Chapter 17
Co-compositionality in Grammar

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Abstract

This entry addresses the problem of how words combine to make meanings that appear non-compositional in their derivation. Specifically, we examine a phenomenon known as co-compositionality, where a new meaning emerges in an expression that is not expected through simple compositional operations. This will be analyzed as a kind of bilateral function application, where both predicate and argument contribute functionally to determine the meaning of the resulting expression. In this article, we differentiate the formal properties of co-compositionality from conventional mechanisms of composition, and examine two co-compositional constructions at work in language: (a) cospecification, where the argument to a verb acts functionally over the predicate selecting it; and (b) subject-induced coercion, where the subject adds an agentive or intentional interpretation to the meaning of the predicate selecting it. All cases of co-composition are ampliative, in that the meaning of the derived expression entails the meanings of the subexpressions. By studying the mechanisms of such constructions, we hope to arrive at a better understanding of the mechanics of argument selection, and with this, a richer appreciation for the nature of compositionality in language.

1 Basic Mechanisms of Selection

Co-compositionality is a semantic property of a linguistic expression in which all constituents contribute functionally to the meaning of the entire expression. As a result, it extends the conventional definition of compositionality. The principle of compositionality in linguistics (cf. Janssen, 1983, Thomason, 1974) and in philosophy (cf. Werning, 2004) involves the notion that the meanings of complex symbols are systematically determined by the composition of their component parts. In order to understand the theoretical motivation behind the theory of co-compositionality, it is necessary to understand where conventional theories of compositionality are unable to explain the meaning of certain natural language constructions. Since these issues are addressed in more detail by other entries in this encyclopedia (Non-compositionality), the present article will focus on the role that compositionality plays in mapping from the lexicon to syntactic form.

At the outset, it should be stated that co-compositonality is not the result of a failure of compositionality, and hence to be viewed as involving non-compositional processes. Rather, as the name would suggest, it entails at least conventional compositional mechanisms for the expressions involved, along with additional interpretive mechanisms not always exploited within a phrasal composition. In order to understand what these are, we first review conventional modes of argument selection in language.

While it is impossible to say how many meanings we create for a particular word in normal language use, we can reasonably ask how many meanings we have stored for that word in our mental lexicon. This is where linguists differ broadly in assigning responsibility for whether meaning shifts occur at all and, if so, how. As a result of this divide, the role that compositionality plays in structuring not only the grammar but also the lexicon is significant.

For example, in conventional models of language meaning, a verb is thought to have several different word senses. For each sense, the verb acts on its parameters (its arguments in syntax) in a compositional manner. This means that the semantics of the result of application of the verbal function to its argument is determined by the semantics of the function itself, a process referred to as *function application*. Consider, for example, the way in which the verbs *throw* and *kill* each have several distinct senses.

(1) a. Mary threw the ball to John. (PROPEL)
    b. They threw a party for Bill. (ORGANIZE)
    c. Mary threw breakfast together quickly. (CREATE)

The use of *throw* in each sentence above illustrates a true verbal ambiguity, one that requires separate senses, each with specific subcategorization and semantic selection as illustrated. Likewise, the verb *kill* as used in (2) below, demonstrates a systematic sense distinction as well.

(2) a. John killed the plant.
    b. Mary killed the conversation.
    c. John killed the evening watching TV.

As with the verb *throw*, each of these senses has a regular and productive distribution in the language, exemplified below.

(3) a. Mary killed the fish.
    b. The President killed any attempt at dialogue with Cuba.
    c. John killed the day reading.

Verb senses like these are distinct, semantic units, perhaps related to each other, but stored separately in the lexicon. Because they have distinct subcategorization and type selection frames, the semantic computation involving these senses in the syntax can be performed compositionally.

These examples with the verbs *throw* and *kill* illustrate that lexical forms may be truly ambiguous, and as such, can be modeled adequately by a sense enumerative lexical (SEL) model (cf. Pustejovsky, 1995). In such a model, each sense of a word, as in (2) above, would be strongly typed, illustrated in (4) below, where the intended sense is glossed as a relation with its appropriate argument types.

