				**y**agniv**u**	

A **single stem for each root/paradigm/tense**:
here past /hignib/*, present /magnib/, future /agnib/

The root fits into a pattern: /hi◦◦i◦/, /ma◦◦i◦/, /a◦◦i◦/

Affixes specifying person, gender, and number—not sensitive to paradigm: /-ti/, /-im/, /t- -u/, etc.

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3.pl	higniv**u**				**y**agniv**u**	

For brevity, assume some phonological details are handled elsewhere:

- Consonant allophony: /b/ is sometimes realized as [v], /k/ as [x], and /p/ as [f]
- Certain root consonants (e.g. /ʔ/, /w/, /h/) will affect the pattern in systematic ways
- Stress-sensitive vowel reduction and deletion
- * The last vowel in this paradigm's past tense stem undergoes the phonological change /i/→[a] in 1st & 2nd person

Morphological Generalizations: Stored or Inferred?

- I will present general morphological constructions as if they are stored in the lexicon along with all other constructions.
- However, some approaches to morphology claim that no constructions below the word level are stored in memory; rather, an online process of distributed analogy is hypothesized to account for morphological productivity. [Gurevich 2006]
  - For those taking this view, the generalizations presented here can be interpreted as formalizing an online analogical process.

Paradigms (*Binyanim*)

P	Traditional Characterization[1]	**Transitivity: always (often)**[2]	/g/▫/n/▫/b/ Verbs[3] **Hebrew**	**Gloss**
1	"Simple"	(Transitive)	ganav	'steal'
2	"Refl., passive"	Intrans. (Passive)	nignav	'be stolen'
3	"Intensive"	(Transitive)	ginev	'steal repeatedly' (lit.)
4	"Intensive Passive"	Passive	gunav	'be stolen/taken stealthily' (lit.)
5	"Causative"	(Transitive)	higniv	'smuggle in, insert stealthily'
6	"Causative Passive"	Passive	hugnav	'be smuggled in/inserted stealthily'
7	"Reflexive-passive"	Intrans. (Passive)	hitganev	'sneak (in, out, or away)'

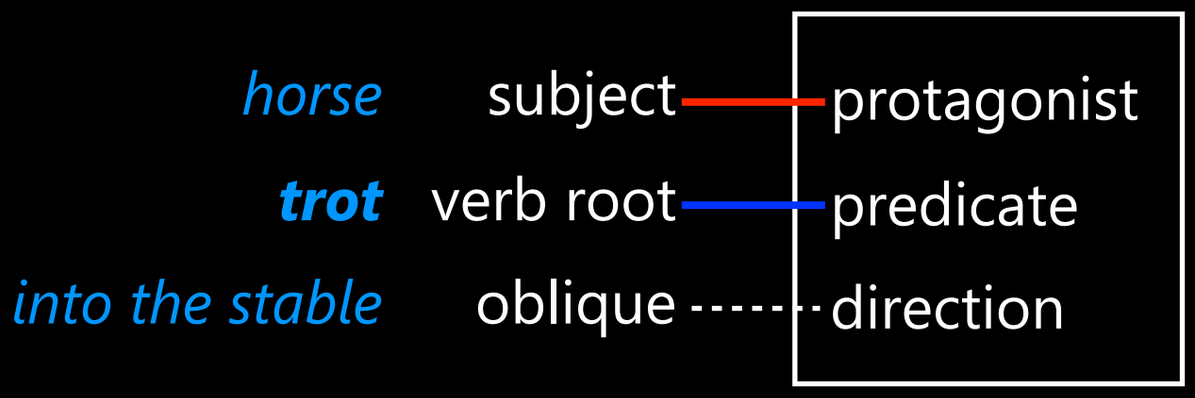
1. [Halkin 1970] 2. [Arad 2005] 3. [Bolozky 1996]

The root /g/▫/n/▫/b/ is one which manifests itself in all seven paradigms, though its P3 and P4 verbs are limited to literary usage.

