Computational Cognitive Morphosemantics: Modeling Morphological Compositionality in Hebrew Verbs with Embodied Construction Grammar

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Introduction

This paper brings together the theoretical framework of construction grammar and studies of verbs in Modern Hebrew to furnish an analysis integrating the form and meaning components of morphological structure. In doing so, this work employs and extends Embodied Construction Grammar (ECG; Bergen and Chang 2005), a computational formalism developed to study grammar from a cognitive linguistic perspective. In developing a formal analysis of Hebrew verbs (section 3), I adapt ECG—until now a lexical/syntactic/semantic formalism—to account for the compositionality of morphological constructions, accommodating idiosyncrasy while encoding generalizations at multiple levels. Similar to syntactic constructions, morpheme constructions are related in an inheritance network, and can be productively composed to form words. With the expanded version of ECG, constructions can readily encode nonconcatenative root-and-pattern morphology and associated (compositional or noncompositional) semantics, cleanly integrated with syntactic constructions. This formal, cognitive study should pave the way for computational models of morphological learning and processing in Hebrew and other languages.

1 Form and Meaning in the Binyanim

Semitic languages are well known for their templatic verbal morphology, traditionally modeled as combining a consonantal root with a pattern belonging to one of a handful of paradigms (e.g. Berman 1978; McCarthy 1979; Bat-El 1989).[1] Modern Hebrew has seven such paradigms, or *binyanim*, summarized in table 1. Each

[1] The consonantal root view is not uncontested—see (Prunet 2006) for a review—but will be adopted here, in part because of the representational challenge it poses.

Hebrew verb is a lexicalized combination of a root and a paradigm, with a specific meaning. For example, the triconsonantal root /g/▫/n/▫/b/ when combined with binyan pa'al means 'steal.' Applying the past tense stem template yields /ganab/ (*ganav*) '(he) stole.' Other inflections are obtained via regular affixation to the stem (subject to phonological considerations that are not of concern here).[2]

Whereas verb *forms* are quite predictable, the *semantic* relationships across paradigms of verbs with a given root are, in general, far murkier. For example, the pa'al-hif'il alternation from table 1 is illustrated below:

(1) *zehavit ganva ʔet ha-daysa (me-ha-bayit).*
Goldilocks stole.**PA'AL**.3.F.SG ACC the-porridge (from-the-house)
'Goldilocks **stole** the porridge (from the house).'

(2) *zehavit higniva ʔet ha-daysa*
Goldilocks stole.**HIF'IL**.3.F.SG ACC the-porridge
(la-bayit/me-ha-bayit).
(into.the-house/from-the-house)
'Goldilocks **smuggled** the porridge (into the house/from the house).

It is difficult to imagine a precise relationship between 'steal' and 'smuggle' that could explain all pa'al-hif'il alternations in other roots. How, then, do the root and paradigm share in contributing meaning to the composite verb (if at all)? Why do speakers converge on a given root-paradigm pair to convey a particular meaning?

Most studies of the binyanim have focused on form to the exclusion of meaning. However, a few recent contributions bear on the issue of binyan/root semantics. In a corpus survey, Arad (2005) found that roots tend to be lexicalized with certain clusters of paradigms. For example, two common patterns were for the hif'il verb to be a causative counterpart of the pa'al verb with the same root, and for the nif'al verb to be the passive counterpart of the pa'al verb. At the very least, these alternations belie the notion that the formation of verbs in certain binyanim is completely arbitary. Moreover, evidence that Hebrew speakers can use the binyanim productively comes from experiments in which subjects were asked to coin novel verbs from nouns: not only did they adapt the nouns to match (or at least resemble) the conventional forms of the binyanim—they also were remarkably consistent in their choice of certain binyanim to convey certain meanings (Bolozky 1999).

Mandelblit (1997) addresses the semantics of the binyanim in the framework of grammatical blending (Fauconnier and Turner 1996). She argues that the prototypical meanings of the binyanim contrast with regard to their framing of a construed causal scenario. Consider the following two examples (Mandelblit 1997, ch. 4):

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[2] About Hebrew transcriptions: Symbols follow IPA, except *y* is used instead of *j*. Words given in italics are broad phonetic transcriptions, with ayin as ʕ and aleph as ʔ (not always pronounced). Mnemonic paradigm names, which by convention inject /p/▫/ʕ/▫/l/ 'do, act' into the pattern, use an apostrophe instead of ʕ for readability.

