Some Remarks on Event Structure, Conceptual Spaces and the Semantics of Verbs

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1. Introduction

The target paper by Massimo Warglien, Peter Gärdenfors and Matthijs Westera (henceforward, WGW) sketches a promising approach to what is perhaps the greatest *lacuna* in linguistic semantics. On the one hand, the Frege/Montague research program, based on the idea that truth-conditions are the core ingredient of clause meaning and that meanings of complex expressions are computed from the meanings of the parts, has been extremely successful. On the other, it did not really address the central question: What, precisely, are the meanings of the smallest parts, the meanings of words, or rather, lexemes?

Classical model-theoretic semantics did not have a real answer. All that it could do was to postulate certain relations between meanings of lexemes (originating with Montague's meaning postulate rendering of Quine's analysis of *seek* as semantically equivalent to *try to find*). Dowty (1979) turned the symbolic representation of word meanings in Generative Semantics into model-theoretic analyses. In this approach, the meaning of e.g. *kill* was broken down into the components of CAUSE, BECOME, NOT and ALIVE, each of which would have their own model-theoretic interpretation. However, while a serious attempt was made for the analysis of the few meanings that had a "logical" flavor, like the first three components, meanings of components like ALIVE were not analyzed further. The rich empirical work on lexical semantics within Cognitive Linguistics mostly developed alongside compositional semantics, as the methods it employed were often not compatible with theories interested in the composition of meanings, and the two research traditions took little notice of each other.

The target article by WGW argues for a semantics based on the notions of vectors in property spaces, where the notion of vector is the classical one, an entity with a direction, a sense, and a magnitude. It makes the point that verb meanings are convex sets of such vectors. In this, verb meanings are more complex than adjectives, which denote regions in simple conceptual spaces, and nouns, which denote bundles of such regions. But ultimately, the meaning of verbs are similar to those of the other parts of speech, as they all denote convex regions in conceptual spaces.

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The notion of vector has been applied before, in particular by Zwarts (1997) for the semantics of spatial prepositional phrases. WGW extend the use of vectors beyond this domain. In their semantic analysis, verbs typically involve two counteracting vectors, which is reminiscent of the force dynamic account of Talmy (2000). But while that account, just as the various accounts due to Jackendoff (e.g. Jackendoff 1997), is essentially symbolic, WGW strive for a semantic representation beyond yet another symbolic system. Their account in the target paper is still quite programmatic, which also applies to Gärdenfors & Warglien (2012); one would have liked to see exemplary, formal representations of verb meanings that also show how verb meanings are composed with arguments and adjuncts. However, the account is detailed enough to be able to see its potentials, and perhaps also some of its problems, quite clearly.

In the following, I will address the following issues; some of them relate to quite specific points, while others are more general. First, I will sketch a possible application of the vector semantics of WGW to the treatment of non-controlled vs. controlled states that can be expressed with verbs of posture like *to sit* and *to lie.* Second, I will argue that WGW's notion of vector should be extended to temporally situated vectors, in order to cover certain phenomena related to movement events. Third, I will address the issue of how the conceptual representations that WGW offer are related to reality. Then, I will turn to the case of *to climb*, also discussed in WGW in the context of the Single Domain Restriction, and argue for a slightly different representation within the vector semantics. In the conclusion I will mention a number of additional issues.

2. Non-Controlled and Controlled States

Among the different verb classes, statives are atypical insofar as they appear not to denote events at all. In WGW's theory, statives denote degenerate vectors, namely, identity vectors. This reflects that they do not denote a change of state, but simply express that a state holds. But WGW suggest that they still may need a force vector as a "balancing" force. However, they do not give examples for that.

It is unclear which role the force vector should play in states as described in cases like *John likes Mary, Mary has a car* and *Sue knows that it is raining.* But there is a class of statives where this notion can be fruitfully applied, namely, verbs of spatial configuration with the subclass of assumed posture verbs (Levin 1993). Unusual for statives, these verbs allow for progressive aspect in English (cf. Dowty 1979 for verbs of posture):

(1) a. *The blanket is lying on the bed.*
b. *Red flowers were dangling from the vines.*

There are a number of proposals for the unusual use of progressives with such statives. For example, Dowty (1979) assumed that the verbs like *sit, stand* and *lie* are true of intervals and not moments, in contrast to other statives. Kearns (1991) proposed that they denote states of limited duration. Bohnemeyer & Swift (2006, handout) have argued that this class of verbs can best be captured within Talmy's force dynamics (Talmy 2000): They involve a force, overtly expressed in the clause or just covertly implied, that counteracts against the gravitational force. Without this counteraction, the object would not remain in its state. For example:

(2) *I was sitting in a bar in the St. Louis airport*.