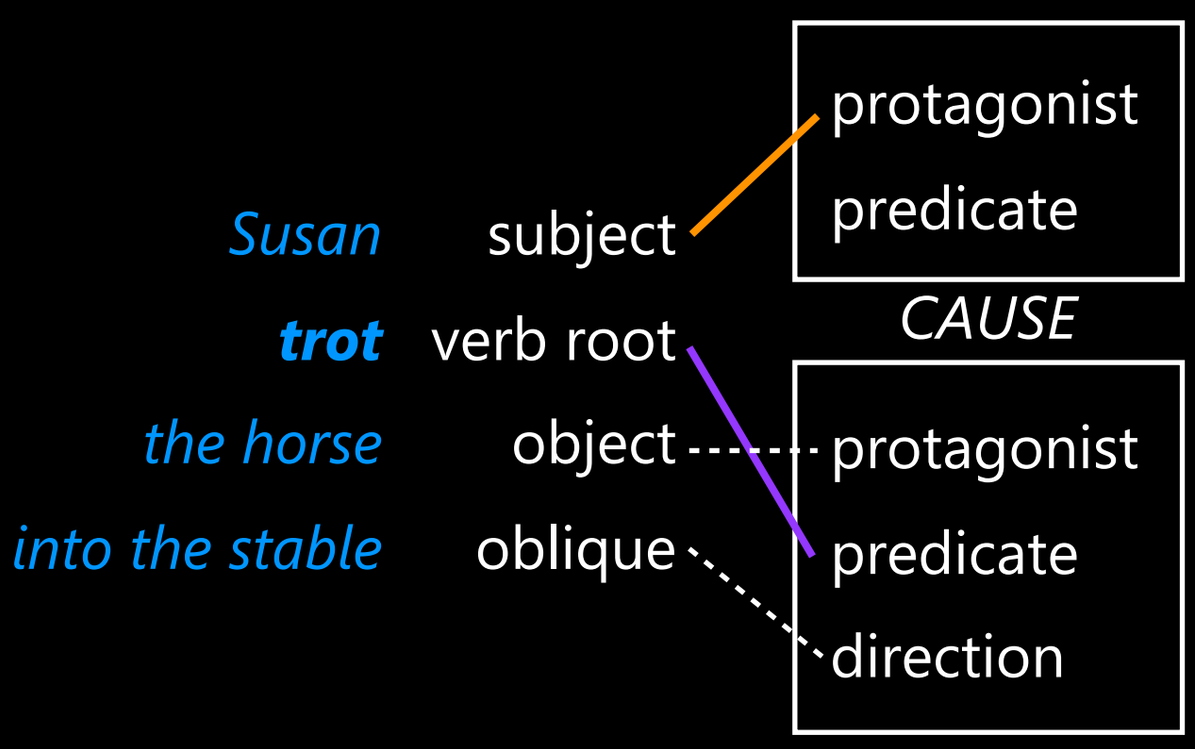
Paradigm Semantics

- There is a lot of idiosyncrasy in the meanings of verbs within the various binyanim. That is, the verb's meaning is often not completely predictable from the root and paradigm.
- Mandelblit [1997] attacks this problem under the rubric of grammatical blending [Fauconnier & Turner 1996]
  - She concludes that the different paradigms arise from a construed causal relationship, which explains the prototypical semantics

Paradigms: An English Analogy



The horse **trotted** into the stable. *(basic)*



Susan **trotted** the horse into the stable. *(causative)*

adapted from [Mandelblit 1997, p. 36]

Paradigm Semantics

Mandelblit argues that the root contributes the "content" of the verb, and the paradigm picks out part of a causal sequence. For example: "The causative *hif'il* verbal pattern is used to mark a single sub-event (the *effected* sub-event) within a conceived causal sequence of events. Marking other sub-events entails the usage of other *binyanim*."

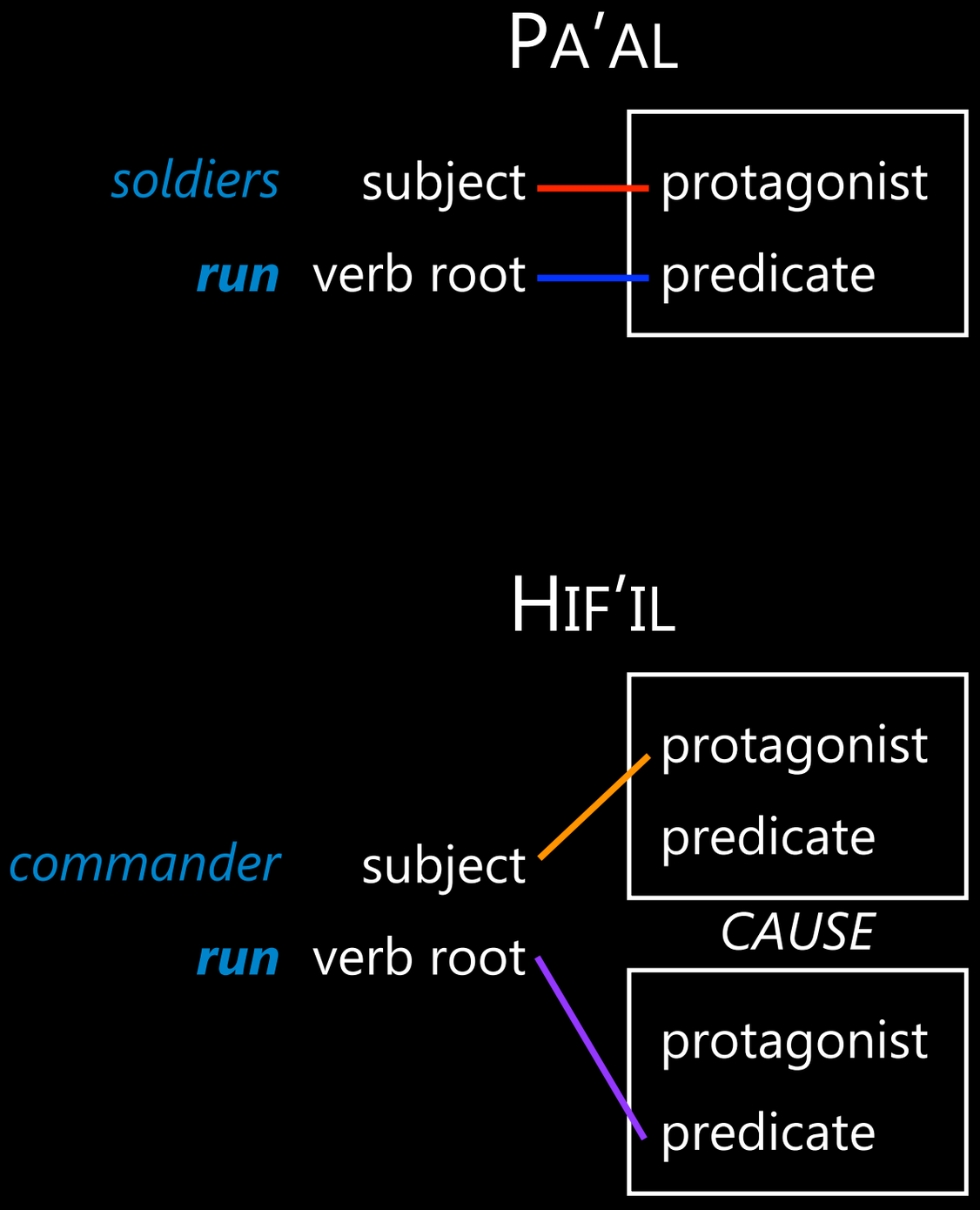
Paradigm Semantics: Hif'il

(10) a. ha-xayal rats misaviv la-migraʃ.
the-soldier run.**PA'AL**.PAST.3.M.SG around to.the-courtyard
'The soldier ran around the courtyard.'

b. ha-məfaked herits ʔet ha-xayal misaviv la-migraʃ.
the-commander run.**HIF'IL**.PAST.3.M.SG ACC the-soldier around to.the-courtyard
'The commander made the soldier run around the courtyard.'