Table 1: Modern Hebrew binyanim (verbal paradigms). • marks the position of a root consonant; ∘ represents the additional consonant(s) in 4- or 5-consonant roots.

Binyan	**Transitivity: always (often)** (Arad 2005)	**Past Stem Pattern**[3]	**Present Stem Pattern**	**Future Stem Pattern**	**/g/□/n/□/b/ Verb** (Bolozky 1996)
PA'AL	(Transitive)	•a•a•	•o•e•	i••o•	*ganav* 'steal'
NIF'AL	Intransitive (Passive)	ni••a•	ni••a•	i•a•e•	*nignav* 'be stolen'
PI'EL	(Transitive)	•i•∘e•	mə•a•∘e•	ə•a•∘e•	*ginev* 'steal repeatedly' (lit.)
PU'AL	Passive	•u•∘a•	mə•u•∘a•	ə•u•∘a•	*gunav* 'be stolen/taken stealthily' (lit.)
HIF'IL	(Transitive)	hi••i•	ma••i•	a••i•	*higniv* 'smuggle in, insert stealthily'
HUF'AL	Passive	hu••a•	mu••a•	u••a•	*hugnav* 'be smuggled in/inserted stealthily'
HITPA'EL	Intransitive (Passive)	hit•a•∘e•[4]	mit•a•∘e•[4]	it•a•∘e•[4]	*hitganev* 'sneak (in, out, or away)'

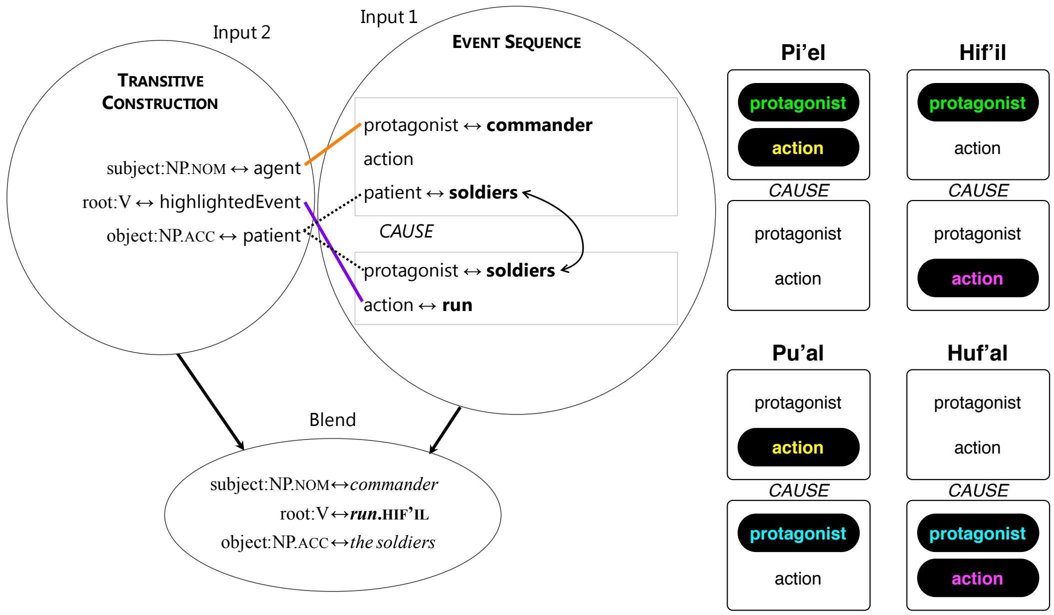
(3) *ha-xayal rats misaviv la-migraʃ.*
the-soldier ran.**PA'AL**.3.M.SG around to.the-courtyard
'The soldier ran around the courtyard.'

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

"The causative *hif'il* verb pattern," she writes, "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*" (Mandelblit 1997, ch. 4). The two subevents for (4) are depicted in boxes within "Input 1" of figure 1a: an unspecified action on the soldiers by the commander causes them to run. Binyan hif'il is said to instantiate the blending schema of figure 1a in that it profiles, or **highlights**, one of the participants and one of the subevents in the sequence, causing these to be made prominent in constructions (e.g. the transitive construction in "Input 2"). In this model, the root is interpreted as expressing the highlighted subevent, and

[3] The stem given here is that of the citation form, the 3rd person masculine singular inflection. In some paradigms there are vowel changes within the stem depending on the conjugation, such as pi'el—*ginev* (3.M.SG.PAST) but *ginav-ti* (1.SG.PAST). For the present purposes this variation will be treated as symptomatic of a general phonological process.

