8 Forceful prepositions[1]

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Introduction

As the title suggests, the focus of this paper is on prepositions with a force-dynamic aspect, as in the following example sentence:

(1) Alex ran into a tree

This sentence does not mean that Alex ended up inside a tree, but that she came forcefully into contact with the tree. There is a spatial component in this sentence (Alex followed a path that ended where the tree was), but there is also a force-dynamic component (the tree blocked her movement).

This use of *into* brings together two conceptual domains that are fundamental in the semantics of natural language: the spatial domain and the force-dynamic domain, each of which comes with its own intricate system of concepts and relations. The spatial domain is primarily concerned with location, movement and direction, the force-dynamic domain with causation, control and interaction. The basic thematic roles of the spatial domain are Figure and Ground (Talmy 1983), Theme, Goal, and Source (Gruber 1976), and Trajector and Landmark (Langacker 1987), while the force-dynamic domain has Agent and Patient (Jackendoff 1987, Dowty 1991) or Agonist and Antagonist (Talmy 1985).

The interaction of these two domains in the verbal domain has been relatively well-studied (for example in Jackendoff 1987, Croft 1991, to appear, and others), but this is different with the prepositions, that seem to be the spatial words *par excellence*. However, there is a growing awareness in the study of prepositions and spatial language that force-dynamic notions do play an important role (Vandeloise 1991, Bowerman and Choi 2001, Coventry and Garrod 2004, Carlson and Van der Zee 2005). It is becoming clear that geometric notions alone do not suffice to capture the meaning of even very basic prepositions like *in* and *on*, let alone an obviously force-dynamic preposition like *against*. However, what is not yet clear is how the role of force-dynamics can be transparently and adequately modeled in representations of the meaning of prepositions. This paper makes some specific proposals about how to do this.

In section 1 I will single out a few important phenomena that concern prepositions, most of which are well-known from the literature, that require reference to forces in one way or another. I will then argue in section 2 that the general semantic mechanics that underlies reference to forces can best be captured in terms of *vectors* (O'Keefe 1996, Zwarts 1997, Zwarts and Winter 2000). These force vectors will allow an interface between the force-dynamic part and the geometric part of the semantics of prepositions along lines worked out in section 3. In a concluding section 4 I will sketch the potentials of the model in understanding cross-linguistic variation in the domain of containment and support.

Forced beyond geometry

In order to illustrate the need for force-dynamics in the semantics of prepositions, this section will briefly discuss some relevant aspects of the interpretation of the English prepositions *against* and *in* and *on* and the Dutch prepositions *op* and *aan*.

Against

Against is the clearest example of a preposition that is not purely geometric:

(2) Alex bumped against the wall

Dictionaries characterize the meaning of *against* in such terms as 'collision', 'impact', and 'support'. It typically combines with verbs like *crash*, *lean*, *push*, *bang*, and *rest,* verbs that all involve forces, either dynamically (3a) or statically (3b):

(3) (a) There was a loud bang against the door
(b) The rifle rested against the tree

Against is a relation that always implies physical contact between the Figure and the Ground. This contact is usually lateral, i.e. from the side, involving horizontal force exertion. We can see this clearly when we contrast *against* with *on*:

(4) (a) Alex leaned against the table
(b) Alex leaned on the table

(4a) refers to a horizontal force, requiring contact with the side of the table, but (4b) to a downward force, involving the tabletop. Notice finally that the result of the force is left unspecified when *against* is used:

(5) (a) Alex pushed against the car
(b) Alex pushed the car (to the garage)

Sentence (5a) does not tell us what the 'reaction' of the car is, whether it moves as a result of the pushing or stays put. It simply leaves the result of Alex' force open. Notice the contrast with (5b) in this respect, a construction that allows directional PPs like *to the garage*, apparently because the transitive use of *push* implies that pushing results in motion of the direct object.

In and *on*

Although probably two of the most common prepositions in English, *in* and *on* have also proved to be the most difficult ones to define in geometric terms (Herkovits 1986). Intuitively, the geometric condition for *in* is 'inclusion' and the geometric for *on* 'contiguity'. But, as Vandeloise (1991) and Coventry and Garrod (2004) have argued, these conditions are not always necessary for the proper use of *in* and *on*, respectively, and they are not always sufficient either. Here are two well-known examples:

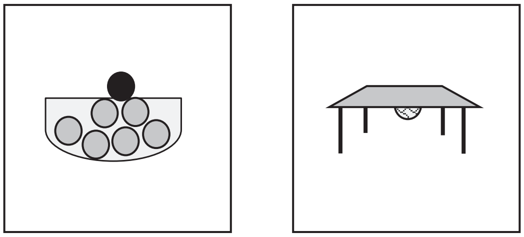

Figure 11 *Figure 1a* *Figure 1b*

In Figure 1a the black marble is not included in the (interior of the) bowl, but we still would describe this situation with sentence (6a) below. In Figure 1b there is contiguity of the ball with the table, but nevertheless, the description in (6b) is not felicitous.