These verbs have the same root, /r/▫/w/▫/ʦ/ 'run'. In the causative hif'il sentence (b), *herits* 'cause to run' indicates that the root refers to the effected event—that is, what the soldiers are made to do. The causing event, i.e. *how* the commander makes them run, is unspecified.

Paradigms Semantics: Hif'il



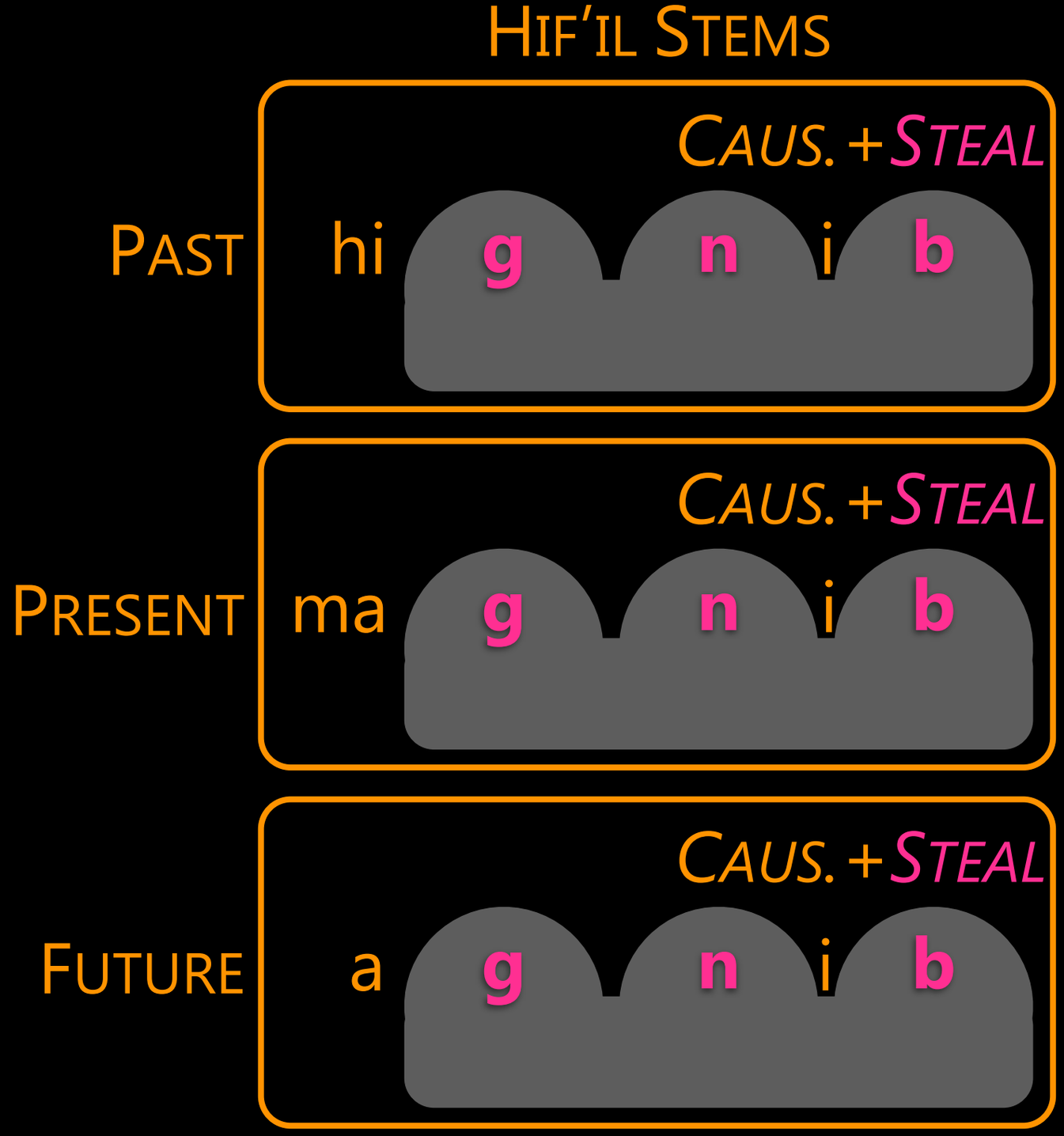
The soldiers **ran**.
(basic)

The commander **ran** the soldiers.
(causative)

[Mandelblit 1997, ch. 4]

The space on the right (Input 1) illustrates the conceived causal relationship bound to specific participants and actions: *she* is understood to have taken some unspecified action—the *causing event*—which resulted in the horse trotting into the stable, trotting being the *effected event*. The space on the left (Input 2) shows how the Caused-Motion construction orders certain types of participants and predicates in an event sequence, associating them with syntactic categories. The Caused-Motion construction is said to be an *integrating* syntactic construction because it frames the sentence as a single event, even though the sentence has *unintegrated* semantics with two events in a causal relationship (depicted in Input 1). The blending operation results in the space at the bottom, with lexical items denoting some of the participants and predicates from Input 1 bound to syntactic positions from Input 2. **Those participants and predicates which are realized in the blend, with increased cognitive salience and overt representation in the sentence, are said to be *profiled* or *highlighted*.**

