DE GRUYTER MOUTON
DOI 10.1515/tl-2012-0016 — Theoretical Linguistics 2012; 38(3-4): 249–264

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Replies to comments

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1 The general project

Conceptual spaces have been developed as a general framework for representing knowledge, including semantics. Already in Gärdenfors (2000, Ch. 5), a semantic analysis of nouns and adjectives was proposed. The theory of conceptual spaces has since then been extended to cover also actions (Gärdenfors 2007) and events (Gärdenfors and Warglien 2012). The main purpose of our article is to show how these models can form a basis for the semantics of verbs.

We are grateful to the commentators for their willingness to evaluate and critically discuss our proposal. The general project is positively received by the commentators. We find this encouraging for future work in the area. There are understandably also critical comments about the project. Some of them argue that we promise much more than we deliver. Some comments point out that our model is a tentative sketch that may not stand up to linguistic scrutiny. We agree that much of the analysis is presented too briefly in the article. We have focused on presenting the potential of the model in different areas of verb semantics rather than developing the details. Further aspects of action and event representations have been presented by Gärdenfors (2007), Gärdenfors and Warglien (2012) as well as a general semantics framework in Warglien and Gärdenfors (2012). That said, we agree that there is still a lot to accomplish to flesh out the model into a viable theory of semantics.

Let us comment on the motivation for our paper. Our aim is to show that concepts from cognitive science, in particular conceptual spaces, can be used to model lexical semantics, in particular the semantics of verbs. As such, it is an attempt to establish a bridge between cognitive science and linguistics. Our emphasis is on presenting the general model and testing its viability. This entails that we

do not go into the details of the semantics of single words, as would be a common strategy for linguists. Of course, we know that this does not exempt the model from rigorous testing against linguistic data. In this way, the paper is a call for cooperation between linguists and cognitive scientists.

2 The event model

2.1 Comparison with Wolff's model

In his studies of causal reasoning, Wolff has developed an account of events that he calls the dynamics model. Just as in our two-vector model, he focuses on the role of forces. What he calls position vector is what we call (motion) result vector. He takes his inspiration from Talmy's (1988) force dynamics, where the situations investigated involve an interaction between the forces exerted by the Agonist (agent) and the Antagonist (patient) and the result of the interaction. Consequently, in contrast to our model, Wolff always considers counterforces. The models have been developed for slightly different purposes: ours is intended as a general model of events while Wolff focuses on causal reasoning. Wolff claims that the dynamics model offers a more detailed account of causation verbs. We agree, but see no conflict with our model. It should be noted that Talmy's analysis, just like Wolff's model, only covers events involving causal concepts and associated with causation, enablement and prevention. Their models are thus less general than the two-vector model we propose.

Wolff writes that the two-vector model of verb semantics cannot fully capture the force dynamic representations in Talmy (1988). That is as it should be: Talmy's examples concern the meaning of full sentences, not just single verbs. However, our model of events, which admits simultaneously patients and agent, forces, counterforces and results, can handle Talmy's examples (even though we have not carried out the details of the analysis). The semantics of verbs is only related to the force or the result vector type, while the event model requires both, together with at least a patient space.

Wolff notes correctly that representations at the level of word meaning are much coarser than those at the level of non-linguistic cognition. He mentions evidence from perception studies and psychophysics that supports this position. Cognitive models involve more vectors and participants than the construals used for generating linguistic expressions. Wolff concludes that people's mental models are richer than what is implied by our two-vector model. We agree, but do not see this as a problem. The two-vector model is presented as

a minimal mental model of an event describing the lexical meaning of a verb, not the entire cognitive construal of an event. We allow further vectors and participants to be added to representations of events and the construals generated from them.