(6) (a) The black marble is in the bowl
    (b) The ball is on the table

So, there are relations without inclusion that we call *in*, as in (6a), and there are relations with contiguity that we don't call *on*, (6b). These observations have led Vandeloise (1991) and Coventry and Garrod (2004) to propose that force-dynamic conditions are needed instead of, or in addition to, the geometric conditions of containment and contiguity. Even though the black marble in Figure 1a is not included in the bowl, its position is in some sense controlled by the bowl through the grey marbles. There is a force-dynamic relation of *containment*. The position of the ball underneath the table in Figure 1b is not controlled by the table in the way that would be necessary for *on* to be apply, namely by *support*, a force relation that requires the ball to be on the opposite, upper side of the tabletop.

Aan and *op*

For the third example of the role of force-dynamics, we need to turn to Dutch. The English preposition *on* corresponds to two distinct Dutch words, *op* and *aan* (Bowerman and Choi 2001, Beliën 2002):

(7)	(a)	a cup on the table	een kopje op de tafel	'support'
	(b)	a bandaid on a leg	een pleister op een been	'adhesion'
	(c)	a picture on the wall	een schilderij aan de muur	'attachment'
	(d)	a handle on the door	een handvat aan de deur	'attachment'
	(e)	a leaf on a twig	een blaadje aan een tak	'attachment'

As Bowerman and Choi (2001) show, Dutch uses *aan* for spatial relations that involve *attachment* (7c-e) while *op* is used for relations of *support* (7a) and *adhesion* (7b). So the distinction between *aan* and *op* is again not purely geometric, but also force-dynamic, given that relations of attachment, support and adhesion presuppose that the related objects exert forces on each other.

Extended location

Herskovits (1986) noted that the applicability of *on* can be extended in an interesting way, crucially involving force-dynamics again. The English sentence (8a) and its Dutch translation (8a') describe the situation in Figure 2a below, even though the cup is really standing on a book that is lying on the table.

(8) (a) The cup is standing on the table
(a') Het kopje staat op de tafel
(b) De lamp hangt aan het plafond
The lamp hangs on the ceiling
'The lamp is hanging from the ceiling'

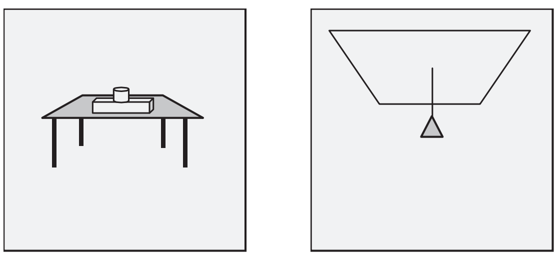

Figure 2 *Figure 2a* *Figure 2b*

In the same way, Figure 2b fits the Dutch description in (8b), although the lamp is not directly hanging from the ceiling, but connected to it by a cable. What we see then is that these prepositions usually require direct contact ('contiguity' or 'attachment') between Figure and Ground, but it is possible to make the relation indirect, by the intervention of a third object.

So, we have seen a range of force-related notions that seem to play a role in the semantics of spatial prepositions: 'impact', 'control', 'containment', 'support', 'adhesion', 'attachment'. What is the force-dynamic system behind these notions? And, given that there is interaction with purely spatial concepts (like vertical and horizontal direction, inclusion and contiguity), how does this force-dynamic system interface with the spatial system? In other words: what is the geometry of forces?

A geometry of forces

Vectors

Since the notion of vector is going to play an important role in our analysis of the geometry of forces, we will start we a brief and informal overview of some core concepts. Vectors are a powerful tool to analyze geometrical concepts. Essentially, a vector **v** is a directed line segment, an arrow, as illustrated in the diagrams in Figure 3. There are different ways to represent a vector in linear algebra, but for our purposes it is sufficient to understand it at this basic level. Free vectors have a length and a direction only, located vectors have a particular starting point. The zero vector has no length and no direction, but it can have a location.

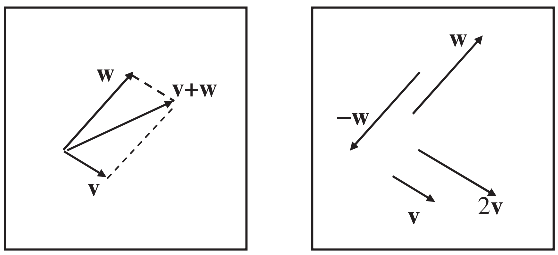

Figure 3 *Figure 3a* *Figure 3b*

In the algebra of vectors two vectors **v** and **w** can be added up to form the vector sum **v**+**w**. Figure 3a illustrates how this vector sum forms the diagonal of the parallelogram of which **v** and **w** are the sides. Scalar multiplication is another operation, in which a vector **v** is multiplied by a real number *s*, to form the scalar multiple *s***v**, which is *s* times as long as **v** (see Figure 3c). Each non-zero vector **v** has an inverse -**v** of the same length, but pointing in the opposite direction. With this background, we can now take a closer look at vectors in the force-dynamic domain.

Force vectors

The literature about force-dynamics is not extensive, but it would still go too far for the purposes of this paper to give here even a short overview of what has been written in Talmy (1985) and works inspired by it, like Johnson (1987), Langacker (1991), Croft (1991, to appear), Jackendoff (1993), Wolff and Zettergren (2002). I will restrict myself to extracting from the literature some useful ingredients for a rudimentary model of forces.