Inherited Generalizations



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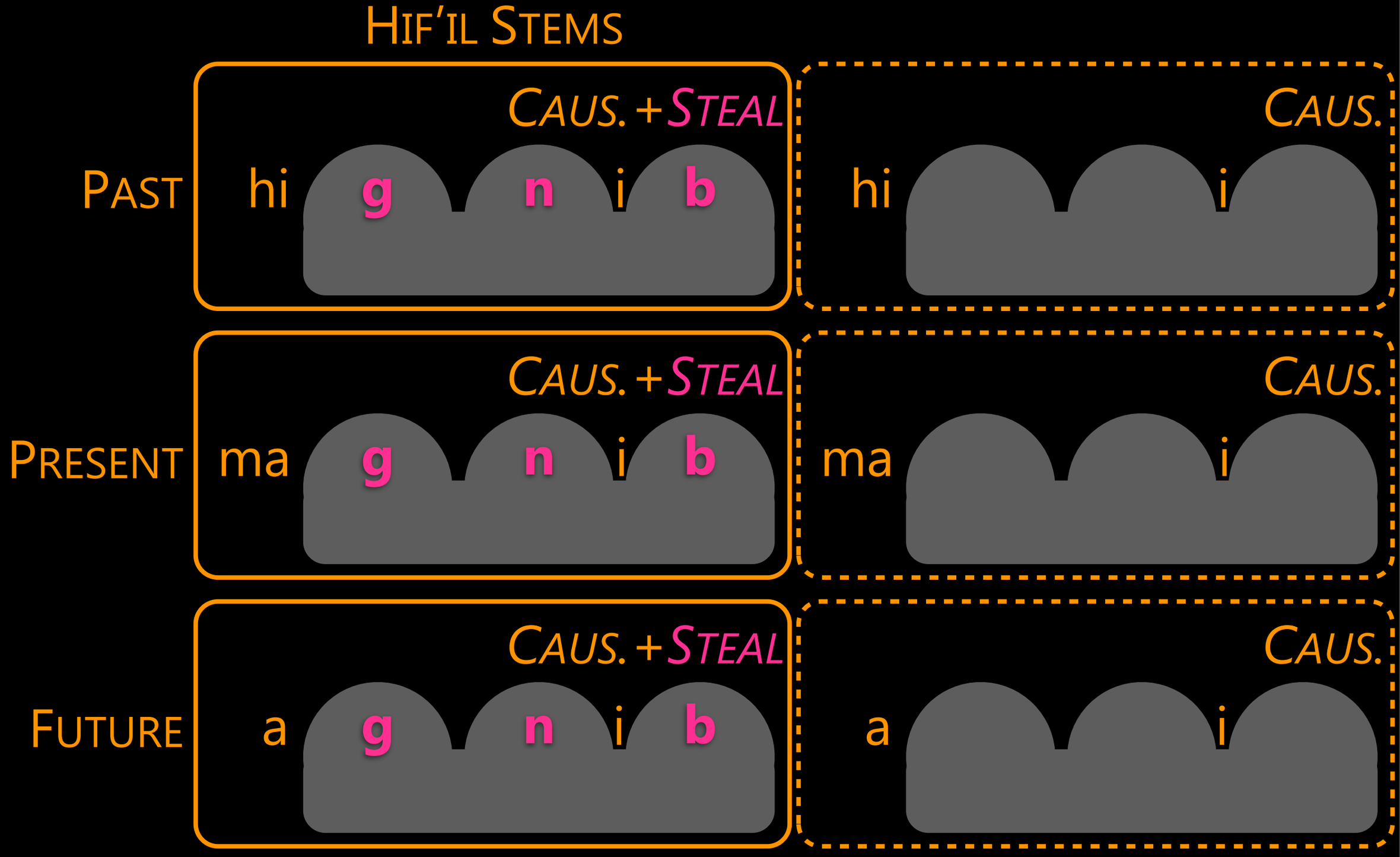

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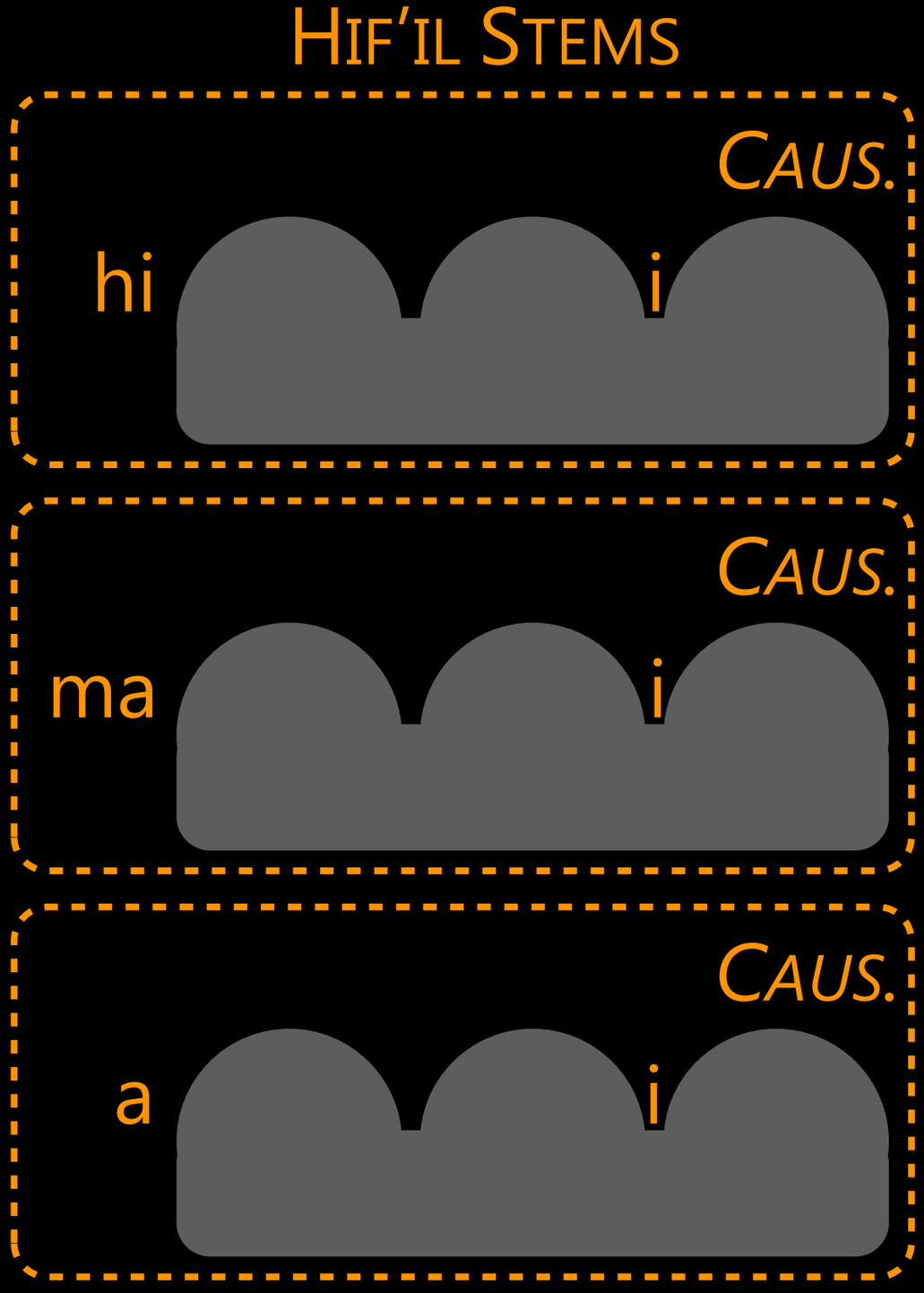