According to Bohnemeyer & Swift, *sitting* implies a counteracting object (like a bar stool) that expresses a counteracting force to the gravitational force on the subject, keeping it in a sitting position. Worked out properly, the WGW framework could express the meaning of such verbs in an appropriate way.

However, things might not be quite as simple. Cases with a conjoined subject consisting of an animate and an inanimate object are rather strange; cf. the following examples:

(3) a. *The blanket and the cushion were lying on the bed.*
b. *Mary and John were lying on the bed.*
c. ?*Mary and the blanket were lying on the bed.*

The last example generates a syllepsis effect – it suggests that Mary is inanimate, like the blanket. There is no obvious reason why this should be so, as coordinations of animate and inanimate noun phrases are possible otherwise – as e.g. in *John noticed Mary and the blanket.*

We can explain the oddity of (3)(c) by assuming that animates with verbs of posture do not express that the counteracting force originates from some object, like a bed or a bar stool, but rather from the animate subject itself. Hence, the semantic roles of the subject in *Mary was lying on the bed* and *The blanket was lying on the bed* are different: In the first case, Mary is an agent who has control over the state; in the second, the blanket is a patient, and the control over the state rather derives from the bed. Semantic roles are assigned to syntactic positions. Hence, if a syntactic position, like the subject, is expressed by a coordinate structure, the parts of the coordination must play the same semantic role. Postural verbs like *sit, stand* and *lie* can assign two distinct roles to their subject: Either an agent; in WGW's theory, this is the role from which the force vector emanates that is responsible for keeping the subject referent in its position. Or a patient; this is an object that undergoes both gravitational force and another counteracting force emanating by an object preventing movement along the gravitational force, and forcing the patient into a particular position. The oddness of (3)(c) arises under the additional assumption that animates tend to assume the agent role, if this is compatible with the semantic roles that can be assigned to a particular position. In the case at hand, the predicate *be lying on the bed* can assign an agent or a patient role to the subject (in the first case the counteracting force comes from the agent, in the second, from the bed); the animate coordinate *Mary* prefers the agent role, while the inanimate coordinate *the blanket* rules out that role.

Within the vector semantics of WGW, this amounts to the following. In *The blanket is lying on the bed*, there would be two vectors involved (cf. Bohnemeyer & Swift 2005): A gravity vector emanating from the blanket, and a counteracting vector emanating from the bed. In *Mary is lying on the bed*, there either would be an additional vector, a force vector emanating from Mary, or the gravity vector involving Mary would not be represented conceptually at all. In either case, the semantic role of the bed and of Mary would be different, as the associated vectors are different. In both cases, the vectors would cancel each other out, as postural verbs do not imply any change.

A similar case as with postural verbs can be made with the German verb *schwimmen*, which is ambiguous between 'to swim' (an activity verb) and the postural 'to float' (a stative verb, incorporating a counter force).

(4) ?*Peter und der Baumstamm schwimmen im Fluß.*
'Peter and the log are swimming/floating in the river'

The sentence with a coordinated subject is odd, for the same reason as discussed above: The animate subject *Peter* favors the activity reading 'swim', which is not an option for the inanimate subject *the log*. Contrary to regular postural verbs, *schwimmen*, as well as English *to float*, allow for change of positions, but only in the horizontal dimension, not in the dimension of the gravitational force. In the case of *to swim*, and in the corresponding reading of *schwimmen*, this horizontal movement is related to the force vector emanating from the agent.

3. Paths, vectors, or events?

Non-stative verbs express change of states. Such change of states have been captured with the notion of path in Cognitive Grammar (cf. e.g. Langacker 1987), but also in model-theoretic semantics (cf. e.g. Krifka 1998). This is most obvious with verbs representing movements in space, as in the following example:

(5) *Mary walked from the train station to the city hall*.