(4) a. kill_1: CAUSE-TO-DIE(THING, ANIMATE)
b. kill_2: TERMINATE(HUMAN, EVENT)
c. kill_3: SPEND(HUMAN, TIME, EVENT)

Given distinct lexical types for these three senses of *kill*, compositional mechanisms in the semantics can compute the sentences in (2) as cases of function application. For this particular example, *function application* assumes that the verb *kill* applies to its arguments in discrete steps. For example, consider the derivation of (2c) as a sequence of function applications, simplifying the arguments (HUMAN, TIME, EVENT) from (4c) as numbered variables.

(5) a. John killed the day reading.
b. $kill(Arg_1, Arg_2, Arg_3)$
c. Apply $kill(Arg_1, Arg_2, Arg_3)$ to "reading"
$\Longrightarrow kill(Arg_1, Arg_2, [reading])$
d. Apply $kill(Arg_1, Arg_2, [reading])$ to "the day"
$\Longrightarrow kill(Arg_1, [day], [reading])$
e. Apply $kill(Arg_1, [day], [reading])$ to "John"
$\Longrightarrow kill(john, [day], [reading])$

This derivation has a successful computation because the verb sense for *kill* selected in (5) has the appropriate typing. If we had tried using the type associated with kill_2, the sentence would not have an interpretation. As we see, compositional operations reflect the ontological and lexical design decisions made in the grammar.

Treating the functional behavior of composition formally, we can state this procedure as an operation over the types of expressions involved, as expressed in (6):

(6) Function Application (FA):
If α is of type a, and β is of type $a \rightarrow b$, then $\beta(\alpha)$ is of type b.

Returning to the example derivation in (5), we can see FA at work on the last application step in (5e), where e stands for any of the specific types mentioned earlier (e.g., THING, HUMAN, TIME, EVENT) and t stands for the propositional type.

(7) a. $kill(Arg_1, [day], [reading])$ is of type $e \rightarrow t$;
b. $john$ is of type e;
c. FA results in applying $e \rightarrow t$ to e;
$\Longrightarrow kill([john], [day], [reading])$, of type t, i.e., a sentence.

Hence, by enumerating separate senses for ambiguous predicates, we can ensure strong (unique) typing on the arguments expected by a verb (function), and thereby maintain compositionality within these constructions.

If function application as described above were inviolable, then we would not expect to encounter examples of type mismatch between verb and argument. But, of course, such data are ubiquitous in language, and involve a process characterized as *type coercion* (Pustejovsky, 1995, Copestake and Briscoe, 1995, Partee and Rooth, 1985). This is an operation that allows an argument to change its type, if it does not match the type requested by the verb. For example, for one of its senses, the aspectual verb *begin* selects for an event as its internal argument:

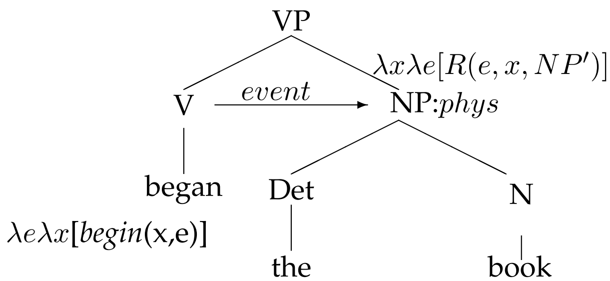
(8) Mary began [reading the book]$_{event}$.

The same sense is used, however, when *begin* selects for a simple NP direct object, as in (9).

(9) Mary began [the book]$_{event}$.

In such configurations, the verb is said to "coerce" the NP argument into an event interpretation (cf. Pustejovsky, 1991,1995). Under such an analysis, the NP actually denotes a salient event that involves the book in some way, e.g., reading it, writing it, and so on. This is schematically represented below, where the NP *the book* has been reinterpreted through coercion, as some relation, *R*, involving the book.

(10)



Our knowledge of the world associates conventional activities, such as reading and writing, with books. This knowledge can be lexically encoded through the use of *Qualia Structure* (Pustejovsky, 1995), thereby providing a mechanism for preserving compositionality in the construction above. In Generative Lexicon Theory (Pustejovsky, 1995), it is assumed that word meaning is structured on the basis of four generative factors (the Qualia roles) that capture how humans understand objects and relations in the world and provide the minimal explanation for the linguistic behavior of lexical items (these are inspired in large part by Moravcsik's (1975, 1990) interpretation of Aristotelian *aitia*). These are: the FORMAL role: the basic category that distinguishes the object within a larger domain; CONSTITUTIVE role: the relation between an object and its constituent parts; the TELIC role : its purpose and function; and the AGENTIVE role: factors involved in the object's origin or "coming into being". Qualia structure is at the core of the generative properties of the lexicon, since it provides a general strategy for creating new types.