[4] If the root begins with a sibilant consonant, it will metathesize with the preceding /t/ in the hitpa'el stem, and the /t/ will assimilate in voicing: e.g. *hizdaken* 'grow old' (/z/□/k/□/n/).



a. Blending schema for causative hif'il in (4)

b. Highlighting in the four causal binyanim

Figure 1: Blending schemas for causal binyanim. Adapted from (Mandelblit 1997).

the noun phrase in subject position as expressing the highlighted protagonist. Thus, voice—and its correlation with the binyanim—is a consequence of highlighting one of the two participants over the other; and causativity alternations are due to a difference in subevent highlighting indicated by the alternative binyanim. Highlighting is shown in figure 1 for the four binyanim at the heart of these contrasts.[5]

Mandelblit's analysis offers a concrete starting point for representing the meanings of the binyanim. The generalizations expressed in the her account are only prototypes, in the sense of (Lakoff 1987); it is impossible to fully predict the idiosyncratic variations on the prototype, such as the alternation in (1) and (2). A complete account necessitates modeling the prototypical interpretation and deviations from it. I will endeavor to show that ECG is capable of representing both.

2 Construction Grammar Framework

In the tradition of construction grammar and related cognitive approaches to linguistic structure (e.g., Fillmore et al. 1988; Lakoff 1987; Langacker 1990; Gold-

[5] Mandelblit (1997) describes pa'al and nif'al as sometimes framing the meaning of the verb as a single, integrated event, and sometimes highlighting neither subevent over the other. Hitpa'el is described as serving many functions, including cases where both subevents have the same protagonist (reflexive) or two individuals are alternately protagonists for both subevents (reciprocal).

berg 1995, 2006), I will treat linguistic knowledge as an organized collection of **constructions**, symbolic units that together constitute the conventions of a language. Each construction maps a form to a meaning: forms include words, bound morphemes, syntactic phrases and clauses, idiomatic expressions, and even some gestures; while meaning ranges from the semantics to the discourse and pragmatic functions of an expression. Constructions are learned and organized within the grammar-lexicon ("constructicon") of a language at many levels of generality; for instance, a general construction might govern the formation of *wh*-questions, while a more specific subcase like *What's X doing Y?* is imbued with added (or idiosyncratic) form and/or meaning (Kay and Fillmore 1999).

A growing body of work has applied construction grammar principles to morphology (Rubba 1993; Orgun 1996; Booij 2005; Gurevich 2006; see the latter for a review). The present study is similar to Rubba (1993) and Orgun (1996) in describing morphemes as compositional constructions. Gurevich (2006) counters that productive morphological behavior is best described as an online analogical process among full words, and bound morphemes should therefore not be modeled as constructions. My view is that, from a representational perspective, it is useful to model morphological productivity as constructional composition, whether or not the productivity-inducing generalizations encoded therein are in fact memorized.[6]

For the purposes of this paper I will set aside many of the phonological complexities of Hebrew and the associated representational concerns. Among others, (Bybee 1985, 2001; Orgun 1996; Inkelas 2008) provide insight that would no doubt be useful in developing an ECG approach to (morpho)phonology.

2.1 Embodied Construction Grammar

This work employs and extends Embodied Construction Grammar (ECG), a formalism developed to study grammar from a cognitive linguistic perspective (Bergen and Chang 2005; Feldman 2006; Feldman et al. 2009). The rationale for ECG is twofold: First, it is believed that a standardized, precise formalism is a descriptive asset to the cognitive linguist. Dodge (2010) uses ECG to that effect in her analysis of motion-related constructions in English. Second is the premise that such a formalism affords us the opportunity to incorporate these constructions in computational models of human language processing, as in Bryant's (2008) psychologically-plausible parsing model and models of language learning (Chang 2008; Mok 2008).

The ECG representation for construction grammars fits within an analysis-and-simulation model of human language understanding. The analysis phase consists of processing that is most directly governed by language, and as such makes direct use of ECG. As input, the analysis phase takes an ECG grammar, an utterance to be processed, and (possibly) contextual information. The desired output is a collection

[6] See (Schneider To appear, to appear) for additional discussion.

