Formalizing the syntax-lexical semantics interface: A type-theoretic approach

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Introduction. An active debate about the interface between conceptual ontologies, the lexicon, the syntax, and the semantics concerns the extent to which different predicates are associated with different argument structure configurations (syntactic frames). Is the fact that, in English, one can *bake* without specifying the object, but one cannot *clear* without specifying what is being cleared, due to the properties of *bake* and *clear* or to how people generally conceive of baking and clearing events? Attempts to understand what components of meaning surface as grammatical factors and how these notions should be formalized are notoriously difficult tasks (Fillmore 1970, Chomsky 1982). Much work in lexical semantics observes that systematic argument structure patterns are captured by an ontology of grammatically-relevant conceptual content, e.g., Manner/Result (Rappaport Hovav & Levin 1998; Beavers & Koontz-Garboden 2017). But the formalization of these insights and their exact place in the syntax (and the grammar more broadly) remains unclear (Levin and Rappaport Hovav 1995, Marantz 1997, Harley 2005, Rappaport-Hovav 2017). Focusing on the roots that make up verbs, we propose a theory of the syntax-lexical semantics interface consisting of two main components designed to make explicit the relationship between conceptual ontologies, semantic primitives, and syntactic/semantic composition. We test this theory on an ontology of three root/verb classes discussed by Levinson (2007, 2010, 2014). Aiming to synthesize insights from lexical semantics with formal work in syntax (the Minimalist Program) and morphology (Distributed Morphology), our approach rests on two fundamental components: The **first component** is the assumptions that (verbal) roots are semantically typed as either <s,t> or <e,<s,t>> (Marantz 2013; Coon 2018) and that semantic composition proceeds through the standard operations of Heim & Kratzer (1998). The **second component** proposes that semantic primitives, which are grounded in grammatically-relevant conceptual terms, are part of the denotation of different verb classes, the effects of which can be detected in acceptability judgments in sentences with these verbs.

Data. We illustrate the approach by building the denotations of three verb/root classes in English and showing how they predict acceptability with respect to three syntactic, verb-based diagnostics from Levinson's work. We build on Levinson's ontology of three root/verb classes: EXPLICIT CREATION (EXPL; e.g., *bake, build*) CHANGE OF STATE (COS; e.g., *open, clear*) and IMPLICIT CREATION (IMPL; e.g., *pile, stack*). Levinson shows a three-way distinction with respect to three syntactic diagnostics, a set of judgements which we verified using an online rating task (N = 58) for three verbs in each class (Table 1). In work on lexical semantics, verb classes are often diagnosed by means of semantic entailments--as in the literature on the Manner/Result distinction; but here we investigate acceptability in syntactic constructions in order to probe the syntax-lexical semantics interface. In Table 1, "No-Theme" means that the sentence is acceptable

Table 1: Verb classes, formal types, and syntactic diagnostics

	No Theme	**Double Obj**	**PseudoRes**
EXPLICIT CREATION <s,t> *bake, build, cook*	✓ John was baking all day yesterday	✓ John baked his mom some cookies	✗ John baked the ingredients tasty
CHANGE OF STATE <e,st> *open, clear, cool*	✗ John was opening all day	✓ John opened his buddy a beer	✗ John opened the door tiny
IMPLICIT CREATION <e,st> *pile, braid, stack*	✗ John was piling all day	✗ John piled his mom some cushions	✓ John piled the cushions high

when theme is left out; "Double-Obj" means that the verb can be used in a double-object, change of possession construction; "Pseudo-Res" refers to the availability of pseudo-resultative modification. Pseudo-Res is perhaps is less well-known as a diagnostic, so it is illustrated in (1)-(2): in (1), *high* modifies not the cushions but the pile that is created using the cushions. By contrast, EXPL verbs like *bake* do not allow such modification: (2) cannot mean that a tasty "baking" was created out of the ingredients.

(1) John piled the cushions high. *'A high pile was created out of the cushions'*

(2) ✘ John baked the ingredients tasty.