The qualia act as type shifting operators, that can allow an expression to satisfy new typing environments. Every expression, α, has some set of operators available to it, that provide such type shifting behavior. Let us refer to this set as Σ_α. Then we can characterize function application under such conditions as follows:

(11) Function Application with Coercion (FA_c):
If α is of type c, and β is of type $a \rightarrow b$, then,
(i) if type $c = a$ then $\beta(\alpha)$ is of type b.
(ii) if there is a $\sigma \in \Sigma_\alpha$ such that $\sigma(\alpha)$ results in an expression of type a, then $\beta(\sigma(\alpha))$ is of type b.
(iii) otherwise a type error is produced.

Such phenomena are quite common in language, and when viewed as a lexically-triggered operation, coercion allows us to maintain a compositional treatment of argument selection in the grammar.

2 Co-compositional Mechanisms

With the additional mechanism of function application with coercion (FA_c), we are able to account for a larger range of data that would otherwise not have been modeled as compositional in nature. But there are many constructions in language which appear to be outside the scope of conventional compositional operations. In this section, we see how these can be analyzed co-compositionally.

As stated above, co-compositionality is a semantic property of a linguistic expression in which all constituents contribute functionally to the meaning of the entire expression. As with compositionality, the notion of co-compositionality is a characterization of how a system constructs the meaning from component parts. It is a mistake to think that an expression in a language is inherently co-compositional or compositional. Rather, it is the set of computations within a specific system that should be characterized as co-compositional for those expressions. To make this distinction clear, consider the verb *run* as it is used in the contexts of (12)-(13) below.

(12) a. John ran.
b. John ran for twenty minutes.
c. John ran two miles.

(13) a. John ran to the store.
b. John ran the race.

There are two senses of *run* that emerge in context with these examples:

(14) a. run_1: manner-of-motion activity, as used in (12);
b. run_2: change-of-location transition, as used in (13);

We can choose to design our semantics and the accompanying lexicon for these cases according to the null hypothesis, and create separate senses, as illustrated in (14). With two separate entries, they will select differently because they will have different types and argument structures. In this case, we say that the data are accounted for compositionally through sense enumeration. What is left unexplained, however, is any logical relation between the senses, a major drawback; this can be overcome, however, with lexical rules that explicitly specify this relationship as a redundancy rule or meaning postulate.

Similar remarks hold for verbs such as *wax* and *wipe* in (15)–(16), which are contextually ambiguous between a process reading and a transition reading, depending on the presence of a resultative adjectival. Normally, lexicons would have to enter both forms as separate lexical entries (cf. Levin and Rappaport, 1995).

(15) a. Mary *waxed* the car.
b. Mary *waxed* the car clean.

(16) a. John *wiped* the counter.
b. John *wiped* the counter dry.

Clearly, the local context is supplying additional information to the meaning of the predicate that is not inherently part of the verb's meaning; namely, the completive aspect that inheres in the resultative constructions (cf. Goldberg (1995) and Jackendoff (2002)).

A related phenomenon of extended word sense in context is what Atkins et al (1988) refer to as "overlapping senses", and it is exhibited by cooking verbs such as *bake*, *fry*, as well as by activities such as *carve*, shown below.

(17) a. John *baked* the potato.
b. John *baked* the cake.

(18) a. Mary *fried* an egg.
b. Mary *fried* an omelette.

(19) a. John *carved* the stick.
b. John *carved* a statue.

These example illustrate that strict lexical typing (preserving compositionality) does not explain when and how verb senses will overlap or be entailed by another sense. Clearly, something is not being captured by the semantic theory with such data. The notion of co-compositionality was introduced to characterize just this type of phenomenon (cf. Pustejovsky, 1991, 1995), In particular, this construction has been referred to as *cospecification*, since the argument being selected by the predicate, seems to have a semantic familiarity with the predicate, and hence, *specifies* the governing predicate.