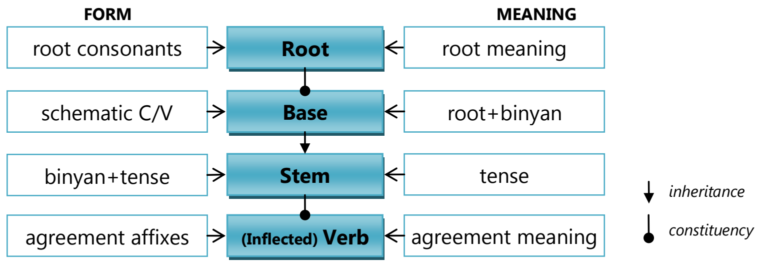


Figure 2: Layers of Hebrew verb constructions.

of bound schemas representing the frame semantics of the most likely interpretation of the utterance. This can be modeled computationally with an analyzer program such as that of Bryant (2008).[7]

We will be concerned with two types of ECG primitives: **schemas** (frames) and **constructions**.[8] Our goal is to develop a limited grammar describing mappings from morphosyntax to frame semantics in a particular language (Modern Hebrew).

One contribution of this paper is a proposal to close the morphology gap in ECG's expressive repertoire: until now there was no way to define constructions smaller than words. The adopted approach is flexible enough to accommodate non-concatenative morphology in Hebrew verbs, as illustrated below, and is intended to generalize to other morphological phenomena (in Hebrew and other languages) as well. It allows for morphological constructions to be integrated cleanly into a grammar alongside their phrasal counterparts. Though considered previously (Bergen 2003), this is the first work to describe and implement a general solution.

3 Constructional Analysis of Hebrew Verbs

What follows is an overview of the proposed ECG analysis of Hebrew verbs (for additional detail see Schneider, to appear). The approach will be to decompose a verb into morphemes—root, stem, and affix—and to represent these morphemes as constructions. Constructional **composition** (constituency) will be used to incorporate the form and meaning of a root in its host stem, and in turn to incorporate that stem into an inflectional affix. Moreover, generalizations over these constructions will allow for efficient organization of information specified by the various categories of roots, binyanim/stems, and affixes. Figure 2 summarizes the four primary sources of verbal information (root, binyan, stem, inflected verb) and their organization via composition and inheritance.

We next visit each of these components in turn, and then in section 3.5 look at the interaction between verbs and argument structure constructions.

[7] The analysis phase also interacts with other ("deeper") inference in the simulation phase.

[8] ECG also supports other semantic representations, including metaphors and mental spaces.

3.1 Root

Frame semantics is realized in ECG through definitions of interrelated schemas. Consider the following (simplified) representations of events:

```
schema Process
  roles
    protagonist : Entity
```

```
schema Transfer
  subcase of TransitiveAction
  roles
    source : Person
    recipient : Person
    goods : Entity
  constraints
    theme ⟷ goods
```

```
schema TransitiveAction
  subcase of Process
  roles
    agent : Entity
    theme : Entity
  constraints
    protagonist ⟷ agent
```

```
schema Rulebreaking
  roles
    action : Process
    perpetrator : Person
    authority : Entity
    rule : Entity
    motive : Reason
```

```
schema Steal
  subcase of Transfer
  evokes
    Rulebreaking as rb
  roles
    thief : Person
    victim : Person
  constraints
    agent ⟷ thief
    rb.perpetrator ⟷ thief
    recipient ⟷ thief
    theme ⟷ goods
    source ⟷ victim
    rb.action ⟷ self
```

These schemas characterize events with different degrees of abstractness. Roles allow the event to be elaborated with participants, props, and attributes. Process, the most abstract, generalizes over all events, and includes a protagonist role for its main participant. The rest of the above schemas are more refined types of processes: e.g. in Steal, the expression **subcase of** Transfer indicates that all instances of stealing are special cases of transfer; thus Steal is thus said to *inherit* from Transfer.[9]

Steal uses *binding* (unification) constraints such as agent ⟷ thief to indicate equivalences of roles defined in different schemas. Additionally, it *evokes*[10] the Rulebreaking schema, because stealing typically entails that the thief is violating a moral or societal rule of some kind. In a Steal event, thief, agent (inherited from TransitiveAction), protagonist (from Process), recipient (from Transfer), and perpetrator (from the evoked schema Rulebreaking) are all aliases of the same individual. The ECG keyword **self** in the expression rb.action ⟷ **self** refers to the containing schema (Steal), allowing it to be bound in its entirety to a role (action) of another schema (Rulebreaking).