Proposal (informal). The relevant lexical semantic features of verb classes are encoded directly onto the denotation of the verbs in two ways. EXPL verbs like *bake* do not entail a product, and so the formal type of the verb is compatible with an object but does not require one (<s,t>). The other two types require an object (<e,<s,t>>). If the latter do not receive an object, the derivation crashes, explaining No-Theme. Next we examine the properties of the IMPL class. As Levinson shows, what is created in a piling event is, for example, a collection of cushions, formed into one pile. Verbs in this class include *powder, stack, heap, dice* and *knot*. We encode the idea that the semantic object of these verbs (the Theme) is a sum of material; the syntactic object of IMPL verbs specifies what this sum is made of.

Formal fragment. Roots modify the category head v (by Event Identification), which has two variants (allosemes): intransitive <s,t> and transitive <e,<s,t>>; the vP is then of type <s,t>. Voice is merged to introduce Agents: $[_{\text{VoiceP}}$ DP [Voice $[_{\text{vP}}$ $[_{\text{v}}$ ROOT v] DP]]]. For simplicity we type all individuals as type *e*. The denotations for three representative verbs are given in (3)-(5). Note in particular the underlined parts of IMPL roots like √PILE.

(3) $[\![\sqrt{\text{OPEN}} + \text{v}]\!]_{\text{COS}} = \lambda x \lambda e.\ \text{open}(e) \ \&\ \text{theme}(x, e)$

(4) $[\![\sqrt{\text{BAKE}} + \text{v}]\!]_{\text{EXPL}} = \lambda e.\ \text{bake}(e)$ **OR** $[\![\sqrt{\text{BAKE}} + \text{v}]\!]_{\text{EXP}} = \lambda x\ \lambda e.\ \text{bake}(e) \ \&\ \text{theme}(x, e)$

(5) $[\![\sqrt{\text{PILE}} + \text{v}]\!]_{\text{IMPL}} = \lambda x \lambda e \underline{\exists y}.\ \underline{\text{sum}(y)} \ \&\ \text{pile}(e) \ \&\ \text{theme}(\underline{y}, e) \ \&\ \underline{\text{made-of}(y,x)}$

Double object constructions (6) are derived using a standard denotation for low applicatives in which Appl introduces the Theme and the Goal (6)-(7). ApplP saturates both these roles and takes the verb as its input by Function Application (Pylkkänen 2008).

(6) John baked Mary a cake.

(7) $[\![\text{Appl}]\!] = \lambda x \lambda y \lambda f_{<e,st>} \lambda e\ .\ f(x,e) \ \&\ \text{Theme}(x,e) \ \&\ \text{transfer-possession}(x,y)$

(8) $[\![\text{ApplP}]\!] = \lambda f_{<e,st>} \lambda e\ .\ f(\textit{cake},e) \ \&\ \text{Theme}(\textit{cake},e) \ \&\ \text{transfer-possession}(\textit{cake},\textit{Mary})$

Combining an ApplP with an IMPL verb results in unacceptability because the Theme of an IMPL verb is already specified--the theme of *pile*, for example, is not "cushions" but a "<u>sum</u> (of cushions)", so Appl cannot introduce the Theme as it standardly does. The case of Psuedo-Res is similar but omitted here for space considerations.

Discussion. The theory described here explains how the effects of lexical semantics on the syntax can be understood and formalized starting with two foundational components. While the type-theoretic distinction is assumed to be universal, we expect individual languages to show variation as to which conceptually-similar roots occur as different formal types. But the system predicts that primitives/building blocks such as our <u>made-of(x,y)</u> will be found crosslinguistically. We would like to extend our approach to the much-discussed Manner/Result distinction, with a starting hypothesis being that Manner roots are of type <s,t> and Result roots of type <e,<s,t>>. Other avenues opened up by this research program includes a new understanding of verbs like *arrive* (which never take an external argument) and *assassinate* (which require both an internal and an external argument). The theory developed here provides a formally explicit way of talking about foundational issues such as these.