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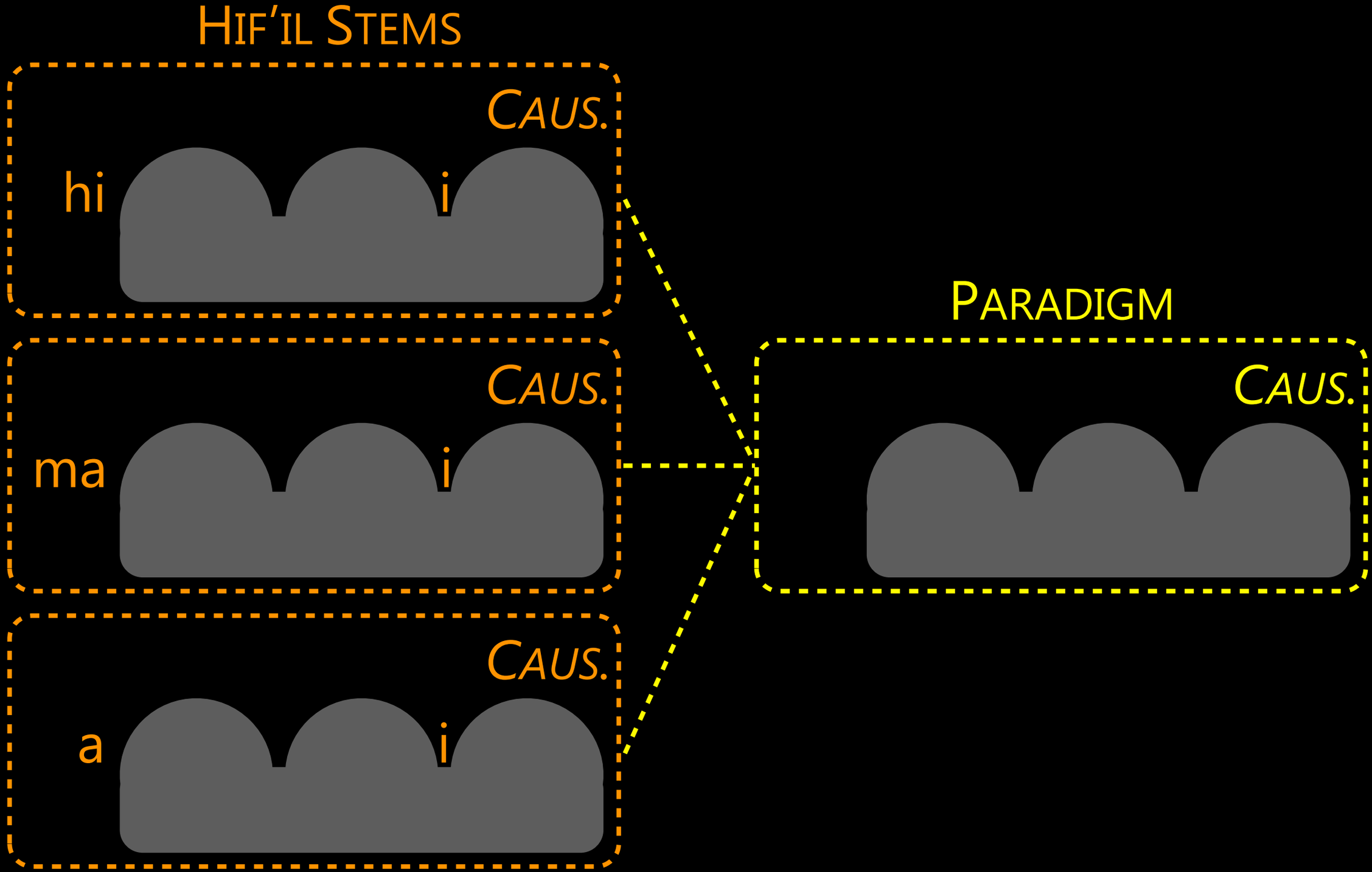


Paradigm Semantics: Pi’el

(10) a. ha-xayal rats misaviv la-migraʃ.
the-soldier run.**PA’AL**.PAST.3.M.SG around to.the-courtyard
‘The soldier ran around the courtyard.’

b. ha-məfaked herits ʔet ha-xayal misaviv la-migraʃ.
the-commander run.**HIF’IL**.PAST.3.M.SG ACC the-soldier around to.the-courtyard
‘The commander made the soldier run around the courtyard.’

Prototypical transitive pi’el verbs have a root denoting a causing event. Thus, they contrast with hif’il verbs much like *sneeze* in *Rachel sneezed the napkin off the table* contrasts with *trot* in *She trotted the horse into the stable*:

(14) ha-maʕasik piter ʔet ha-ʕoved.
the-employer fire.**PI’EL**.PAST.3.M.SG ACC the-worker
‘The employer fired the worker.’