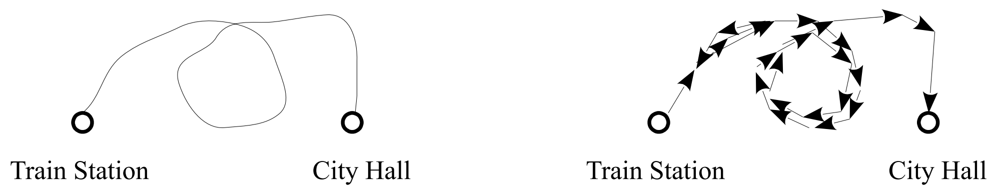
The notion of path can also be applied to verbs that do not obviously denote a movement, such as *paint.* Thus, *Mary painted the door green* can be understood as Mary causing the door to change from a current state in which it is not green to a state in which it is.

WGW propose to represent paths with the help of the notion of vectors, entities consisting of direction, sense, and magnitude. A change of state is a (non-zero) vector in a conceptual space, or rather a concatenation of such vectors. For example, the denotation of the verb *walk* will involve a change of states in space, as the walker changes its location while walking. Walking along a path then is represented as a concatenation of such changes of states. For example, (5) entails that Mary underwent a series of spatial changes that started at the train station and ended at the city hall.

This is a more complex notion of path than the notion of path as the local trace of an event, understood as the set of contiguous points or regions in space, or a mereological sum of such a set. In particular, the notion of vector adds a direction, and the concatenation of vectors inherits this direction from the concatenated vectors. Under the ordinary notion of path, the path from the train station to the city hall is identical to the path from the city hall to the train station. Under WGW's construction, these paths would differ in their direction. This corresponds to the notion of directed paths developed in Krifka (1998).

In Krifka (1998), I have also pointed out that there are phenomena that show that movements cannot be just reduced to directed paths. For example, the way Mary took may have included circles or back-and-forth movements, which I termed “Alcatraz” and “Echternach” movements. A representation that just considers paths as local traces of events, as in (6)(a), would not be able to describe such movements. A representation that reconstructs paths as a concatenation of vectors as in (6)(b) would not suffice either, as it would not specify how often a back-and-forth movement or a circular movement is repeated.

(6) Movement represented by
a. path as local trace b. path as sequence of vectors



Notice that we can observe back-and-forth movements not only with regular movement events in space, but also with other events – for example, the reading of a text might include re-readings of passages, or the warming of the atmosphere might include periods in which it is cooling down a bit.

In Krifka (1998) I proposed the richer notion of event structure to capture phenomena like back-and-forth movements and circular movements. In addition to local traces, or mappings to other quality dimensions, events also have temporal traces – they are mapped to their run time. Times in turn are ordered by a linear precedence relation, imposing a temporal order on events. The temporal order of events allows for a reconstruction of back-and-forth and circular movements, as the same path can be covered by different parts of an event that happen at different times.

The vector-based analysis of WGW could be enriched by a reference to times, to handle such phenomena. For example, one could add a time coordinate to the beginning of a vector, and a (later) time coordinate to its end. To compare the two notions, observe first that WGW’s located vectors are represented as pairs $\langle s_0, s_1\rangle$, where s_0 is the starting point, and s_1 is the end point (the magnitude then can be derived as the distance from s_0 to s_1). Adding start times and end times, we would have quadruples $\langle s_0, t_0, s_1, t_1\rangle$, where s_0 and t_0 are the space and time coordinate of the starting point, and s_1, t_1 are the space and time coordinate of the end point. The time coordinates would be part of all vectors; the space coordinates would depend on the specific conceptual space of the verb in question (e.g., with *to walk*, it would be regular space, with *to warm*, it would be temperature space, etc.)

The representation of spatial/temporal vectors by quadruples is overly expressive, as the time of the end point t_1 can never precede the time of the start point, t_0. There are two ways to proceed here. First, we can assume that the direction of the vector is imposed by the flow of time, established independently by the temporal precedence relation $\leq$ for time points. This allows for a simpler representation of spatially and temporally located vectors, as a set of two pairs: $\{\langle s_0, t_0\rangle, \langle s_1, t_1\rangle\}$, where $t_0 \leq t_1$. This representation admits for two kinds of "degenerate" cases: First, maintaining of states, as in $\{\langle s_0, t_0\rangle, \langle s_0, t_1\rangle\}$, where the spatial component of the vector is zero. Second, simple states, as in $\{\langle s_0, t_0\rangle, \langle s_0, t_0\rangle\}$, which is equal to $\{\langle s_0, t_0\rangle\}$, where both vector components are zero. Cases like $\{\langle s_0, t_0\rangle, \langle s_1, t_0\rangle\}$, however, should be ruled out as a matter of principle, as they would impose conflicting properties to an object. The other way to proceed is to take spatial/temporal vectors $\langle s_0, t_0, s_1, t_1\rangle$ as basic, and derive from that the flow of time. That is, we have $t < t'$ iff there is a vector $\langle s, t, s', t'\rangle$ – i.e., iff there is a development of an object from s to s', where $s \neq s'$.