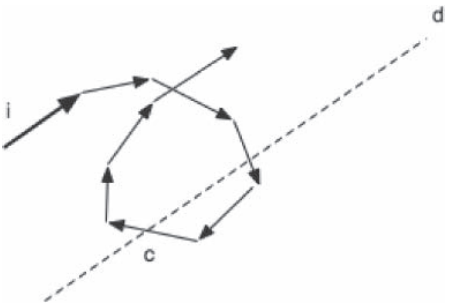
2.2 Paths and vectors

Some comments ask us to elaborate more on the relationship between vectors and paths. Krifka writes about different levels of complexity of paths (in physical space or in some property domain) and suggests that temporally situating vectors might considerably enrich the semantics of our model, in particular to cover certain phenomena related to movement events. The key implication of his comments is that vectors do not carry enough information to capture the temporal aspects of events.

We don't deny the role of time in characterizing many events, but instead suggest that temporal aspects can be derived more economically from the order of composition of vectors (a point already made by many philosophers, from Reichenbach onwards, and echoed indeed by Krifka himself in his comment as an alternative to explicit time indexing).

In the case of movement events, because a (directed) path through space can be represented by a chaining of displacement vectors, and vectors are chained by taking the head of the preceding vector as the tail of the following one, the ordered series of compositions (the "snapshots" of movement) provides a basic representation from which to derive temporal succession. Of course, the grain of event representations (the length of elementary displacement vectors) will determine the extent to which more or less subtle features of the path can be captured. Krifka points to the interesting example of paths with back and forth movement. While of course an explicit temporal indexing of vectors would provide a direct way to represent back and forth motion, other non-temporal representations can do the job. For example, one might capture "back and forth" motion in terms of whether (and how many times) vectors in a path cross the direction of the initial vector.[1] Two crossings will capture one back and forth loop, four crossings will capture two such loops, etc. Similarly, you can count how many times you have been running in a circle without an explicit representation of time (see Kracht & Klein's comments).

1 The approach is reminiscent of the use of "winding numbers" in topology (Poincaré), The original topological treatment of the winding number of a path relates only to closed paths and the associated vector fields (Henle 1979).

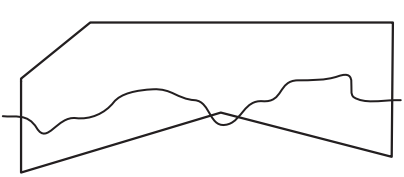


The vector c crosses the direction d of the initial vector i.

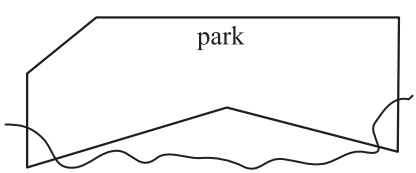
Thus, while we do not deny the usefulness and intuitiveness of a temporal notation, the "crossing vectors" approach provides a simple example of a way to account for back and forth motion or circular motion without introducing time.

Krifka is right in that these complexities are important for some linguistic distinctions and that we do not explicitly consider the complexities. It should be recalled, however, that our model of events is cognitive, so a mental construal of an event may occur at different levels of granularity. When Mary walks in a crooked way from the train station to the city hall, she can be described as walking three kilometres in a course construal of the event where only the start and end point of the path are considered. On the other hand, at a finer level of construal of the same event where the different segments of the path are represented as combined movement vectors, she can be said to have walked for six kilometres.

Issues of the grain of event representations surface also in Krifka's discussion of the *crossing the park* example. Why should the path in his 9a example be accepted as a *crossing the park* event (despite violating the topological constraint that the path should be within the boundaries of the park) while the example in 9b should not?



9a



9b

In order to deal with such a question, one should recall that in our semantic framework an expression like "crossing the park" represents a *category* of events. Whether a concrete example (like 9a or 9b) can be accepted as belonging to such a category will depend on the similarity to the prototype of the category. One might argue that when modest differences in the coarseness of the representation eliminate the violation of the topological constraints (as in 9a), the "amount" of the violation will be small and thus the example will be accepted as belonging to the *crossing the park* category, although with a modest degree of typicality. Thus, where Krifka sees a problematic relationship between reality and mental representation, we see instead a classical issue of categorization.

Still reality may matter in determining what is an acceptable grain of representation. For example, if a traveller's path through China passes Hong Kong, it could generally be accepted as an example of a crossing of China, but if the traveller has a single entry visa, visiting Hong Kong is considered as going out of China.