When a schema such as Steal is used in an analysis of an utterance, it is said to be *instantiated*, at which point its roles may be filled (elaborated) with other schema instances via binding. Some roles are defined with type constraints; e.g. any thief

[9] We are assuming that other necessary schemas have been defined as well: for example, the Person schema represents the category of all people, and inherits from Entity, the category of all things.

[10] An *evoked* schema is one which may or may not be indicated directly by some other linguistic expression, but is recruited as part of understanding the schemas denoted by the utterance. Just as Steal evokes Rulebreaking, the Transfer schema could be said to evoke a Motion schema, etc.

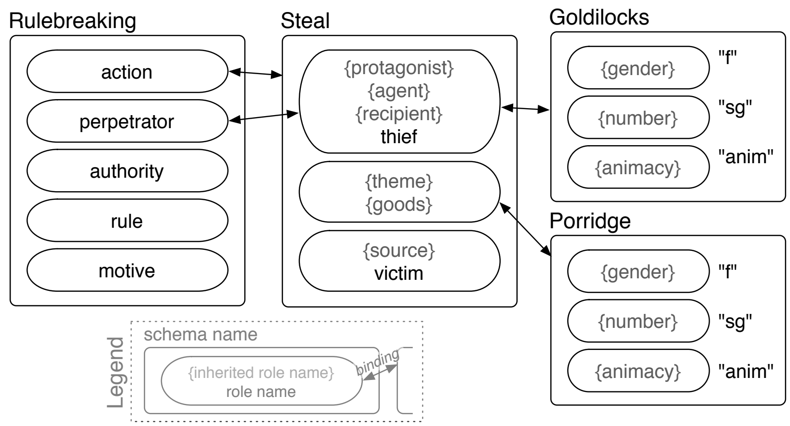


Figure 3: Semantic specification—schema instances and bindings—for an interpretation of (1), *Goldilocks stole the porridge*. (Tense information is not shown.)

must be a *subtype*[11] of Person for the analysis to be valid under this grammar. Thus, the analysis process entails finding a best interpretation of the input, subject to structures and constraints in the grammar. Assuming the necessary schemas for Goldilocks and porridge, the desired interpretation of the (Hebrew or English) sentence in (1) would resemble the *semantic specification* shown in figure 3.

In our framework, root constructions map an ordered series of consonant phonemes onto a semantic schema. Because the form of the root is complex, we represent its structure as a **form schema** with roles for phonemes, as in figure 4. Like semantic schemas, form schemas are organized in an inheritance hierarchy: three-consonant and four-consonant schemas are related under a common supertype.

Each construction in figure 4 maps a form to a meaning. The form for consonantal roots is a subtype of RootForm, which provides slots for consonant phonemes. The construction for /g/□/n/□/b/, Root_GNB, assigns these consonants as expected and specifies the semantic schema Steal as its meaning. The other two are abstract, or **general**, constructions: they generalize over roots, but are underspecified on their own, and as such cannot be used directly in an analysis. Importantly, Root imposes an ordering on the roles denoting the consonants with the expression r1 **before** r2 **before** r3. The **before** keyword imposes a relative ordering but permits intervening material; **meets** is used elsewhere to denote strict adjacency.

3.2 Base

Now we need a way to augment the roots with binyan-specific contributions to the form and meaning of the resulting verb. I will represent each binyan as a construction that composes with a root to yield the compositional (prototypical) meaning.

[11]Every schema/construction is its own subtype, along with all of its descendants.

```
schema RootForm
  roles
    r1 : C
    r2 : C
    r3 : C
```

```
schema Root3CForm
  subcase of RootForm
```

```
general construction Root3C
  subcase of Root
  form : Root3CForm
```

```
schema Root4CForm
  subcase of RootForm
  roles
    r2 : CC
```

```
general construction Root
  form : RootForm
    constraints
      r1 before r2 before r3
  meaning : Process
```

```
construction Root_GNB
  subcase of Root3C
  form constraints
    r1 ⟵ "g"
    r2 ⟵ "n"
    r3 ⟵ "b"
  meaning : Steal
```

Figure 4: Root schemas and constructions.

This essentially formalizes Mandelblit's (1997) blending schemas as constructions.