Paradigm Semantics: Huf'al and Pu'al

(10) **Huf'al** is the passive counterpart of **hif'il**, and **pu'al** is the passive counterpart of **pi'el**:

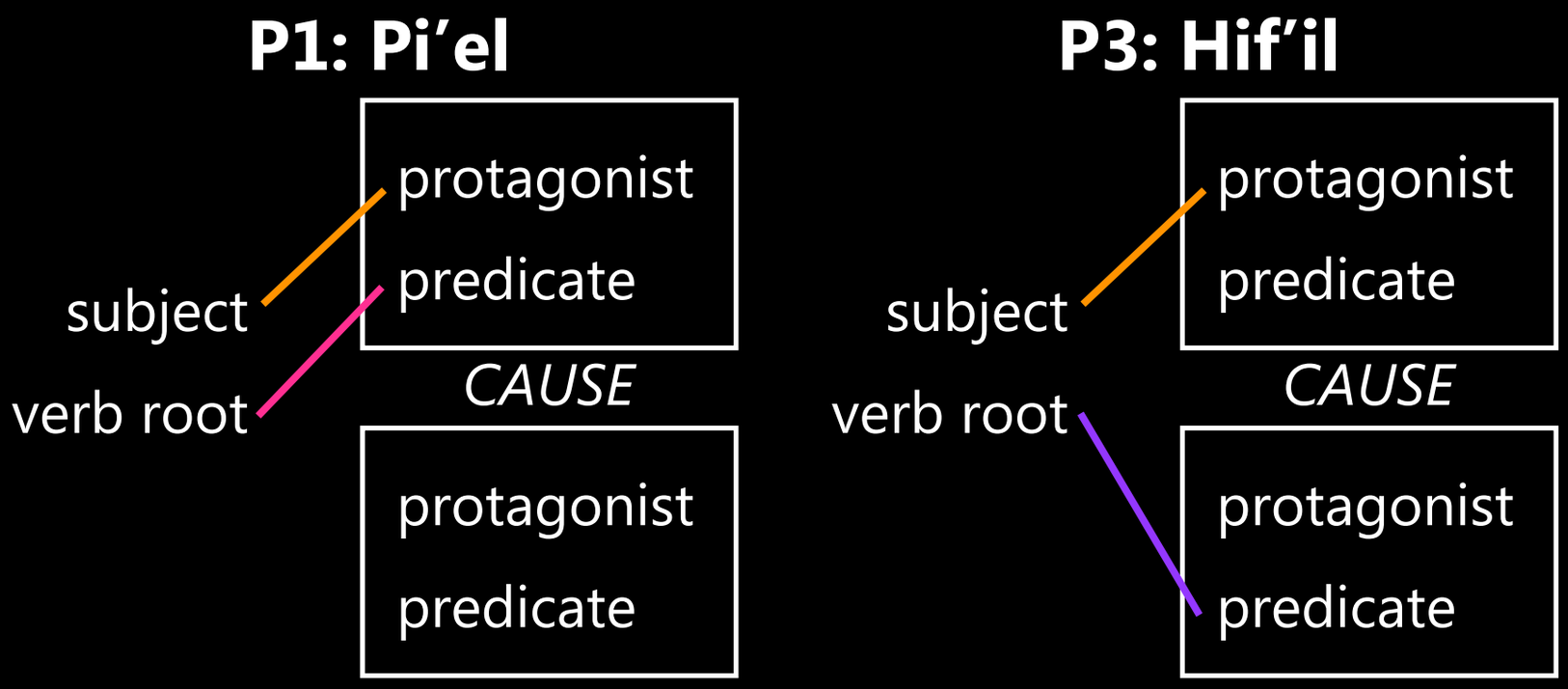
b. ha-məfaked herits ʔet ha-xayal misaviv la-migraʃ.
the-commander run.**HIF'IL**.PAST.3.M.SG ACC the-soldier around to.the-courtyard
'The commander made the soldier run around the courtyard.'

(15) ha-xayal hurats (ʕal yədei ha-məfaked).
the-soldier run.**HUF'AL**.PAST.3.M.SG (on account.of the-commander)
'The soldier was made to run (by the commander).'

(14) ha-maʕasik piter ʔet ha-ʕoved.
the-employer fire.**PI'EL**.PAST.3.M.SG ACC the-worker
'The employer fired the worker.'

(16) ha-ʕoved putar (ʕal yədei ha-maʕasik).
the-worker fire.**PU'AL**.PAST.3.M.SG (on account.of the-employer)
'The worker was fired (by the employer).'

Paradigms Semantics



Blending schemas for paradigms P1 & P3 (active) and P2 & P4 (passive). The construed causal sequence on the RHS of each paradigm contains a causing event (top box) and an effected event (bottom box), each with agent and predicate. Paradigm constructions map one of the protagonists (agents) to the subject and one of the predicates to the verb root.