A similar point is made by Kracht & Klein, who also complain that our model of events is not fine-grained enough. They write that we reduce continuous change to summary change, which allows us to reduce the representation of an event to a pair of vectors. Again, we believe that by considering different levels of granularity in the event construals, our model can accommodate their points in a systematic manner. We agree that it remains to be done.

Kracht & Klein also argue that for some types of movement verbs, such as *turning*, a single vector is not sufficient to describe the change component of the event. This gives us an opportunity to clarify an ambiguity in our paper. We expect verbs to be modelled by a single *type* of vector, namely force or result, in a given domain. Of course many trajectories or paths cannot be reduced to a linear vector, but can be approximated by a sequence of result vectors of the same type. In the case of *turning*, the angular momentum can be derived (as a derivative) from the trajectory. Our use of the term result vector is a shorthand notation for result type of vector, including both single vectors and path composition of same type of vector. We realize that our paper is not clear on this point. Thus just as the force vector should in general be seen as a force pattern, the result vector should in general be seen as a chaining of vectors.

Wolff suggests that our result vectors are of a different kind than force and position vectors. He asks what the length of a result vector implies. We connect a result vector to a particular domain, for example temperature or weight. The meaning of the length of a vector is dependent on the geometric structure of the domain. In the case of temperature, for example, the vector denotes the change of temperature. For example, *boil* (accomplishment) involves a vector that reaches the boiling temperature of a liquid. The length of the vector corresponds to the amount of change.

More generally, it should be stressed that our vectors do not occur in a vacuum, but are always construed in relation to a domain, and thus inherit all the structural domain information. For example, since the domain of temperature is one-dimensional the heating vector has only one direction and two possible verses (up and down), while in the three-dimensional domain of colour, multiple directions are possible. In our opinion, the grounding of vectors in conceptual spaces is an advantage of our model. Many of the comments seem to ignore that behind the vector is a wealth of information coming from the domains that add semantic content.

A parallel problem of representation complexity arises with our use of "force vectors" and "pattern of forces" to characterize manner. At the heart of the use of the concept of force is a simple idea. Using force vectors, we reframe the "naive" view that "within particular semantic domains there can be verbs that . . . describe carrying out activities – manners of doing" (Rappaport Hovav and Levin 2010). A force vector is thus our elementary building block in the representation of "carrying out activities".

Of course, in general, the characterization of an action requires more than a single force vector. It requires patterns of force vectors. For example, cycling involves a (near circular) pattern of forces exerted with a 180° phase difference between the two feet. Just as single result vectors can be chained in paths, so single force vectors can be composed in patterns of forces. What characterizes manner is not a single force vector, but again a single *type* of vector, either in isolation or composed in a pattern.

More broadly, Geuder speculates that events have a conceptual architecture that is similar to that of object concepts. He suggests that an event can be described as a multi-domain construction in a way similar to the construction of object categories. We find this idea extremely interesting and well worth developing. However, we will not attempt to present any such model here.

3 Comparison with Croft's theory

Croft asks whether our theory is identical with his. There are indeed many similarities. Both theories are based on vectorial representations of events that eschew logical or model-theoretic formalisms. However, there are also important differences between the theories. We will present here the differences a bit more explicitly than we do in the paper.

First we compare our analyses of *events*. Croft (2012, section 5.4.2) presents a "three-dimensional representation of causal and aspectual structure in events".

What he calls dimension does not quite match our use of the term. The first two dimensions are the time dimension combined with a dimension of "qualitative state". These two dimensions are used for his "phasal analysis of aspectual types" (Croft 2012, section 2.3.2). They are used to describe "subevents" that involve only one participant with its own aspectual contour (Croft 2012, p. 212). Croft treats all qualitative dimensions on a par and does not separate out the force domain as a special case. What he calls the dimension of qualitative state corresponds to what we call domains. In general we allow domains to be multi-dimensional and have a rich structure. As mentioned above, our vectors inherit a lot of information from the underlying domain structure. The q-dimensions in Croft's model leave open such structure.