Base constructions that pertain to the hif'il paradigm appear in figure 5. Base specifies a root constituent and three roles. The first, highlightedProtagonist, will be set by specific binyan constructions (e.g., Hif'ilBase) depending on their voice; the argument structure construction will therefore have access to the highlighted protagonist (whether it is the causing or affected protagonist) to put in subject position. The second, highlightedProcess, will similarly be set by the binyan to encode the highlighted process. The constraint highlightedProcess ⟷ root.m specifies that the meaning of the root is that of the highlighted process. Finally, intransitiveOnly ("false" by default, but overridden where necessary) will be used by transitive argument structure constructions to avoid licensing verbs in intransitive-only binyanim.

CausationBase categorizes the binyanim with prototypically causal construals (primarily pi'el, pu'al, hif'il, and huf'al). Its meaning is the Causation schema, also in figure 5. Causation enacts roles for the two subevents in the causal sequence.

Individual binyan constructions such as Hif'ilBase introduce the highlighting of participants/subevents and vocalic templates for the stem. These templates generalize over the binyan's three tensed stems, and hence will be partially abstract. Binyanim that only host 3-consonant roots enforce this with a type constraint on the root constituent.

Hif'ilBase is a general construction because it is not commonplace to derive a new root-binyan pair (to do so amounts to coining a new word). Lexicalized root-binyan pairs like Hignib inherit from the appropriate binyan construction, and type-constrain the constituent to be the root in question. Such constructions need not specify a meaning if it is fully compositional. On the other hand, an idiosyncratic meaning is easily achieved by replacing the inherited meaning, as in Hignib: recall that *hignib* means 'smuggle' rather than 'cause to steal.'

general construction Base
  constructional constituents
    root **:** Root
  meaning : Process
    roles
      highlightedProtagonist **:** Entity
      highlightedProcess **:** Process
      intransitiveOnly
    constraints
      intransitiveOnly ⟵ “false”
      highlightedProcess ⟷ root.m

general construction CausationBase
  subcase of Base
  meaning : Causation
    roles
      unhighlightedProtagonist **:** Entity

construction Hignib
  subcase of Hif’ilBase
  constructional constituents
    root **:** Root_GNB
  meaning : Smuggle

general construction Hif’ilBase
  subcase of CausationBase
  constructional constituents
    root **:** Root3C
  form constraints
    (C)V **meets** r1 **meets** r2 **meets** “i” **meets** r3
  meaning constraints
    highlightedProcess ⟷ effectedProcess
    highlightedProtagonist ⟷ causingProcess.protagonist

schema Causation
  subcase of TransitiveAction
  roles
    causingProcess **:** Process
    effectedProcess **:** Process
  constraints
    causingProcess.protagonist ⟷ agent
    effectedProcess.protagonist ⟷ theme

Figure 5: Base constructions and the Causation schema.

general construction Stem
  subcase of Base
  constructional roles
    tense

construction HignibFutureStem
  subcase of Hif’ilFutureStem, Hignib

general construction Hif’ilFutureStem
  subcase of Stem, Hif’ilBase
  constructional constraints
    tense ⟵ “fut”
  form constraints
    “a” **meets** root.r1 **meets** root.r2
      meets “i” **meets** root.r3

Figure 6: Stem constructions.

Schemas for the idiosyncratic /g/□/n/□/b/ verbs are not provided here for want of space. A Smuggle schema would be similar to Steal: both involve illicit transfer, though Smuggle requires deceitful entry/exit of some container or region, might not involve a victim, and requires only that the smuggler be the agent (not necessarily the recipient) of transfer. The Hebrew Sneak schema would involve illicit, deceitful locomotion—though not necessarily transfer—with respect to some landmark. (These similarities suggest that it might be useful to model each *root's*, as well as each *binyan's*, verbs as a prototype-based category; this is left to future work.)

3.3 Stem

Some example stem constructions are shown in figure 6. These incorporate the tense and fully specify the form of the stem. There are 21 binyan-tense combinations, each of which will need its own construction (e.g. Hif'ilFutureStem) to specify a specific form. HignibFutureStem needs only to inherit from Hif'ilFutureStem and Hignib to acquire all of its form and meaning properties.

3.4 Inflected Verb

Finally, we are ready to compose the stem within an inflectional affix to arrive at the fully-inflected verb. Figure 7 shows examples of full-verb constructions. The general construction Verb takes a stem constituent and defines roles for inflectional features. Then, inflectional constructions like Future3FsgVerb specify inflectional affixes along with their morphological properties.