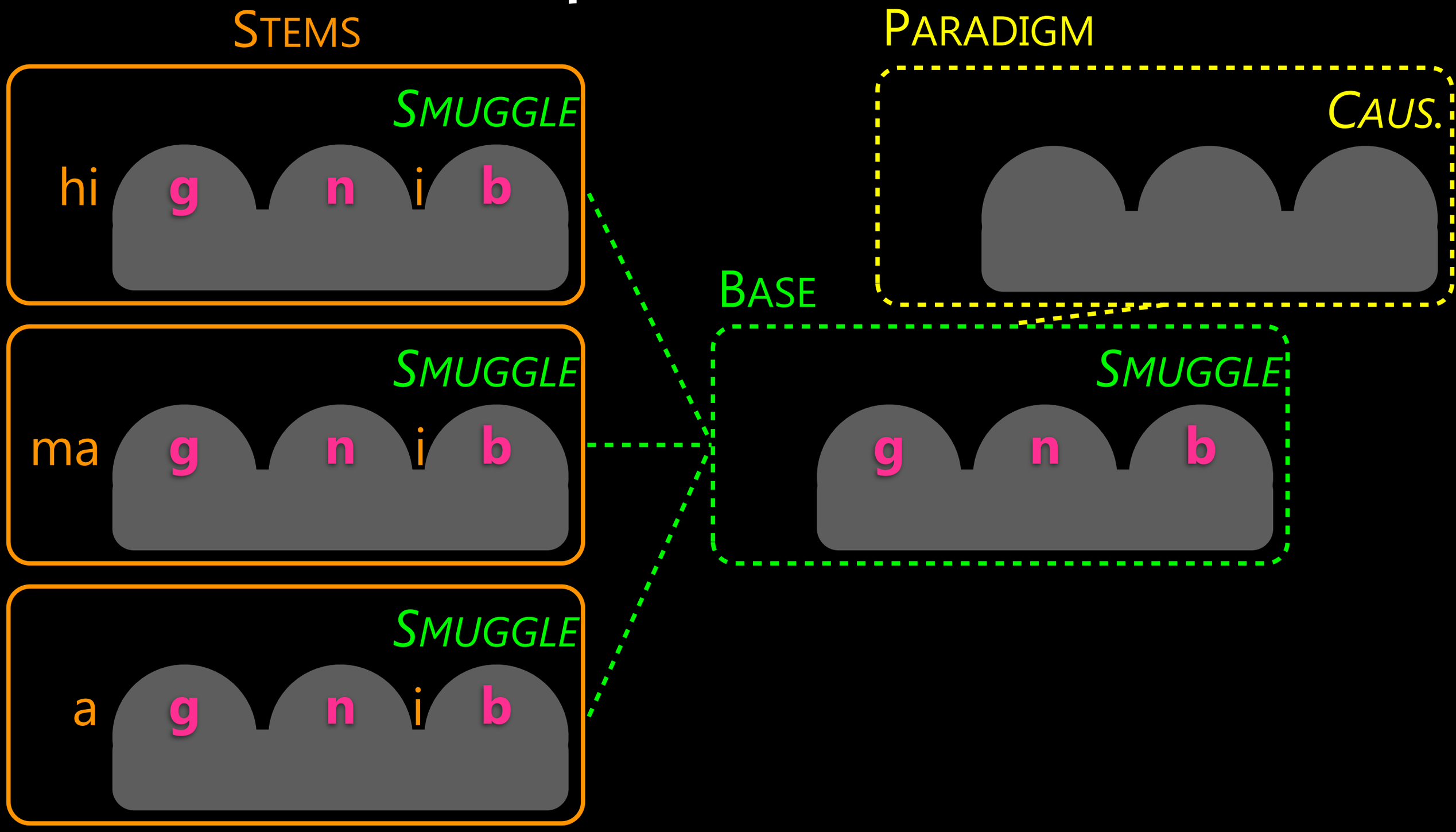
adapated from [Mandelblit 1997, p. 133]

The space on the right (Input 1) illustrates the conceived causal relationship bound to specific participants and actions: *she* is understood to have taken some unspecified action—the *causing event*—which resulted in the horse trotting into the stable, trotting being the *effected event*. The space on the left (Input 2) shows how the Caused-Motion construction orders certain types of participants and predicates in an event sequence, associating them with syntactic categories. The Caused-Motion construction is said to be an *integrating* syntactic construction because it frames the sentence as a single event, even though the sentence has *unintegrated* semantics with two events in a causal relationship (depicted in Input 1). The blending operation results in the space at the bottom, with lexical items denoting some of the participants and predicates from Input 1 bound to syntactic positions from Input 2. **Those participants and predicates which are realized in the blend, with increased cognitive salience and overt representation in the sentence, are said to be *profiled* or *highlighted*.**