Returning to the representation of spatial/temporal vectors by quadruples, we observe that the notion of vector used by WGW can be derived as an equivalence class of such quadruples. The vector $\langle s_0, s_1\rangle$ can be represented by the set $\{\langle s_0, t, s_1, t'\rangle \mid t \leq t'\}$. The notion of vector concatenation can be represented in a particularly easy way in the set representation: It is the union of two vectors such that one vector's end point is identical to the other's starting point, e.g. $\{\langle s_0, t_0\rangle, \langle s_1, t_1\rangle\}$ and $\{\langle s_1, t_1\rangle, \langle s_2, t_2\rangle\}$ concatenate to $\{\langle s_0, t_0\rangle, \langle s_1, t_1\rangle, \langle s_2, t_2\rangle\}$. This procedure can be applied recursively.

The reader might wonder whether we indeed need to represent back-and-forth movements and circular movements in semantics. We do, as they are important for certain interpretations of measure phrases. For example, both (7)(a) and (b) may be considered true, as simple length measure phrases may refer to paths as local traces, whereas measure phrases headed by the proposition *for* measure the spatial extent of the event itself.

(7) a. *Mary walked three kilometers.*
b. *Mary walked for six kilometers*

Here, the prominent reading of (7)(a) can be represented by assuming that *three kilometers* has a kind of object status with the semantic role of extent. All that is required is that each part of the path object is covered by a part of the event; the path object is specified as *three kilometers.* In (7)(b), there is no path object. Rather, the measure phrase *six kilometers* is applied directly to the event, including its back-and-forth and circular movement. We find such event-related measure phrases in other circumstances as well. For example, in Krifka (1990) I argued that in one reading of (8), the subject *4000 ships* serves as a measure for the event of ship passings.

(8) *4000 ships passed through the lock last year.*

In this section, I have pointed out that we actually need a more complex representation than the vectors that WGW propose, to cover certain semantic phenomena. We need vectors that are not only located in space but also situated in time. Should we then, perhaps, turn to event structures, as proposed in Krifka (1998)? I think that temporally situated vectors may actually have advantages for the representation of events. In the philosophical literature on the individuation of events, problems have been discussed like the ball that is rotating and at the same time warming up (Davidson 1980). This shows that events cannot be reduced to space-time regions, as the rotation and the warming happen in the same space-time region. However, we can represent these two events by two distinct vectors that have share their beginning times and end times, where one represents a movement in temperature space, and the other one a movement in real space (in fact, a circular movement of the parts). Thus, the notion of temporally situated vectors may lead to a satisfying reconstruction of the notion of event.

4. How fine-grained?

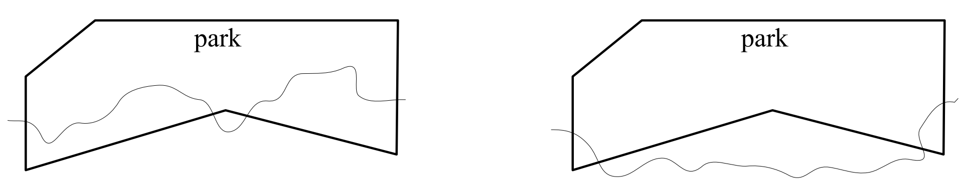
WGW allude to the possibility of more or less fine-grained representations of verb denotations. For example, they state that while representing a path by all its points is a cognitively expensive operation, a representation by a chaining of vectors is much simpler. This is shown by (6)(b) above, where a sequence of discrete change of states approximates a continuous change in space.

Here, the question arises how coarse-grained or how fine-grained the representation can or should be. WGW discuss the example of *crossing the park*, for which they suggest that this expression denotes a set of vector chains that start at one end of the park and ends at another, and which is located completely inside the region denoted by *the park*. They also suggest that a minimal, "prototypical" representation might be a chaining of two vectors, where the point of chaining lies inside the park.