Informally, we can view co-compositionality as the introduction of new information to an expression by the argument, beyond what it contributes as an argument to the function within the phrase. Hence, it can be considered an *ampliative* operation, relative to the function application. Returning to the examples considered above, let us see how this characterization fits the data. First, consider the shift from the process interpretation of *run* to the accomplishment sense in (12)-(13). The sense of the verb *run* in (13b) clearly overlaps (indeed, it entails) the sense exploited in (12a). We say that the NP *the race* in (13b) cospecifies the predicate selecting it, repeated below in (20).

(20) John ran the race.

The semantic composition results in an interpretation entailing the activity of running, which is either quantified by a measure phrase with a specific distance (as in (12c) with *two miles*), or entails the completion of a specific course or event (as in (20) with *the race*).

With the verbs *wax* and *wipe*, similar extensions to the basic meaning are at play in (15b) and (16b). What is still unclear is how the extended meaning is first licensed and then how it is computed formally through compositional mechanisms.

To better understand the mechanisms involved in the ampliative interpretations that result in such constructions, we examine the relationship between the core and derived senses of the verb *bake*, as presented above in (17). In the context of particular objects, the verb *bake* assumes the interpretation of a *creation* predicate, while with other objects, it maintains the underlying *change-of-state* predicate meaning. Certain NPs are said to *cospecify* the verb selecting it, as does the noun *cake* in its agentive qualia value. That is, the type structure for *cake* references the predicate selecting it as an argument. With this, the activity of baking assumes a resultative interpretation when combined with co-specifying arguments.

Assume that the lexical semantics for the change-of-state sense of *bake* is given as in (21), where the qualia roles are abbreviated as F (Formal), C (Constitutive), T (Telic), and A (Agentive).

(21) $$\lambda y \lambda x \lambda e \begin{bmatrix} \textbf{bake} \\ \text{AS} = \begin{bmatrix} \text{A1} = x : phys \\ \text{A2} = y : phys \end{bmatrix} \text{ES} = \begin{bmatrix} \text{E1} = e : process \end{bmatrix} \\ \text{QS} = \begin{bmatrix} \text{A} = bake\_act(e, x, y) \end{bmatrix} \end{bmatrix}$$

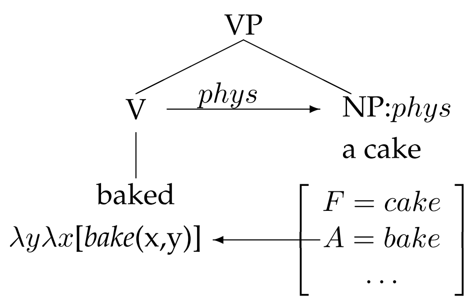
The lexical representation for an artifactual concept such as the noun *cake* is shown below in (22).

(22) $\lambda x \exists y \left[\begin{array}{l} \textbf{cake} \\ \text{AS} = \left[\begin{array}{l} \text{ARG1} = x : phys \\ \text{D-ARG1} = y : mass \end{array} \right] \text{QS} = \left[\begin{array}{l} \text{F} = cake(x) \\ \text{C} = made\_of(x,y) \\ \text{T} = \lambda z, e[eat(e,z,x)] \\ \text{A} = \exists w, e[bake(e,w,y)] \end{array} \right] \end{array} \right]$

Notice that the Agentive qualia value for the noun *cake* makes reference to the very process within which it is embedded in the sentence in (17) (i.e., *bake a cake*), which is a case of cospecification.

We now define the conditions under which the derivation of an expression is said to be *co-compositional*. Ignoring the event structure for discussion, according to the type structure for the predicate *bake*, function application, as defined above, applies as expected to its argument *a cake*.[1] But the direct object cospecifies the verb selecting it, since its type structure makes reference to the governing verb, *bake*. This is illustrated graphically in (23).

(23)



From the underlying process *change-of-state* sense of *bake*, the *creation* sense emerges when combined with the triggering NP *a cake*. This results in a logical form such as that shown in (24).

(24) $\exists e_1 \exists e_2 \exists x \exists y[bake(e_1, j, y) \wedge cake(e_2, x) \wedge made\_of(x, y) \wedge e_1 \leq e_2]$

The operation of co-composition results in a qualia structure for the VP that reflects aspects of both constituents. These include:

(A) The governing verb *bake* applies to its complement;

(B) The complement co-specifies the verb;

[1] We also ignore the type shifting involved for the predicate to take the generalized quantifier *a cake* as its argument. For discussion, we assume the indefinite is treated as a discourse variable denoting an individual type.