Croft's third "dimension" is the causal chain linking the individual participant subevents. (Croft's writes that this "dimension" is actually a graph structure.) This roughly corresponds to our mapping between the force vector and the result vector. A difference is that Croft allows events to form causal chains involving several subevents. This is illustrated by his analysis of "Sue broke the coconut for Greg with a hammer" (see the figure on p. 214 in Croft (2012)). Here Sue applying force is a subevent that causes the subevent of the hammer impacting the coconut that in turn causes the subevent of the coconut breaking, which finally causes the subevent of Greg benefiting from the broken coconut.

This example brings out a fundamental difference in our analyses of what constitutes an event. For Croft, an event is a chain of causally linked subevents, each consisting of a participant with an aspectual contour. For us, an event consists minimally of three necessary components: a force vector (that may be nil), a patient that the force vector acts on, and a result vector (may be a zero vector, that is, a point) that describes the change of the properties of the patient. To this minimal representation of an event, we can add further participants (agent, instrument, beneficiary . . .) and vectors (the force vector exerted by the agent, goal vectors in intentional events . . .). Events can be chained by causal links, but we have no concept corresponding to "subevent". Croft complains that we do not represent force dynamic relations between participants. It is true that we do not exploit them as extensively as he does in his subevent analysis. However, the model can include dynamic relations between agent and patient and between agent, instrument and patient via the various force vectors.

A second difference between the theories is the treatment of *actions*. Croft presents no analysis of what constitutes an action, nor of the role of actions in events. Even though it is only sketchily presented in section 2.3 of our paper, our account contains a vector-based model of actions. It is presented in further

detail in Gärdenfors (2007) and Gärdenfors and Warglien (2012). This model is central to our analysis of events since an action is represented by the force vector (or more generally pattern of force vectors) of an event. Furthermore, following the analysis of properties in Gärdenfors (2000), we define an action category as a convex set of force vectors (this is elaborated in Gärdenfors and Warglien 2012).

In his commentary, Croft asks what is the difference between a force vector and a result vector. Our answer is that in our model of events, force vectors are those acting on patients. (It should be noted that forces can be mental/social and not just physical.) In Croft's model of subevents there is no difference in principle between qualitative dimensions involving forces and other dimensions. In contrast, our model contains a fundamental asymmetry. This is not a mathematical difference but a semantic difference in the "contents" of the force domain in contrast to other domains. One way to express this is that force vectors are used to represent causes, while result vectors represent effects.

A third difference is that Croft explicitly includes the *time* dimension in his two-dimensional schemas. In contrast, our basic model does not require a time dimension. Time is implicit in the dynamics created by the force vector. We do not, however, exclude a time dimension as a semantic factor as Croft claims in his commentary. On the contrary, we agree with Croft that for some verbs and adverbs, the time dimension is a necessary part of the semantic representation. We realize that we should have presented this point more clearly in the main article.

Next, Croft asks how the mathematical properties of vectors contribute to an understanding of the structure of events. We will here give three examples of the benefits of vector representations. First, vectors can be more or less *close* to one another. This corresponds to similarity of actions (via the closeness of the corresponding force vectors or force patterns) and similarity of results. We argue in section 4.2 that similarities of vectors provide a natural explanation for similarities of verb meanings. Second, vectors can be *added* and *multiplied*. The force vector acting on a patient can be added to a counterforce exerted by the patient. Wolff (2007, 2008) has shown that subjects' judgements of causality are dependent on such additions of forces and counterforces. Furthermore, in many cases a force vector is balanced by a counterforce resulting in a state (for example, *prevent*). We use multiplication of vectors in our analysis of the meaning of adverbs.

Third, sets of vectors can form *convex* sets. In particular, Gärdenfors and Warglien (2012) define an action category as a convex set of force vectors (force patterns). Since convexity has also been used in Gärdenfors (2000) to characterize properties and object categories it is natural to propose that action catego-

ries share a similar structure to object categories (Hemeren, 2008, p. 25). Indeed, there are strong reasons to believe that action categories exhibit many of the *prototype effects* that Rosch (1975) presented for object categories. In support of this, Hemeren (2008) has shown that action categories show a similar hierarchical structure and have similar typicality effects to object concepts.