This raises a number of interesting issues. The most fundamental one concerns the relation between the conceptual entities and reality. In some strands of formal semantics, such as in the work of David Lewis, this issue does not arise because meanings are directly related to reality (specifically, to possible worlds). The problems of this realistic view have been discussed, early on – cf. e.g. Partee (1980), who argues that a "psychological" interpretation is needed in order to deal with the semantics of propositional attitude verbs. For WGW, denotations do not directly concern reality, but rather conceptual representations thereof. The issue then is, how are conceptual representations related to reality? Clearly, conceptual representations will be a simplified and perhaps distorted version of reality – but how simple can they be, and which kinds of distortions are tenable?

For example, assume that the park has the shape in (9)(a), and that John's path is described by the indicated line. John's walk can be described as *crossing the park*, or *walking through the park*, even though John's path is not totally within the park. John's walk through the park can be approximated by a vector, or a sequence of vectors, that is totally within the park, neglecting the short excursion outside the park. But then the question arises why this cannot be done in the case of (b).

(9) a. Crossing / walking through the park b. Crossing the park?



A related issue is, how fine-grained a conceptual representation by vectors should be. For example, is it possible to represent the walk from the train station to the city hall in (6) by a single vector? It seems that this partly depends on the general purpose of conversation, but also on the type of expressions involved. For measure expressions, there are two extreme representations: One, the simplest representation by a single vector, which may be inherent in verbs like *advance*; if the straight line from the train station to the city hall is two kilometers, Mary's walk can be described by (10).

(10) *Mary advanced two kilometers, from the train station to the city hall.*

The other extreme is a representation that cannot substantially be refined anymore. As argued for with the examples in (7), this can either refer to the path or to the actual walking event. In the latter case, this is the distance that a pedometer would measure. If we represent Mary's movements by vectors representing a step at a time, then further refinements would not yield a different measurements, i.e. a fixed point is reached.

An additional factor in the determination of such fixed points in the conceptual representation is the scale of the measure expression itself. The examples in (7) suggest scales in which only whole kilometers are represented. So, if Mary actually walked just 5893 meters, (7)(b) will still count as a true statement, for most purposes. I have shown in Krifka (2009) how the roundedness of numbers affects how fine-grained reality has to be represented in conceptual structures.

5. The Single Domain Restriction: The case of *climb*

WGW capture the single semantic role constraint of Kiparsky (1997) by claiming that verbs can denote a convex region of vectors that depend on only a single semantic domain. For example, as Levin & Rappaport-Hovav (2010) stress, verbs can either express the manner of an action, like *wipe*, or the result, like *clean*, but not both. Together with the assumption that events combine two vectors, it follows that one domain remains unexpressed, even though it is assumed in the cognitive representation. For example, on hearing *John cleaned the table*, one can ask: *How did he do it – with a brush?*, and on hearing *John wiped the table*, one can ask: *What happened to the table – did it become clean?*

Since Jackendoff (1985), this principle has been discussed with the example *climb*, which appears to require a disjunctive characterization: Either it denotes a movement along an upward-directed path, as in (11)(a), or a clambering manner of motion, the latter being necessary for cases involving downward movement, as in (11) (b).

(11) a. *John climbed the mountain.*
b. *John climbed down the mountain.*

Geuder & Weisgerber (2008) propose that what is essential for the meaning of *climb* is that it involves force exertion against gravity. This also allows for transversal movement as in the following example:

(12) *John climbed across a rope ladder*.

WGW appear to take up this suggestion, which fits well into their force-dynamic theory. Here, I would like to add one qualification. WGW appear to assume that the upward direction of the force vector wins out, if not specified otherwise; hence (11)(a) refers to an upward movement only. But there is evidence to assume that this is just a default interpretation of the force vector in general, which can be overruled by any kind of contextual information. This shows up, for example, in (13)(a), which invites the inference that the wagon moved, if this is not cancelled by contextual information, as in (b) and (c). This pattern is characteristic for R-based implicatures in the sense of Horn (1984), or I-Implicatures in the sense of Levinson (2000), that allow to infer that the prototypical case holds in case no contradictory information is given.

(13) a. *John pushed the wagon.*
b. *John pushed the wagon, but it didn't move.*
c. *John pushed the wagon, but he couldn't stop it.*

In a similar way, movement associated with *climb* is typically upwards because the agent force is stronger than the opposing gravity force by default. This information can be cancelled explicitly by indicating the resulting vector by a prepositional phrase, as in (12)(b), but also by the nature of the object and the inferred position, as in the following example (from a file with hints of how to play a computer game):

(14) STAGE 6: Retrace your steps left and go back down the ladder, right a bit, then down. [...] Run right and use the yellow key to enter the well.
STAGE 7: Climb the well to reach a position just right of the starting position.