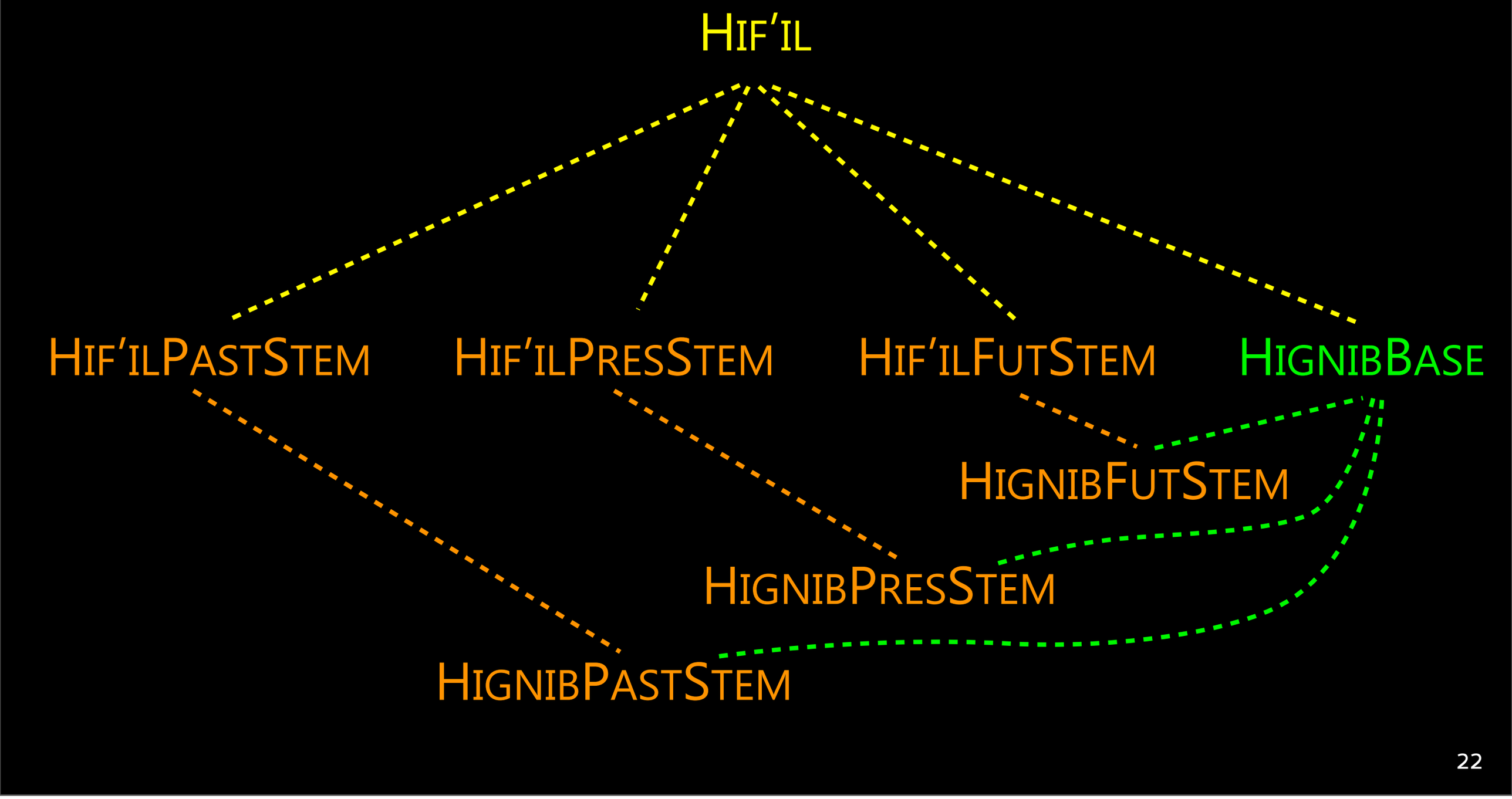
Noncompositional Verbs

- The story until now assumes the paradigm semantics is fully compositional given the root: the verb cxn may be deduced online
- To handle noncompositional verbs, we introduce a verb-specific base construction which pairs a particular root with a particular paradigm, and the associated semantics
  - Tense/other inflectional information does not alter the verb-specific meaning

Noncompositional Verbs



Noncompositional Verbs



This shows an inheritance hierarchy of constructions (à la HPSG): Hif'il is the most general and more specific cases inherit and elaborate upon its properties. HignibBase and its subtypes are idiosyncratic with respect to meaning, overriding the inherited prototypical causative meaning.

Embodied Construction Grammar

- Unification-based, semantically-rich formalism for describing lexical and syntactic—and now morphological—constructions [Bergen & Chang 2005] [Feldman 2006] [Feldman et al. 2009]
  - Part of the Neural Theory of Language project to develop computational simulations of language understanding
  - ECG grammars can represent embodied semantics: primitives include schemas/ frames, as well as metaphors and mental spaces [Gilardi to appear]

Embodied Construction Grammar

- Facilitates (verifiably consistent) analyses of particular linguistic phenomena, e.g. motion-related constructions in English [Dodge 2010]
- Facilitates cognitive computational models of sentence processing [Bryant 2008] and language learning [Chang 2008] [Mok 2008]
- Tools include the probabilistic parser of [Bryant 2008] and a user-friendly interface for grammar engineering [Gilardi to appear]

ECG Analysis: Setup

- We want to formally specify a "constructicon" for Hebrew verbs
  - Small but very detailed decomposition of morphology and semantics
  - For our purposes, phonology is simplified to string concatenation
- Given this constructicon, a computer program can take an input word and list its possible analyses—including semantic frames and their bindings

Schemas and Constructions

```
schema Causation
    subcase of ComplexProcess
    roles
        causingProcess: Process
        effectedProcess: Process
        causalProtagonist: Entity
        affectedProtagonist: Entity
```

In ECG, meaning schemas are used to represent the frame semantics of a construction, and form schemas are used to decompose morphological forms. Schemas exist in an inheritance lattice and can define roles, which may be string-valued or may point to other schema instances.

Schemas and Constructions

schema Causation
  subcase of ComplexProcess
  roles
    causingProcess: Process
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    affectedProtagonist: Entity

schema GNB
  subcase of Root
  roles
    r1
    r2
    r3
  constraints
    r1 ← "g"
    r2 ← "n"
    r3 ← "b"

In ECG, meaning schemas are used to represent the frame semantics of a construction, and form schemas are used to decompose morphological forms. Schemas exist in an inheritance lattice and can define roles, which may be string-valued or may point to other schema instances.

construction Root_GNB
  subcase of VerbRoot
  form: GNB
  meaning: Steal

Constructional Levels: Base

general construction Hif'il
  subcase of Paradigm
  constructional constituents
    root: Root
  form constraints
    root.r1 **before** root.r2 **before** root.r3
  meaning: Causation
    roles
      highlightedProtagonist: Entity
      highlightedProcess: Process
  constraints
    highlightedProcess ↔ root.m
    highlightedProcess ↔ effectedProcess
    highlightedProtagonist ↔ causalProtagonist

hif'il-specific

Recall that paradigm hif'il highlights the *effected* process and the *causal* protagonist.

The Hif'il construction on the left specifies the compositional meaning and gives (underspecified) constraints on the form. HignibBase inherits from Hif'il for the root GNB, overriding the compositional meaning. The tense-specific stem constructions will inherit from HignibBase in turn.

Constructional Levels: Base

general construction Hif'il
  subcase of Paradigm
  constructional constituents
    root: Root
  form constraints
    root.r1 **before** root.r2 **before** root.r3
  meaning: Causation
    roles
      highlightedProtagonist: Entity
      highlightedProcess: Process
  constraints
    highlightedProcess ↔ root.m
    highlightedProcess ↔ effectedProcess
    highlightedProtagonist ↔ causalProtagonist

construction HignibBase
  subcase of Hif'il
  constructional constituents
    root: Root_GNB
  meaning: Smuggle

an idiosyncratic meaning (overrides Causation)

— hif'il-specific

Recall that paradigm hif'il highlights the *effected* process and the *causal* protagonist.

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Conclusion

The aforementioned approach

- brings together the theoretical framework of Construction Grammar and studies of verbs in Modern Hebrew;
- integrates the form and meaning components of morphological structures in a single analysis; and
- employs and extends the Embodied Construction Grammar formalism so as to enable cognitive computational modeling of morphology.

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