(C) The composition of qualia structures results in a derived sense of the verb, where the verbal and complement AGENTIVE roles match, and the complement FORMAL quale becomes the FORMAL role for the entire VP.

The derived sense is computed from an operation called *qualia unification*, introduced in Pustejovsky (1995). The conditions under which this operation can apply are stated in (25) below:

(25) FUNCTION APPLICATION WITH QUALIA UNIFICATION: For two expressions, α, of type `<a,b>`, and β, of type `a`, with qualia structures QS_α and QS_β, respectively, then, if there is a quale value shared by α and β, $[_{QS_\alpha} \ldots [Q_i = \gamma\ ]]$ and $[_{QS_\beta} \ldots [Q_i = \gamma\ ]]$, then we can define the qualia unification of QS_α and QS_β, $QS_\alpha \sqcap QS_\beta$, as the unique greatest lower bound of these two qualia structures. Further, $\alpha(\beta)$ is of type `b` with $QS_{\alpha(\beta)} = QS_\alpha \sqcap QS_\beta$.

The composition in (23) can be illustrated schematically in (26) below.

(26) $\begin{bmatrix}\text{V} & A = bake\end{bmatrix} \sqcap \begin{bmatrix}\text{NP} & \begin{matrix} F = cake \\ A = bake \end{matrix}\end{bmatrix} = \begin{bmatrix}\text{VP} & \begin{matrix} F = cake \\ A = bake \end{matrix}\end{bmatrix}$

3 Further Extensions of Co-composition

Further examination of the derivation above suggests that co-composition involves a more general process where conventional function application from an anchor function (e.g., the governing verb), along with ampliative information supplied by a triggering argument type. These properties can be summarized as follows in (27).

(27) Properties of Co-compositional Derivations:
a. Within an expression, α, consisting of two subexpressions, α_1 and α_2, i.e., $[_\alpha\ \alpha_1\ \alpha_2]$, one of the subexpressions is an *anchor* that acts as the primary functor;
b. Within the argument expression, there is explicit reference to the anchor or the anchor's type (that is, the complement co-specifies the functor);
c. The composition of lexical structures results in a derived sense of the functor, within α.

This can be formalized as follows:

(28) Co-compositionality:

a. The derivation for an expression α, is *co-compositional* with respective to its constituent elements, α_1 and α_2, if and only if one of α_1 or α_2 applies to the other, $\alpha_i(\alpha_j)$, $i \neq j$, and $\beta_j(\alpha_i)$, for some type structure β_j within the type of α_j, i.e., $\beta_j \sqsubseteq type(\alpha_j)$.

b. $[\![\alpha]\!] = \alpha_i(\alpha_j) \sqcap \beta_j(\alpha_i)$.

For the example at hand, the overall expression α is *bake a cake*. The anchor functional term is the verb *bake* (α_1), and the ampliative interpretation comes from the Agentive Qualia value for the NP (β_j). Given this formulation of co-composition, it is now clear now when co-composition is licensed. If any component of the type of the argument in a construction makes reference to the anchor functional term in a construction, then co-composition should be permitted. This is, in fact, what we see in all the cases of cospecification we encountered above.

With the more general characterization of composition given above, we can now analyze a number of constructions as co-compositional in nature. These include, among others, subject-derived agentive interpretations (*subject-induced coercion*) and certain light verb constructions, e.g., *functionally dependent verbs*. For example, it has long been noted that certain classes of predicates select for non-agentive subjects, but allow agentive interpretations in the appropriate context, as illustrated in the examples below (cf. Wechsler, ref, others).

(29) a. The storm killed the deer.
b. An angry rioter killed a policeman.

(30) a. The glass touched the painting.
b. The curious child touched the painting.

(31) a. The ball rolled down the hill.
b. John rolled down the hill as fast as he could.

(32) a. The room cooled off quickly.
b. John cooled off with an iced latte.