Clearly, *climb the well* means, in the given context, 'climb down the well'. Rappaport-Hovav & Levin (2008) provide other examples of this type.

If we assume that upward movement is a default inference following from a prototype that the force vector is greater than competing factors, we do not need a disjunctive specification for cases like *climb* (and neither for cases like *push*). There is, in fact, evidence against a disjunctive specification. If the meaning of *climb* indeed would contain a disjunctive component, this would amount to the claim that *climb* is ambiguous. But it does not satisfy the usual ambiguity test, just as in other cases in which the force vector does not win out against opposing vectors. For example, the gapping structures in (15)(a), (b) do not seem to trigger any syllepsis or zeugma effect, in contrast to (16), where two different senses of *get* are involved ('receive something' and 'acquire a property').

(15) a. *Mary climbed the roof and John the well.*
b. *Mary pushed the cart and John the wagon, but the wagon didn't move.*

(16) $^{?}$*Mary got a present and John a headache.*

Incidentally, the compatibility of *climb* with downward movement appears to be a relatively recent phenomenon. A search for "climb down" with Google books, cf. http://googlebooks.byu.edu/x.asp, which covers a substantial proportion of all published texts in English, reveals that the frequency of this collocation in English books rose sharply, more than tenfold, from < 0.02 per million before 1850 to > 0.2 per million after 1910, whereas the frequency of "climb up" rose only slightly from about 0,6 per million to about 1 per million in the same time. This is consistent with a view that *climb* used to specify upward movement before 1850, a meaning component that dropped out after 1900. According to the hypothesis proposed here, it would also be consistent with a more general change in language use, namely that the prototypical view of force vectors as overriding opposing vectors was stricter before 1850 than after – itself an interesting hypothesis that, unfortunately, would be hard to prove or disprove.

Let us come back to the single domain restriction. So far we have seen that the meaning of *climb* involves a movement that can be described by a vector that results from a gravity vector and an opposing force vector, where typically the force vector wins out. This fits into the single domain restriction, as conceived by WGW. The single domain restriction also predicts that *climb* cannot specify an additional manner component, as the manner is already specified by the opposing gravitational field. In particular, it follows from the single domain restriction that *climb* cannot specify that the movement involves any clambering, understood as a movement involving some labor, typically involving the hands as well. It is true that movement in a gravity field, as described by *climb*, often involves more labor, and hence cases of climbing are more likely to involve clambering, but this is not a part of the lexical meaning of *climb*. For example, we cannot use *climb* for a careful movement on all four limbs on a flat, slimy surface.

So, it seems that the problematic case of *climb*, on closer inspection, satisfies the single semantic domain restriction. However, there is the case of German *klettern* vs. *steigen*, which Geuder & Weisgerber (2001) argue to potentially differ according to a manner component. Both express movement in a gravitational field, just as *climb*. In addition, *klettern* expresses a higher effort; for example, for humans it may involve the use of hands and feet. In contrast, *steigen* requires less effort; for example, for humans it is used for walking, just involving the feet. There might be ways to save the single semantic domain restriction by claiming that the agent force is different in both cases, e.g. stronger in the case of *klettern*, weaker in the case of *steigen*. But certainly, further research is needed to find out whether this leads to a plausible explanation of this semantic contrast.

6. Conclusion

Above, I have tried to show that WGW's vector semantics for verbs is a promising approach that can be extended to a number of interesting applications. One could easily add more of such applications. For example, in Krifka (1999) I had argued that verbs like *pull* imply a continuous imparting of force, in contrast to verbs like *throw*, resulting in different preferred patterns for the dative alternation. It is easy to see how this can be phrased within a semantics involving vector addition: In the case of continuous imparting of force, a concatenation of force vectors must be applied to describe the resulting movement.

I have also argued that the vector semantics of WGW is not sufficiently expressive, as it does not consider the temporal dimension, and I have shown how reference to times could be added.

In the introduction, I pointed out that providing the successful program of compositional semantics with a promising way to specify lexical meanings is one of the most important tasks within the field of linguistic semantics. I think that WGW propose a promising framework in which this could be done. However, I should also point out that there article does not address the issue how the (informally specified) vector semantics for verbs actually would relate to compositional semantics, not even by way of examples. This remains an important task for the future.

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