In section 4.2 of our paper, we claim that the similarity of vectors and the convexity of vectors sets representing verbs can explain similarities of verb meanings, sub-categorizations of verbs and metaphorical uses of verbs. Admittedly, the arguments are presented in a sketchy manner and much work remains to spell it out in detail. Nevertheless, as far as we can see, these predictions do not follow from Croft's (2012) model (although they are compatible with it).

To sum up, Croft's theory and ours are presumably compatible, but there are substantial differences. In particular, Croft uses a "dimension" of qualitative state in his model. We enrich this by having a full conceptual space representation of action and result vectors, exploiting vector properties and convexity. This allows us, among other things, to explain similarities of verb meanings. On the other hand, Croft's model generates a more fine-grained analysis of aspect than our does. For example, as he mentions in his commentary, his model can distinguish three types of states.

4 The single domain constraint

Our single domain constraint is a new proposal within verb semantics. If valid, it will have far-reaching consequences. Therefore, it is important to evaluate it. Several of the commentators discuss it, in particular Kracht & Klein who question its validity.

4.1 Manner/result complementarity

Let us begin our replies by discussing the manner/result complementarity among verbs. Levin and Rappaport Hovav (Levin and Rappaport Hovav 1991, Rappaport Hovav and Levin 2010) formulate a strong version of the complementarity: the lexical meaning of any verb root is either manner or result. They derive this from their ACT-BECOME model of events together with the constraint that a verb root can only be associated with one primitive predicate in an event schema, as either an argument or a modifier. Since they assume that manner roots modify the predicate ACT and result roots are arguments of BECOME, the manner/result complementarity follows (Rappaport Hovav and Levin 2010, Section 2). Our distinction

between force and result vectors maps quite clearly onto their ACT and BECOME, but adds a grounding in conceptual spaces.

Their version claims that the manner/result complementarity is inherent in the lexical meaning of a verb root. This claim has been criticized (Goldberg 2010, Koontz-Garbooden and Beavers 2012). In particular, there are verbs that seemingly can be used to express both manner and result, for example verbs of killing (Koontz-Garbooden and Beavers, 2012) such as *drown*, *hang* and *crucify* and verbs of cooking (Goldberg 2010) such as *roast*, *fry* and *stew*. In our paper we agree that some of these verbs have a double use. One could therefore formulate a weaker version of the constraint manner/result complementarity:

Weak version of manner/result complementarity: Each occurrence of a verb in an utterance is either manner or result.

In this version, the manner/result complementarity is not supposed to be part of the lexical meaning of the verb, but is determined from the meaning of the utterance. However, we find this version far too weak. Therefore we propose to at least identify a basic manner or result use of a single verb, and propose the following modified version of Rappaport Hovav and Levin's (2010) constraint:

Intermediary version of manner/result complementarity: Each verb root has a default manner or result type of meaning, but the other type can also become lexicalized.

This version of the complementarity still claims that a manner or result component is the default meaning, but it allows that some verbs have a secondary meaning that can override the default in specific contexts.[2] The intermediary version is still compatible with the single domain constraint.

Two common mechanisms for meaning extension should be mentioned. The first is that a manner verb root such as *fry* is transformed in a metonymic way to the strongly expected result that the food becomes fried. The result meaning of the verb is then sometimes used unaccusatively: "The chicken fries." The second mechanism is that a result verb such as *drown* is transformed into a manner verb with the meaning "cause to drown" by reprofiling the event. We realize that to make this story complete, we need to present a test for which meaning of a verb is primary. Of course, which verbs have a second meaning lexical-

2 Rappaport Hovav and Levin (2010) make a distinction between what a verb lexicalizes and what can be inferred from a particular use of that verb in a context. According to them the criterion for lexicalized meaning is constancy of entailments across all uses. This still excludes that a verb is lexicalized as both manner and result. Our intermediary version preserves the idea that in any instance of use of a verb, it is either manner of result, but we do not exclude that both meanings are lexicalized.

ized is dependent on the history of a particular language and it varies between languages.