(i) The first ingredient is that forces have vector properties. Even though this is not made explicit by all the authors mentioned above, forces have two parameters: they have a *magnitude* (they can be smaller or bigger) and they have a *direction* (they point in a particular, spatial, direction). These two parameters define a vector. The third parameter, less relevant here, is the *location* of the force, i.e. the physical point where the force is exerted.

(ii) Usually, a force is exerted by one object, the Agent, on another object, the Patient. The Agent is what Talmy (1985) calls the Antagonist, the Patient is the Agonist. Talmy's terms have not found general currency and I will therefore use the more common terms Agent and Patient here, even though this occasionally leads to somewhat awkward results, as we will see at the end of the next section.

(iii) The Patient may also have its own force vector. This vector represents the inherent tendency of the Patient to move in a particular direction. The tendency of material objects to go downwards, because of gravitation, is an example of such an inherent force vector (even though, strictly speaking, the earth is the Agent here).

(iv) Because of the interaction between the forces of Agent and Patient, there is a resultant vector that determines the result of this interaction. This resultant vector is simply the sum of the Agent's and the Patient's vector (according to the parallelogram rule) and this sum can be zero, when the forces of Agent and Patient are equal but opposite.

All of these ingredients can be illustrated with a concrete example, based on the experiment and analysis of Wolff and Zettergren (2002). Consider the example:

(9) The fan prevented the boat from hitting the cone

In their experiment, subjects were asked to judge whether sentences like these applied to short and simple animations in which different kinds of objects were seen to exert forces on a moving boat. Wolff and Zettergren found that the conditions for using causative verbs like *prevent* could be analyzed in terms of the vector force interaction of the objects involved. A situation that falls under sentence (9) might look as follows:

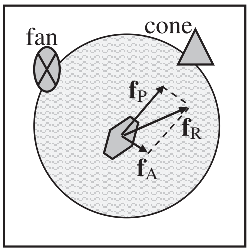

Figure 4

In this picture, $\mathbf{f}_A$ is the force of the Agent, the fan, blowing against the Patient, the boat. The boat has its own force tendency $\mathbf{f}_P$, that is directed towards the cone. In this example, the Patient's force vector is determined by the engine and the rudder of the boat. When we add up the two vectors we get the resultant vector $\mathbf{f}_R = \mathbf{f}_A + \mathbf{f}_P$ that tells us where the boat is heading, as a result of the combination of the two forces. All of this is simple high-school physics, but it allows Wolff and Zettergren to isolate the directional parameters that determine how people actually apply causative verbs to dynamic scenes: the directions of $\mathbf{f}_A$, $\mathbf{f}_P$ and $\mathbf{f}_A+\mathbf{f}_P$ with respect to a target T.

In the model of Wolff and Zettergren, the relative magnitudes of these force vectors are essential for understanding how people label particular situations. A stronger force vector $\mathbf{f}_A$ results in a stronger sum $\mathbf{f}_A+\mathbf{f}_P$, which will then bring the Patient far enough away from the target to judge the situation as an instance of *prevent*. Notice that the *absolute* lengths of the force vectors in the spatial diagrams have no direct linguistic significance. Multiplying all the force vectors in a situation by the same scalar would represent the same force-dynamic concept. What matters for the understanding of verbs like *prevent* are ultimately the relative magnitudes and absolute directions of the three vectors.

For *prevent* to be applied to a force-dynamic situation, it is necessary that $\mathbf{f}_P$ is directed towards the target T, while $\mathbf{f}_A$ and $\mathbf{f}_A+\mathbf{f}_P$ are not. The verbs *cause* and *enable* are different, in that the result $\mathbf{f}_A+\mathbf{f}_P$ is directed towards the target. *Enable* requires that the vectors of both Patient and Agent point towards the Target, with *cause* they are opposite. See Wolff and Zettergren (2002) for further explanation and evidence concerning this vector-based force-dynamics of causative verbs. I will turn now to a class of verbs that refer to forces in a more direct and more spatial way.

Forceful verbs

The first two verbs that I would like to consider are *push* and *pull*. Obviously, these two verbs are opposites, more specifically directional opposites (Cruse 1986):

(10) (a) Alex pushed the pram
     (b) Alex pulled the pram

But what is it exactly about their meanings that makes them opposite? It is not the directions of motion that are opposite, because Alex can push or pull the pram without the pram actually moving. In this respect, *push* and *pull* are different from opposite motion verbs like *enter* and *leave* or *come* and *go* that have opposite spatial trajectories. The opposition of *push* and *pull* is also different from the opposition between *cause* and *prevent* seen in the following examples:

(11) (a) The fan caused the boat to hit the cone
(b) The fan prevented the boat from hitting the cone

where the results are in opposition (hitting the cone vs. not hitting the cone). The opposition between *push* and *pull* lies purely in the opposite directions of the force vectors involved, relative to the Agent. With *push* the force vector is pointing away from the Agent, with *pull* it is pointing in the direction of the Agent. This is schematically indicated in the following two figures:

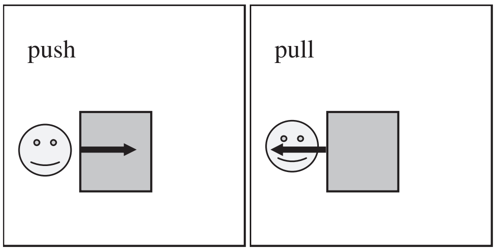

Figure 5 *Figure 5a* *Figure 5b*

The vector is located at that point of the Patient where the Agent exerts its force and its length represents the magnitude of the force. If there are no other forces interacting with the pushing or pulling force, the Patient will move in the direction of the force vector, so either away from the Agent in Figure 5a or towards the Agent in Figure 5b. The force relation between Agent and Patient is closely related to a purely locative relation between them. With pushing, the Agent is *behind* the Patient, with pulling it is *in front of* the Patient. We can already see here how force-dynamic and spatial notions interface in a way that is crucially based on direction and that requires forces to have spatial direction.

What is the role of the *length* of the force vectors in Figure 5? As I said above, the particular scale with which we represent force vectors in spatial diagrams is arbitrary. However, the magnitude of forces does play a role, in two ways. First, verbs like *push* and *pull* can be modified by an adverb like *hard*, which suggests that the length of a force vector has linguistic relevance, although in a non-quantitative way, of course. Second, on a more conceptual level, we could imagine that there are two people pulling *equally hard* on opposite sides. In that case, we need to compare the magnitudes of forces to conceptualize and describe this situation as one of balance.

Because I am mainly interested here in the *directions* of the force vectors, relative to Agent and Patient, and not so much in their location and length, I will use a simpler and much more schematic graphical representation, that abstracts away from the other two parameters:

(12) push: Agent --> Patient
pull: Agent <-- Patient

The arrows in (12) represent the spatial directions of the force vector, either pointing from Agent to Patient, or from Patient to Agent.

Let me make a bit more precise how this could be represented in a formal vector model. Let us assume that the *spatial* relation between Agent and Patient is represented by a spatial vector $\mathbf{v}_{PA}$ pointing from the Patient to the Agent (connecting their centers of gravity, for instance). This vector $\mathbf{v}_{PA}$ then gives us the spatial frame with respect to which we can represent a *force* vector $\mathbf{f}_A$, as indicated in Figure 6a and 6b. What *push* and *pull* express, is how $\mathbf{f}_A$ is aligned with respect to vector $\mathbf{v}_{PA}$. $\mathbf{v}_{PA}$ and $\mathbf{f}_A$ are opposite for *push*, they point in the same direction for *pull*. This is what (12) intends to represent in an informal way.

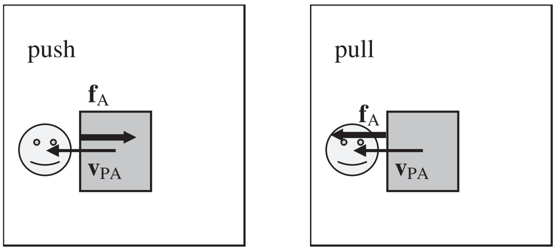

Figure 6a *Figure 6b*

Figure 6

Another pair of opposite force verbs is *squeeze* and *stretch*, that are very close to *push* and *pull*. *Squeeze* can be defined as 'press from opposite sides', while *stretch* is 'pull in opposite directions:

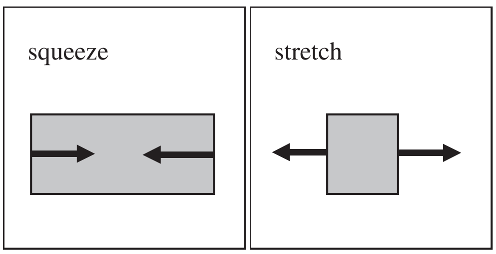

Figure 7a *Figure 7b*

Figure 7

Again, there is a close relation with basic spatial notions: the forces of *squeeze* have an *inward* direction with respect to the Patient and the forces of *stretch* an *outward* direction. If there is a resulting change, it is a change of shape or volume, a shrinking or expanding. Here also, I will use a more schematic representation of the force-dynamic relation between Agent and Patient:

(13) squeeze: Agent –> Patient <– Agent
stretch: Agent <– Patient –> Agent

The third and last pair of forceful verbs to be discussed here is *lean* – *hang*. Both verbs can refer to a downward force exerted by the subject, as in the following examples:

(14) (a) Alex was leaning on the table with his elbows
(b) There was a light bulb hanging from the ceiling

The distinction lies in the relative position of the Agent and the Patient. In (14a) the Agent (Alex, or rather, his elbows) is above the Patient (the table), in (14b) the Agent (the light bulb) is below the Patient (the ceiling). In one sense, leaning and hanging are a bit like pushing and pulling. Leaning is like pushing from above and hanging is like pulling from below. But there are two important differences. The first difference is that the forces don't come from within the Agent, but are the result of gravitation. Alex does not have to *do* something to the table when he is leaning on it. The second difference is that the force exerted by the Agent is counterbalanced by an equal but opposite force of the Patient (indicated by the grey arrow), creating a static situation of balance, as illustrated in the following two figures:

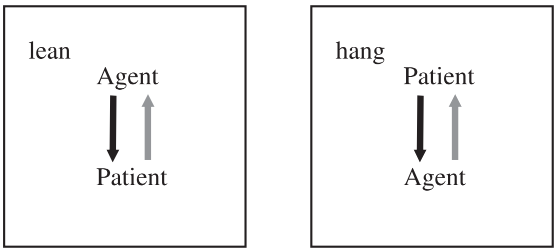

Figure 8 *Figure 8a* *Figure 8b*

We can see the configuration of Figure 8a as a representation of *support*: the Patient is supporting the Agent. Figure 8b, on the other hand, captures an important aspect of the notion of *attachment*: the Agent is attached to the Patient.