TAGNIB illustrates a construction definition for a fully-inflected verb. The compositionality of this verb is depicted at the bottom of figure 7. Because in ECG constructional composition can be a productive (online) process, it is not strictly necessary to define the fully-inflected form in the grammar: our morphological analyzer will be capable of parsing all inflections of a known verb. Nonetheless, the ability to define fully compositional constructions such as TAGNIB is desirable in light of *usage-based* theories, which claim that frequent enough patterns are memorized even if they are fully predictable from more general patterns (Langacker 1990; Bybee 2001; Tomasello 2003; Goldberg 2006).

3.5 Verbs in Argument Structure Constructions

A major advantage of our representation is that morphological constructions are easily integrated within syntactic constructions. Figure 8 shows two argument structure constructions that specify the relative ordering of subject, verb, and object; enforce case marking and subject-verb agreement; and prevent verbs in always-intransitive binyanim from appearing in the transitive argument structure. As a whole, each argument structure construction takes on the meaning of its head verb.

```
general construction Verb
  subcase of ComplexWord
  constructional
    constituents
      stem : Stem
    roles
      tense
      personGenderNumber
    constraints
      tense ⟷ stem.tense
  meaning constraints
    self.m ⟷ stem.m
```

```
construction Future3FsgVerb
  subcase of Verb
  constructional constraints
    stem.tense ⟵ "fut"
    personGenderNumber ⟵ "3.f.sg"
  form constraints
    "t" meets stem.f
```

```
construction TAGNIB
  subcase of Future3FsgVerb
  constructional constituents
    stem : HignibFutureStem
```

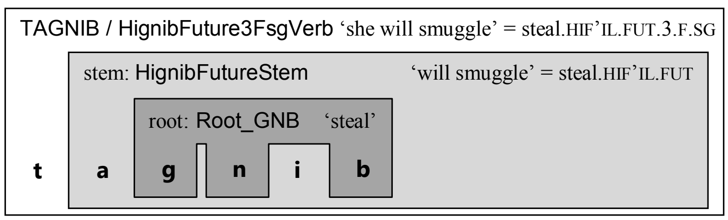


Figure 7: Verb constructions and an illustration of constructional composition.

```
construction ArgumentStructure
  constructional
    constituents
      subject : NP
      verb : Verb
    constraints
      subject.PGN ⟷ PGN
      subject.case ⟵ "nom"
  form constraints
    subject before verb
  meaning constraints
    self.m ⟷ verb.m
    subject.m ⟷ verb.m.highlightedProt
```

```
construction Transitive
  subcase of ArgumentStructure
  constructional
    constituents
      object : NP
    constraints
      verb.stem.intransitiveOnly ⟵ "false"
      object.case ⟵ "acc"
  form constraints
    subject before verb before object
  meaning constraints
    object.m ⟷ verb.m.unhighlightedProt
```

Figure 8: Argument structure constructions. PGN is short for personGenderNumber and Prot for Protagonist.

4 Conclusion

I have outlined a construction grammar analysis of templatic morphology in Modern Hebrew verbs, and used it to introduce a representation that augments the Embodied Construction Grammar formalism with support for morphological phenomena. This analysis captures compositionality of both form and meaning; it is notable in its support for many levels of generalization, category prototypes, and idiosyncratic special cases. The representation is flexible enough to encode nonconcatenative phenomena, and allows for clean integration with syntactic constructions.

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References

Arad, Maya. 2005. *Roots and Patterns: Hebrew Morpho-Syntax*. Dordrecht: Springer.

Bat-El, Outi. 1989. Phonology and Word Structure in Modern Hebrew. Ph.D. dissertation, University of California, Los Angeles.

Bergen, Benjamin K. 2003. Towards Morphology and Agreement in Embodied Construction Grammar. URL `www2.hawaii.edu/~bergen/papers/ECGmorph.pdf`.

Bergen, Benjamin K. and Nancy Chang. 2005. Embodied Construction Grammar in Simulation-Based Language Understanding. In Jan-Ola Östman and Mirjam Fried, eds., *Construction Grammars: Cognitive Grounding and Theoretical Extensions*, 147–190, Amsterdam: John Benjamins.

Berman, Ruth Aronson. 1978. *Modern Hebrew Structure*. Tel-Aviv: University Publishing Projects.