On the explanatory side, we strongly subscribe to Kracht & Klein's proposal that constraints on learnability explain both the general tendency of manner-result complementarity (or the single-domains constraint in general) and the exceptions to it. In particular, when the link between manner and result is reliable, there should be a strong tendency for either of the two mechanisms to apply, and for a verb to gain a secondary meaning.

Another explanatory consideration concerns verb modifiers as Geuder suggests. In particular, force vectors have dimensions which are not shared by patient spaces representing result. The magnitude of force is peculiar to the force domain only and therefore adverbs expressing such magnitude, for example *strongly*, should apply to manners verbs (push strongly, hit strongly), but not to result verbs (#move strongly, #fall strongly, #break strongly). This principle applies as well for manner verbs that are represented by a single force vector, for example contact verbs. In the situation of manner verbs that are represented by patterns of forces, however, the situation is less transparent. While force magnitude is peculiar to manner, direction clearly is not. So modifiers expressing direction are generally shared by force and result vectors, for example *ahead* and *left* (push ahead, move ahead).

In his commentary, Geuder complains that our force-result distinction does not correspond to the manner-result distinction that has been used in linguistics. He uses Rappaport Hovav and Levin's (2010) scalarity test to make the distinction and he claims that our division between force and result vectors does not correspond to the results of this test. In our paper, we give arguments for not accepting the scalarity test (it has been proven problematic by, among others, Goldberg 2010). For example *pull*, which is a manner verb, can exhibit scalar changes. Hence, we do not find Geuder's arguments against the force-result distinction valid. He also claims that durativity, which is part of the meaning of many manner verbs, cannot be modelled by forces. It is true that we do not present such a model, but we see no problem in adding a durativity component to the force vector of an event.

Krifka takes up our analysis of *climb* in his commentary. He agrees with our and Geuder and Weisgerber's (2008) diagnosis of the verb as determined by a force with an upward direction where the upward movement often is expected, but optional. We find his evidence that the compatibility of *climb* with downward movement is a relatively recent phenomenon very interesting. What is changing historically, in our opinion, is not the default meaning of climb as a force vector, but the result expectations associated with it. As regards the difference between German *klettern* and *steigen*, the primary meaning of *steigen*

may be a result vector (cf. *rise* in English) as in "Der Ballong steigt" ("The balloon is rising") and "Die Temperatur steigt" ("The temperature is rising"). This calls for further investigation.

4.2 Posture verbs

Krifka discusses posture verbs such as *sit, stand* and *lie* that are unusual stative verbs in that that they allow progressive aspect in English. (Incidentally, they express transitory states in Croft's (2012) terminology). His proposal is that verbs such as *sitting* and *lying* imply not only that the agent exerts a force on the object sat on or lain on, but also that the object exerts a balancing counterforce on the agent. The stative situation thus involves a dynamic balance. The analysis is elegant and it is an interesting application of our framework.

Krifka also notices that there is a difference in the meaning of the verbs between the following two cases:

a. Mary is lying on the bed.
b. The blanket is lying on the bed.

He suggests, correctly in our opinion, that the difference lies in (no pun intended) that Mary can control her state, while the blanket cannot. Krifka writes that the posture verbs can assign two types of roles to their subject – either as an agent or as patient. We almost agree. In our terminology, Mary is *both* agent and patient in (a), while the blanket is only patient in (b). The difference shows up as follows:

c. Mary laid the blanket down on the bed. (Mary agent, blanket patient)
d. Mary laid (herself) down on the bed. (Mary agent and patient)[3]
e. #The blanket laid (itself) down on the bed. (The blanket cannot be agent)

In the case of an animate agent/patient, *lying*, *sitting*, *standing* and other posture verbs involve an intentional component, that is, the agent is taking its posture on purpose. Krifka writes that the agent has control over situation. We see this as a special case of intentionality being part of many verb meanings.