It is in this situation that the use of the terms Agent and Patient becomes somewhat awkward. From the perspective of the theory of thematic roles, we would not usually call the subject of *lean* or *hang* an Agent and the table or the ceiling a Patient, because we cannot say that the subject is doing something to the object of the prepositions. Talmy's term Agonist and Antagonist are not appropriate either. I will therefore use a slightly different representation for situations of leaning and hanging, respectively:

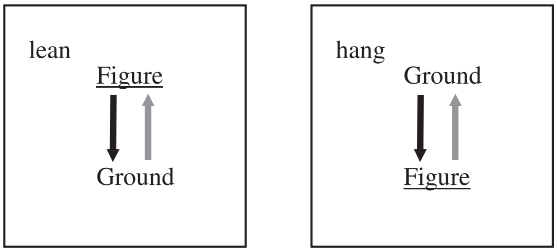

Figure 9 *Figure 9a* *Figure 9b*

The objects are labeled Figure and Ground here. The underlining of Figure indicates that it is this participant that exerts the primary downward force to which the Ground is reacting. What is not made explicit in the representation is that gravitation is responsible for the Figure's force.

Two kinds of arrows

The arrows in the representation that I proposed in the previous section should not confused with the arrows that are found in Langacker (1991) and Croft (1991, to appear). There an arrow is used to indicate the direction in which energy is transmitted from one object to another. The direction of the arrow is non-spatial and non-vectorial, and it is always pointing from the Agent to the Patient, or from a more agentive to a less agentive participant in a situation, e.g. from an Agent to an Instrument. In fact, notions like Agent, Patient and Instrument can be more or less defined from their position in a chain of causal relations:

(15) X --> Y --> Z

In such a chain, X will be the Agent, Y the Instrument and Z the Patient. In other words, the arrow is *thematic*, representing the roles that objects play in a force *relation*.

In the representation that is used here, and also in Johnson (1987) and Wolff and Zettergren (2002), the arrow represents the spatial direction of the force with respect to given objects and dimensions. (15) then means that there is a force working away from X and towards Y and a force working away from Y towards Z. It does not specify the origins of these forces: this is where we need to label objects as Agent or Patient, or underline them to indicate their force-dynamic primacy.

Both representations are justified, but for different reasons and for different purposes. The first kind of arrow is useful for representing the thematic side of causal relations, particularly for analyzing aspectual and argument structure, as argued for in Croft's work. The second kind of arrow is needed for the spatial side of causal relations and is indispensable for understanding verbs with a directional component, as we saw in this section, but also for force-dynamic prepositions, as we will see in the next section.

Prepositional forces

Verbs and prepositions in Dutch

Verbal forces and prepositional forces interact. One area where we can see this clearly is in some relevant verb preposition patterns in Dutch (Beliën 2002). While *trekken* 'pull' is used with *aan*, as shown in (16a) and (16b), the opposites *duwen* 'push' or *drukken* 'press' are used with *op* or *tegen*, (16a') and (16b'):

(16)	(a)	aan de wagen trekken on the car pull 'pull the car'	(a')	tegen de wagen duwen against the car push 'push the car'
	(b)	aan de bel trekken on the bell pull 'pull the bell'	(b')	op de bel drukken on the bell press 'press the bell'

The choice between *op* and *tegen* is subtle, depending on the direction and the granularity of the force. While (16a') is used for a horizontal force exertion, (17a) below is used for a force that comes from above. *Op* in (16b') is the normal preposition to use when a bell is pressed with a finger, but *tegen* is found, as in (17b) when something bigger exerts a force on the bell, in a non-canonical way:

(17) (a) op de wagen duwen
on the car push
'push on the car'

(b) tegen de bel drukken
against the bell press
'press against the bell'

Hangen 'hang' and *leunen* 'lean' also correlate with particular prepositions:

(18)	(a)	aan de wagen hangen on the car hang 'hang on the car'	(a')	op/tegen de wagen leunen on/against the car lean 'lean on/against the car'
	(b)	aan de bel hangen on the bell hang 'hang on the bell'	(b')	op/tegen de bel leunen on/against the bell hang 'lean against the bell'

Hangen clearly goes with *aan*, (18a) and (18b), while *leunen* goes with *op* and *tegen*, (18a') and (18b'). However, *hangen* is also possible with *op* and *tegen*. Notice the contrasts in the following examples:

(19) (a) Het gordijn hangt aan het plafond
The curtain hangs on the ceiling
'The curtain is hanging from the ceiling'

(b) Het gordijn hangt op de grond
The curtain hangs on the ground
'The curtain is hanging on the ground'

(c) Het gordijn hangt tegen het raam
The curtain hangs against the window
'The curtain is hanging against the window'

The curtain is suspended from the ceiling, and *aan* is used in (19a) to describe this relation. However, to describe the situation in which the curtain touches the ground at the lower end *op* is used in (19b) and its contact with the window in the vertical direction is indicated by *tegen* in (19c). In the remained of this paper I will ignore the use in (19b) and (19c).