Bolozky, Shmuel. 1996. *501 Hebrew Verbs*. Hauppauge, NY: Barron's Educational Series.

Bolozky, Shmuel. 1999. *Measuring Productivity in Word Formation: The Case of Israeli Hebrew*. Leiden, Netherlands: BRILL.

Booij, Geert. 2005. Compounding and Derivation: Evidence for Construction Morphology. In Wolfgang U. Dressler, Franz Rainer, Dieter Kastovsky, and Oskar Pfeiffer, eds., *Morphology and its Demarcations*, 109–132, Amsterdam: John Benjamins.

Bryant, John. 2008. Best-Fit Constructional Analysis. Ph.D. dissertation, University of California, Berkeley.

Bybee, Joan L. 1985. *Morphology: A Study of the Relation Between Meaning and Form*. Typological studies in language, Amsterdam: John Benjamins.

Bybee, Joan L. 2001. *Phonology and Language Use*. Cambridge University Press.

Chang, Nancy. 2008. Constructing Grammar: A Computational Model of the Emergence of Early Constructions. Ph.D. dissertation, University of California, Berkeley.

Dodge, Ellen. 2010. Conceptual and Constructional Composition. Ph.D. dissertation, University of California, Berkeley.

Fauconnier, Gilles and Mark Turner. 1996. Blending as a Central Process of Grammar. In Adele E. Goldberg, ed., *Conceptual Structure, Discourse, and Language*, 113–129, Stanford, CA: CLSI, Cambridge University Press.

Feldman, Jerome A. 2006. *From Molecule to Metaphor: A Neural Theory of Language*. Cambridge, MA: MIT Press.

Feldman, Jerome A., Ellen Dodge, and John Bryant. 2009. A Neural Theory of Language and Embodied Construction Grammar. In Bernd Heine and Heiko Narrog, eds., *The Oxford Handbook of Linguistic Analysis*, Oxford: Oxford University Press.

Fillmore, Charles J., Paul Kay, and Mary Catherine O'Connor. 1988. Regularity and idiomaticity in grammatical constructions: the case of 'let alone'. *Language* 64(3):501–538.

Goldberg, Adele E. 1995. *Constructions: A Construction Grammar Approach to Argument Structure*. Chicago: University of Chicago Press.

Goldberg, Adele E. 2006. *Constructions At Work: The Nature of Generalization in Language*. Oxford: Oxford University Press.

Gurevich, Olya. 2006. Constructional Morphology: The Georgian Version. Ph.D. dissertation, University of California, Berkeley.

Inkelas, Sharon. 2008. The Morphology-Phonology Connection. In *Proceedings of the 34th meeting of the Berkeley Linguistics Society*, Berkeley, CA.

Kay, Paul and Charles J. Fillmore. 1999. Grammatical constructions and linguistic generalizations: the *What's X doing Y?* construction. *Language* 75(1):1–33.

Lakoff, George. 1987. *Women, Fire, and Dangerous Things: What Categories Reveal About the Mind*. Chicago: University of Chicago Press.

Langacker, Ronald W. 1990. *Concept, Image, and Symbol: The Cognitive Basis of Grammar*. Berlin: Mouton de Gruyter.

Mandelblit, Nili. 1997. Grammatical Blending: Creative and Schematic Aspects in Sentence Processing and Translation. Ph.D. dissertation, University of California, San Diego.

McCarthy, John J. 1979. Formal Problems in Semitic Phonology and Morphology. Ph.D. dissertation, MIT.

Mok, Eva. 2008. Contextual Bootstrapping for Grammar Learning. Ph.D. dissertation, University of California, Berkeley.

Orgun, Cemil Orhan. 1996. Sign-Based Morphology and Phonology with Special Attention to Optimality Theory. Ph.D. dissertation, University of California, Berkeley.

Prunet, Jean-François. 2006. External Evidence and the Semitic Root. *Morphology* 16(1):41–67.

Rubba, Johanna. 1993. Discontinuous Morphology in Modern Aramaic. Ph.D. dissertation, University of California, San Diego.

Schneider, Nathan. To appear. Constructional Morphosemantics: Building Hebrew Verbs. In Hans C. Boas, ed., *Computational Approaches to Construction Grammar and Frame Semantics*, Amsterdam: John Benjamins.

Tomasello, Michael. 2003. *Constructing a Language: A Usage-Based Theory of Language Acquisition*. Cambridge, MA: Harvard University Press.

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