3 In German and several other languages the reflexive is compulsory: "Mary legte *sich* auf das Bett".

Krifka suggests that a verb like *lie* is ambiguous between assigning an "active" force vector to the subject, that would be the result of her being a volitional agent, and assigning a "passive" vector to the subject, that is the result of gravity. Our model, however, does not distinguish different types of vectors (i.e., active vs. passive). Rather, to accommodate the intentional aspect of stative verbs with an animate subject, our basic model is extended by a goal space as described in Section 3.2. We would treat stative verbs that behave like *lie* as being semantically underspecified, having an optional goal space.

4.3 Causal verbs and verbs involving two events

In their commentary, Kracht & Klein present two types of examples that they claim will violate the single-domain constraint. The first is verbs of (mental) coercion (*persuade*, *force*, *compel*). Kracht and Klein claim that these verbs lexicalize both a manner and a result component. We partly agree, but we do not see these examples as counter-examples to the single domain constraint. The reason is that constructions with these verbs involve *another* verb. The form is "X persuades/forces/compels Y to V", where V is a verb. The coercion verb is a manner verb in an event generated by an agent X acting on a patient Y that combines with another verb describing another event where Y is agent.[4] The second event can be seen as a result of the coercion event, but this does not mean that the coercion verb lexicalizes a result component. This is the job of the second verb V. As a matter of fact, V can be almost any verb – manner or result. What makes the coercion verbs special is that the result of the force vector is not a result vector of the type we consider in our article, but rather a new event. In brief, coercion verbs have a more complicated meaning structure than the verbs we consider, but they do not invalidate the singe domain constraint.

The second class of verbs considered by Kracht & Klein are verbs involving establishment of conventional fact: *buy*, *inherit*, etc. They argue that the difference between *buy* and *inherit* is part of a manner component, while the verbs also involve the result component that a change of ownership takes place. We agree to this, but do not see it as a counterexample to the single domain case, since we propose that again two event construals are involved: the intended result and the manner of achieving the result.

In section 4.6 of our paper, we give a brief description of some such intentional verbs. Kracht & Klein acknowledge this, but they are not convinced by our

4 This is clear from the lexicon definition cited by Kracht & Klein.

arguments. They doubt that the intention of buying something is part of the lexical meaning of *buy*. It is true that in the modern world one can unintentionally buy something by clicking on a button or by waving one's hand at the wrong moment during an auction. Nevertheless, these unintentional actions are consequences of conventional routines for settling a transaction. In our opinion, the original meaning of buy involves an intention on the part of the agent, but the meaning of *buy* has later been extended to cover also "happen to buy".

In line with Kracht & Klein's first class of verbs, Wolff argues that verbs of causation – for example *cause*, *allow*, *enable*, *block* – cannot be single domain since they involve both force and result. However, his examples involve interactions between two force vectors (from the Agonist and the Antagonist), a case which is not covered by our model, but it does not really leave the single domain of forces.[5] These cases always require either another verb – "X prevents Y from infracting the law" – or a nominalization of a verb – "X allows an infraction of the law by Y". Again, the causation verbs involve more complicated situations than our basic model.

Furthermore, Wolff suggests that in order to express causation verbs one needs to specify the "tendency" of the Antagonist, which requires endpoints – once more a positional notation outside the force domain. However, the counterforce of the antagonist already points in such direction, which makes it sufficient to express the manner component of causal events.

Wolff objects that force vectors are not sufficient to distinguish between manner verbs like *push* and *pull*, because they imply a position vector for the agent. However, it should be recalled that vectors are associated with a domain space in which things can be located: a push or pull force vector is applied on a point in a domain space (typically, but not necessarily the physical space). It verse splits the space in two halves, one behind and the other in front of this point. The force expresses *pull* if the agent is located in the in-front half and *push* if it is located in the behind half. Once more, one should should not forget the rich information conveyed by the space in which vectors are construed.