In order to make sense of the patterns of (16) and (18), the prepositions *aan*, *tegen* and *op* need to involve a force relation between the Figure and the Ground. The basic idea is that *aan* 'on' is like pulling and hanging: a relation in which the Figure is at the same time a kind of Agent, exerting a force on the Ground that is directed towards itself. I will represent this as follows:

(20) aan: Figure <-- Ground

What characterizes *aan* is that the force vector is pointing from the Ground towards the Figure. The Figure is underlined to indicate the division of agentivity in this relation: it is the Figure that has an intrinsic tendency to move. *Tegen* 'against' and *op* 'on' are the opposite of *aan*, in the sense that the force points away from the Figure towards the Ground:

(21) tegen: Figure --> Ground
op: Figure --> Ground

In this respect, *tegen* and *op* are like pushing and leaning. The directional nature of forces allows us to capture the distinction between *aan* on the one hand from *op* and *tegen* on the other hand, but it also explains why prepositions cooccur with push and pull verbs in the way they do.

Interestingly, the directional nature of forces has a direct reflex in English in the the use of the directional preposition *from* with the verb *hang*:

(22) The lamp was hanging from the ceiling

The *from* that usually designates a *path of motion* away from the Ground is used here for a force vector pointing away from the Ground. It is difficult to account for this use if we don't allow forces to have spatial directions.

More properties of support and attachment

What we have seen in the previous section is just the basic core of the force-dynamics of contact prepositions like *on* in English and and *op* and *aan* in Dutch. There are a number of other observations to make about these prepositions.

The first effect is the contact effect: the Figure and the Ground are in contact or spatially contiguous. But note that this is not a spatial condition that is separate from their force-dynamic properties. As we noted already with forceful verbs, spatial contact is necessary for force-dynamic interaction. The Figure and Ground have to touch to allow the configurations in (20) and (21) to obtain in the first place. So, the force-dynamic and spatial components of the relations expressed by prepositions like *on* and *against* are closely tied together.

The second effect, which we already described in section 1, is the chaining effect, a way of extending the contiguity between two objects. The force interaction between objects does not need to be direct, but it can be mediated by a third object. In our schematic representation, we can represent this for *op* and *aan* (support and attachment) as follows:

(23) op: Figure --> X --> Ground (support)
aan: Figure <-- X <-- Ground (attachment)

With *op* the Figure has a pushing relation with X and X with the Ground, with *aan* the Figure is pulling X and X is pulling the Ground. The X can only fulfil its role if it is literally between Figure and Ground, so if it is also a spatial intermediary, which is also what we see in the situations from section 1, repeated here:

(24) (a) Het kopje staat op de tafel
The cup stands on the table
'The cup is standing on the table'

(b) De lamp hangt aan het plafond
The lamps hangs on the ceiling
'The lamp is hanging from the ceiling'

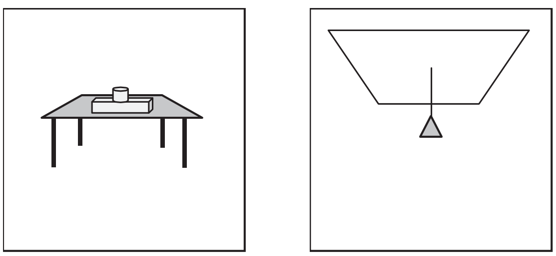

Figure 10 *Figure 10a* *Figure 10b*

The book in Figure 10a is between the table and the cup, just as the cable in Figure 10b is between the ceiling and the lamp.

There is a third effect that usually occurs with *aan* and *op*. We can call it a default effect, because it concerns the prototypical use of these prepositions. Again, we need to refer to the spatial direction of forces to account for this effect. Unless otherwise specified by the context or the sentence, we assume that *aan* (attachment) applies in a situation in which the force vector is downward, because of gravitation. *Aan* is not just 'pulling', it is downward pulling, i.e. 'hanging'. This is especially the case if the sentence does not have an explicit Agent. Also with *op* (support) the default is downward, as a result of the gravitational pull. So, this is what we get in prototypical situations:

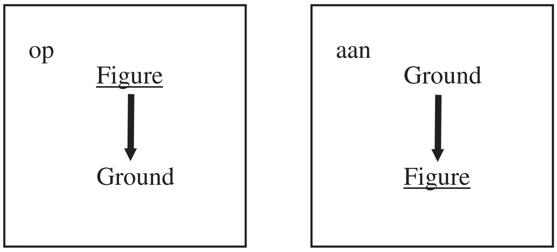

Figure 11 *Figure 11a* *Figure 11b*

This also implies that in the prototypical case, *aan* (attachment) implies 'under', while *op* (support) implies 'above'. These spatial relations follow again from the force-dynamic specifications. However, it is not difficult to find situations in which the force relations hold in a different direction, especially with *on*/*op*:

(25) (a) The fly is sitting on the wall
(a′) De vlieg zit op de muur

(b) The fly is sitting on the ceiling
(b′) De vlieg zit op het plafond

Finally, with *aan* and *op*, we get what we might call stative effects: situations in which the force that the Figure exerts on the Ground is counterbalanced by an equal but oppositely direction force exerted by the Ground. We normally interpret the sentences in (18) as referring to situations of stasis, similar to what we saw with *lean* and *hang*:

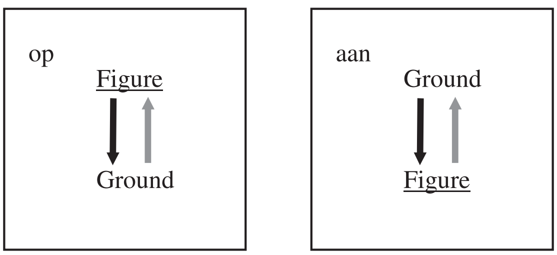

Figure 12 *Figure 12a* *Figure 12b*

In general, in such a situation of stasis, the force vectors $\mathbf{f}_{\text{Figure}}$ and $\mathbf{f}_{\text{Ground}}$ are opposite and of equal length, i.e. $\mathbf{f}_{\text{Ground}} = -\mathbf{f}_{\text{Figure}}$, or, in other words: $\mathbf{f}_{\text{Ground}} + \mathbf{f}_{\text{Figure}} = \mathbf{0}$, where $\mathbf{0}$ is the zero force vector.[1]

Stasis is not necessary, however. There can also be situations with *on*, *op* and *aan* in which the counterforce is non-existent or such that no balance results:

(26) (a) Alex trok aan de wagen
Alex pulled on the car
'Alex pulled the car'

(b') Alex drukte op de bel
Alex pressed on the bell
'Alex pressed the bell'

These Dutch sentences don't specify what happens with the car and the bell. This depends on particulars of the situation and properties of these objects.

Containment as a force-relation

We have finally come now to the most common and at the same time most complicated preposition of Dutch and English: *in*. Vandeloise (1991) and others have argued that the semantics of this preposition should be understood in terms of containment. Given what we know now about force vectors, how can we capture containment in these terms, such that the phenomena in section 1 are accounted for?

The idea is to take our inspiration again from what we see with verbs. We take *in* to share important force-dynamic characteristics with *squeeze*. We have proposed in section 2 to treat *squeeze* as a configuration in which there is concavity of forces: the Patient is between (parts of) the Agent and the Agent's forces are pointing towards the Patient. I propose to represent *in* in a similar way, but since we are talking about prepositional relations, I will use Figure and Ground:

(27) in: <u>Ground</u> –> Figure <– <u>Ground</u>

This is like a minimal configuration, which says that the Ground exerts forces on the Figure from at least two opposite sides. Of course, the Ground might enclose the Figure on all sides (and maybe this is even true for typical containment), but for the time being I will assume that containment minimally requires what we see in (27). Notice that a kind of spatial inclusion follows from this force-dynamic configuration. The forces of the Ground can only come from different sides if the Ground somehow spatially includes the Figure. Just as with *on*, *aan* and *op*, we see an intimate connection between forces and locations, made possible by the way force vectors are embedded in space.

Obviously, there are important differences between *squeeze* and *in*. The verb *squeeze* involves active and dynamic exertion of forces from at least two opposite sides, involving close contact, typically by an animate Agent. The preposition *in* involves a passive and stative configuration of forces, not necessarily involving contact, typically by an inanimate Ground. I believe that many of these differences correlate with the fact that *squeeze* is a verb, while *in* is a preposition. Nevertheless, the two words both take part in an abstract force-dynamic schema.

The configuration in (27) gives a basic condition for containment. What we see are only two *parts* of the Ground, on opposite sides of the Figure. In a sense, (27) gives us a one-dimensional cross-section of a two-dimensional situation in which the Ground is a ring around the Figure or of a three-dimensional situation in which the Ground is all around the Figure.

Even though (27) is very rudimentary, it does give us a way to capture what goes on in the following two situations, both describable by *the black marble in the bowl*:

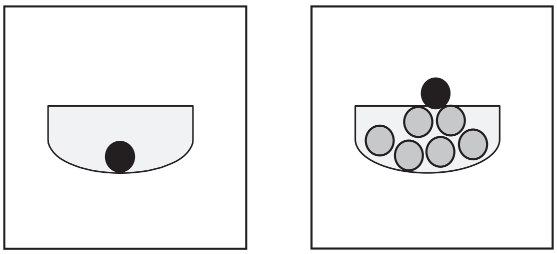

Figure 13 *Figure 13a* *Figure 13b*

Figure 13a is the simple situation in which there are two forces of the Ground pointing from opposite sides towards the Figure, as in (27). However, in Figure 12b, there is *chaining*:

(28) in: Figure
↓
Ground –> X <– Ground

There are force vectors pointing from the Ground to X, but there is also a force vector connecting X to the Figure. The force-dynamics of containment by the Ground is transmitted here through an object X to the Figure. What is interesting here is that the chaining is not homogeneous. The force-dynamic relation between the black marble in Figure 11b (the Figure in (28)) and the other marbles (X in (28)) is not itself a relation of containment, but rather one of *support*, it seems. But because the grey marbles contained in the bowl support the black marble this marble is also indirectly contained in the bowl.