We will refer to these as *subject-induced coercions*, since, in each of these pairs, the subject in the (b)-sentence introduces agency or intentionality towards the predicated event. Rather than suggesting that each of these verbs is ambiguous between agentive/non-agentive readings, we can view the computation in the (b)-sentences as co-compositional, where an agentive subject introduces the appropriate intentional component to the interpretation of the VP. For the present discussion, let us characterized "agency", in terms of Qualia Structure, as referring to the potential to act towards a goal. For a cognitive agent, such as a *human*, this amounts to associating a set of particular activities, $\mathcal{A}$, as the value of the Agentive role, and a set of goals, $\mathcal{G}$, associated with the Telic role in the Qualia for that concept, as illustrated below in (33).

(33) $$\lambda x \begin{bmatrix} \textbf{human\_agent} & \\ \text{QS} = \begin{bmatrix} \text{F} = human(x) \\ \text{T} = \lambda e'[\mathcal{G}\mathbf{(e',x)}] \\ \text{A} = \lambda e[\mathcal{A}\mathbf{(e,x)}] \end{bmatrix} \end{bmatrix}$$

Consider how this composition is instantiated for the subject-induced coercion in (29b). Causative verbs such as *kill* denote transitions from one state to a resulting state, by virtue of a causing event. This can be represented as the lexical structure given in (34).

(34) $$\lambda y \lambda x \lambda e_2 \lambda e_1 \begin{bmatrix} \textbf{kill} \\ \text{AS} = \begin{bmatrix} \text{A1} = x : phys \\ \text{A2} = y : phys \end{bmatrix} \text{ES} = \begin{bmatrix} \text{E1} = e_1 : process \\ \text{E2} = e_2 : state \end{bmatrix} \\ \text{QS} = \begin{bmatrix} \text{F} = dead(e_2, y) \\ \text{A} = kill\_act(e, x, y) \end{bmatrix} \end{bmatrix}$$

Co-composition of the subject with the VP results in an agentive predicate replacing the underspecified predicate (i.e., $kill\_act$) in the VP's agentive Qualia Structure. The resulting interpretation is shown in (35).

(35) $\exists x, y, e_1, e_2[rioter(e_1, x) \wedge \mathcal{A}(e_1, x, y) \wedge police(y) \wedge dead(e_2, y) \wedge e_1 \leq e_2]$

In fact, most cases of subject-induced coercion can be characterized in the manner defined above, as ampliative readings resulting from co-composition (cf. Pustejovsky, 2011 for further discussion).

Another interesting case of co-composition can be seen in certain light verb constructions (Rosen, 1997, Goldberg, 1995, Butt, 1997, Mohanan, 1997), where much of the semantic content of the predicate is contributed by the complement meaning. Of particular interest to the current discussion are *functionally dependent verb* readings (Pustejovsky, 1995). These involve a range of verb classes, characterized by the verb's dependence on the specific *function* of the complement selected. Included in this class are the verbs *open*, *close*, *break*, and *fix*. The problem for compositionality for light verb constructions in general, and this class in particular, is the recurring issue of sense specificity. That is, can the different uses of *open*, for example, in (36) , be captured with one verb meaning or are multiple senses required?

(36) a. Mary opened the letter from her mother.
b. The rangers opened the trail for the season.
c. John opened the door for the guests.
d. Mary opened up the application.
e. She then opened a window and started writing.

Viewed as a co-compositional operation, in each case above, the sense of the verb *open* has been enriched through the context of the meaning associated with a specific object type. As with subject-induced coercions, the resulting VP meaning is ampliative relative to the function application of the verb over its object. This additional inference is derived from the complement itself. Briefly, we can view the verb *open* as bringing about a change of state, one which *enables* the activities associated with the complement's TELIC role. These are spelled out, somewhat informally in the glosses for each of the cases in (36) below.

(37) a. The letter can now be *read*.
b. The trail can now be *walked on*.
c. The door can be *walked through*.
d. The application is *running*.
e. The window is *ready for typing*.

1 Future Directions

In this entry we have defined the general characteristics associated with co-compositional analyses of a modest range of linguistic phenomena. It is obvious that there is much still to study with the behavior of co-compositionality in language. For example, there are clearly *degrees* of co-compositionality in the cases we have reviewed, and even more with cases we have not presented here. Current research on these areas focus on broadening the definition of co-composition to include both finer degrees of sense modulation (cf. Pustejovsky and Rumshisky, 2009, Pustejovsky and Jezek, 2008), and deeper sense extensions to metaphorical shifts of meaning (cf. Pustejovsky and Rumshisky, 2010).

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