5 Conclusion: May the force be with you!

The separation of forces from results is one of the central themes of our model. It is similar to Wolff's idea, but he only considers a class of verbs related to causa-

5 In our paper we suggest that adding counterforces is an extension of our prototypical model that does not violate its principal structure.

tion. Croft's theory is also similar to ours and as general, but he does not bring out the force domain as having a special status.

While many comments have been focusing on the separation of forces from results, our model should draw attention to the problem of how they interact and of their grounding in spatial concepts, that is, the structure of different domains. What we need is a better understanding of the mapping from force vector to result vector. This is a core problem for understanding causal thinking, but it will also help us better understand the semantics of verbs.

The single domain constraint for verbs has been under heavy fire. We have tried to defend it, but to determine its validity much more detailed work is required. However, we still think the single domain constraint is valuable because it could become, perhaps in a more precise formulation, a central part of an explanation why children can learn language so efficiently (cf. Bloom 2000). It also reminds us that forces and results are rooted in the underlying domain structure that contains key semantic information.

We are grateful to the commentators who have directed us to areas where we need to develop the model further. As we have tried to explain in these replies, we believe that this can still be done within the general framework of our event model.

References

Bloom, P. (2000). *How Children Learn the Meaning of Words*, Cambridge, MA: MIT Press.

Croft, W. (2012). *Verbs: Aspect and Causal Structure*, Oxford: Oxford University Press.

Gärdenfors, P. (2000). *Conceptual Spaces: The Geometry of Thought*. Cambridge, MA: MIT Press.

Gärdenfors, P. (2007). Representing actions and functional properties in conceptual spaces. In: Ziemke, Tom, Jordan Zlatev & Rosalyn M. Frank, (eds.). *Body, Language and Mind, Volume 1: Embodiment* (pp. 167–195). Berlin, Leipzig: Mouton de Gruyter.

Gärdenfors, Peter and Warglien, Massimo (2012). Using conceptual spaces to model actions and events. To appear in *Journal of Semantics*.

Geuder, Wilhelm and Weisgerber, Matthias (2008). Manner of movement and the conceptualisation of force. Slides via: http://semanticsarchive.net.

Goldberg, Adele (2010). Verbs, construction and semantic frames. In: Rappaport Hovav, Malka, Edit Doron & Ivy Sichel (eds.), *Syntax, Lexical Semantics and Event Structure* (pp. 39–58). Oxford: Oxford University Press.

Hemeren, Paul (2008). *Mind in Action*, Lund: Lund University Cognitive Studies 140.

Henle, Michael (1979). *A Combinatorial Introduction to Topology*, San Francisco, CA. W. H. Freeman.

Koontz-Garbooden, Andrew and Beavers, John (2012). Manner and result in the roots of verbal meaning. "Linguistic Inquiry, Volume 43:3, pp. 331–369."

Levin, Beth and Rappaport Hovav, Malka (1991). Wiping the slate clean: A lexical semantics exploration. *Cognition,* 41, pp. 123–51.

Rappaport Hovav, Malka and Levin, Beth (2010). Reflections on manner/result complementarity. In: Rappaport Hovav, Malka, Edit Doron & Ivy Sichel (eds.), *Lexical semantics, Syntax, and Event Structure* (pp. 21–38). Oxford: Oxford University Press.

Rosch, Eleanor (1975). Cognitive representations of semantic categories, *Journal of Experimental Psychology: General,* 104, 192–233.

Talmy, Leon (1988). Force dynamics in language and cognition. *Cognitive Science*, 12, pp. 49–100.

Warglien, Massimo and Gärdenfors, Peter (2012). Semantics, conceptual spaces, and the meeting of minds. To appear in *Synthese* (DOI 10.1007/s11229-011-9963-z).

Wolff, Philip (2007). Representing causation. *Journal of Experimental Psychology: General*, 136, pp. 82–111.

Wolff, Philip (2008). Dynamics and the perception of causal events. In Shipley, Thomas and Zacks, Jefrey (eds.), *Understanding events: How humans see, represent, and act on events* (pp. 555–587). Oxford: Oxford University Press.