This is only one simple example and it is not clear what will happen with this primitive model of prepositional force-dynamics when we confront it with the diversity of uses of topological prepositions like *in* and *on*. Nevertheless, as semanticists we should go beyond simple descriptive labels like 'containment' and 'support' and look for the system behind these relations. Modeling such a system will allow us to generate testable hypotheses about the role that containment and support play in the semantics of prepositions. We would predict, for example, that *in* can also be used in a situation where Ground and Figure are related through attachment:

```
(29) in:   Ground –> X <– Ground
                      ↓
                    Figure
```

Whether this is the case remains to be seen, but it illustrates an important point. With a general unanalyzed notion of containment it remains unclear what is possible and impossible. A model of force-dynamic relations in which we can manipulate parameters is more adequate from a semantic point of view.

Conclusion

In this paper I have shown that verbs and prepositions are based on the same 'geometry' of forces. The notion of geometry can be taken quite literally, because forces are represented as vectors with a direction in space. This is essential for providing the interface between probably the two most basic components of natural language semantics: force-dynamics and space.

One avenue to explore is how this model can help us to model the typological results of Bowerman and Choi (2001:485). They show that there is a universal hierarchy of topological static relations that ranges from a typical instance of support (cup on table) to containment (apple in bowl), with less typical relations in between:

```
(30) cup        bandaid   picture   handle    apple     apple
     on table   on leg    on wall   on door   on twig   in bowl
     <------------------- ON ---------------------->   <–IN–>
     <--------OP------><-----------AAN------------->   <–IN–>
     <-------------------------EN---------------------------->
```

Languages carve up this scale in different ways, but terms always correspond to *continuous* regions. If a language uses a term X for two situations then it also uses it for every situation in between. This is illustrated in (30) for English, Dutch and Spanish, respectively. This continuity property is strongly related to the property of *convexity* that Gärdenfors (2000) proposed as a constraint on regions in conceptual spaces, but also to the notion of *connectivity* in the semantic map approach in typology (Haspelmath 2003).

My point here concerns not so much the nature of this general property, but rather the way we could use the force-dynamic schemas proposed here to give us more insight into the conceptual space underlying prepositions like *in* and *on* in various languages, in other words, in the conceptual space of containment and support. If we compare our representations for Dutch *op*, *aan* and *in*, we can see the beginnings of a way to model the hierarchy in (30).

(31) op: Figure --> Ground
aan: Figure <-- Ground
in: Ground -> Figure <- Ground

There are different parameters here that can be manipulated: whether the Figure or the Ground is the agentive participant, whether the force vector is directed towards the Ground or towards the Figure and additionally, whether the force vector is typical downward (as with *op*) or not. Another parameter is whether the force is simplex (with *op* and *aan*) or complex (with *in*). In this way, we might hope to get a scale in which (the prototypes of) *op* and *in* are maximally distinct with a gradient in between, in which the parameters change from *op* to *in*:

(32)

	op	*in*
Force source:	Figure	Ground
Force orientation:	Ground	Figure
Force direction:	Down	Not down
Force complexity:	Simplex..........................	Complex

In this way the analysis of forceful prepositions proposed here is not only relevant for English and Dutch, but for all languages across the world that refer to notions of containment, support and attachment.

If the approach of this paper is on the right track, then it also sheds an interesting light on two common and influential ideas in the literature on topological prepositions like *in* and *on*, which go back to work of Herskovits (1986) and Vandeloise (1991). One idea is that the semantics of *in* and *on* is based on a particular type of geometry, namely the *topological* one, in which basic relations between spatial regions play a role (as opposed to the axis-based semantics of *projective* prepositions like *above* and *behind*). *In* corresponds to 'inclusion' while *on* corresponds to 'contiguity' or 'connectedness'. Vandeloise came with an alternative, non-geometric approach based on functional or force-dynamic notions like 'containment' and 'support'. The results of this paper suggest, however, that geometry vs. function may be a false dichotomy. Spatial geometry and force-dynamics are not mutually exclusive, but they are both based on a more fundamental notion of vector, which makes it possible to take a more unified approach towards these conceptual domains.

Notes

1 This paper was presented at the ICLC 9 in Seoul, July 22, 2005. The research for this paper was financially supported by a grant from the Netherlands Organization for Scientific Research NWO to the PIONIER project 'Case Cross-Linguistically' (number 220–70–003), which is gratefully acknowledged. The comments of an anonymous reviewer have been very helpful for me in revising the paper.

2 This zero *force* vector should be kept distinct with the zero *spatial* vector that might potentially be used to represent the purely spatial relation of *contact* between Figure and

Ground. However, as argued in Zwarts and Winter (2000), there are several reasons to analyze the spatial contact relation of *on* in terms of non-zero vectors.

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