Measure Phrase Modification in Vector Space Semantics

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1. Introduction

Spatial and temporal Measure Phrases (MPs) such as *ten meters, five years* etc. appear with various linguistic items, including locative prepositions, adjectives and comparatives, and show certain systematic contrasts in these domains. Consider for instance the following examples.

(1) a. The bird is ten meters above/behind/beside/outside the house.
b. The bird is ten meters *near/*on/*in/?inside the house.

(2) a. The box is ten cm. wide/*narrow.
b. The boy is five years old/*young.
c. The man is five feet tall/*short.
d. The well is one meter deep/*shallow.
e. The road is one km. long/*short.

(3) a. The box is ten cm. wider/narrower than the closet.
b. The boy is five years older/younger than the girl.
c. The man is one feet taller/shorter than the woman.
d. The well is one meter deeper/shallower than the pool.
e. The road is one km. longer/shorter than the highway.

These sentences exemplify three main facts about MP modification:

(F1) Some locative prepositions and degree adjectives allow MP modification while others do not.

(F2) When an adjective allows MP modification, it loses the 'value judgment' part of its meaning. For instance: a box that is *ten cm. wide* is not necessarily wide; a child that is *five years old* is normally not considered old.

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(F3) In their comparative form, both positive and negative adjectives allow MP modification (cf. (2) vs. (3)).

Adjectives such as *wide* and *old*, which allow MP modification, are often classified as *positive*, whereas their antonyms *narrow* and *young* (or *new*) are called *negative* adjectives (cf. Seuren (1978)).

In order to account for facts (F1)-(F3), this paper generalizes the *modification condition* of (Zwarts, 1997) and (Zwarts and Winter, 2000), which handles MP modification of locatives in *Vector Space Semantics* (VSS). In this theory, vectors – mathematical objects that can be conceived of as directed line segments between points in space – are used as the basic entities in the spatial ontology of natural language. Following (Faller, 2000), VSS is also used to account for the semantics of degree adjectives and comparatives, in a way that resembles their interval semantics proposed by (Kennedy, 2000) and others. It will be shown that Faller's proposal can be refined in a way that also captures the three facts above about MP modification. The modification condition of Zwarts/Winter requires that in order for a set of vectors to be modified by an MP it has to include vectors of all possible lengths. This happens whenever the set that is being modified is both upward and downward *monotone*. In this way, the condition guarantees that a modification construction is never semantically trivial if the MP itself is not trivial.

Section 2 briefly reviews some basic notions in VSS. Section 3 reviews the semantics of locative prepositions as proposed by (Zwarts and Winter, 2000), and modifies Faller's vector-based analysis of degree adjectives and comparatives. Section 4 introduces the proposed usage of the general modification condition, which accounts for the acceptability of MP modification using these denotations.

2. Basic notions in Vector Space Semantics

Vector Space Semantics (VSS), as introduced in (Zwarts, 1997) and (Zwarts and Winter, 2000), assumes that the main ontological primitive in the semantics of spatial expressions is a *vector space* V over the real numbers $\mathbf{R}$. This means that for V the following constants and operations are defined:

- An addition operator $+$ on elements in V.
- A zero element 0 that satisfies $v + 0 = v$ for every element v in V.
- An opposite element $-v$ for each element v in V, which satisfies $v + (-v) = 0$.
- A scalar multiplication operator $\cdot$ between real numbers in $\mathbf{R}$ and elements in V, such that for all real numbers $s \in \mathbf{R}$ and elements $v \in V$:

$s \cdot v$ is an element in V.

These notions and their algebraic properties define the *structure* of the vector space V. To define a metrics for *distances* in V, we also assume a *norm function* $|\ |$ that send every vector v in V to a non-negative scalar in $\mathbf{R}$. For surveys on the mathematics of vector spaces see (Lang, 1977) or any other introduction to Linear Algebra.

In a sentence such as *the bird is above the house* we say that the house is the *reference object* and the bird is the *located object*. The sentence is analyzed using vectors that start on the reference object and end at the located object. This means that these vectors all belong to one vector space with a zero element that describes the location of the reference object. In general, in each vector space there is exactly one zero vector. Roughly speaking – all the vectors in a vector space have the same "starting point". However, in natural language, locative prepositions are used in order to describe location in relation to different reference objects. For instance, in sentence (4) the bird is located with respect to both the house and the cloud.

(4) The bird is above the house, and it is also below the cloud.

In order to allow both the location of the house and the location of the cloud to be the "starting points" of vectors in the analysis, we observe the following fact.

Fact 1 *If V is a vector space, then the Cartesian product $V \times V$ (the set of pairs of elements from V) is equal to $\cup_{w \in V} V_w$, where $V_w = \{\langle w, v\rangle : v \in V\}$. For any vector $v \in V$, the set V_w is a vector space with a zero vector $\langle w, 0\rangle$ and the naturally defined operations for addition, negation and scalar multiplication.*

Thus, $V \times V$ is a collection of vector spaces V_w, where the "starting point" of each vector in them is determined by the vector w. We refer to the elements in $V \times V$ as *located vectors.* These conventions are illustrated in figure 1. In this figure, the pair of vectors w and v is conceived of as the located vector $\mathbf{u}$, where w is conceived of as the starting point $\mathbf{p}$ of $\mathbf{u}$, and the sum $w + v$ is conceived of as its "end point" $\mathbf{q}$.

Sentence (4) is analyzed as making an existence claim about two located vectors. One of them is a pair of vectors $\langle w_1, v_1\rangle \in V \times V$, where w_1 describes the location of the house and v_1 describes the relative location of the bird with respect to the house. A second located vector $\langle w_2, v_2\rangle$ similarly describes the location of the cloud and the relative location of the bird with respect to the cloud. This is schematically illustrated in figure 2. The denotations assigned to the locative prepositions (see the following section) guarantee that these vectors specify the location of the bird as being *above* the house and *below* the cloud.

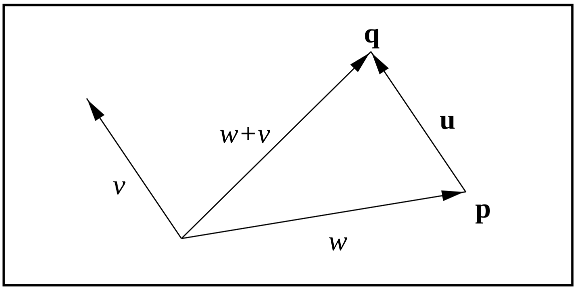

Figure 1: vectors and located vectors

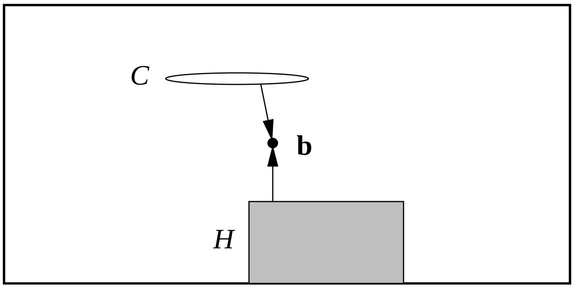

Figure 2: the bird is above the house and below the cloud

3. Denotations in Vector Space Semantics

(Zwarts, 1997) argues that MP modification shows an advantage of vector spaces as the underlying ontology for spatial expressions. Modified locatives as in (1) are commonly assigned the structure in (5) below.

(5) [$_{\mathrm{MP}}$ ten meters] [$_{P'}$ behind the house]

However, Zwarts points out that this structure leads to a problem of compositionality: for an object x to be in the extension of the prepositional phrase *ten meters behind the house*, the location of x itself is insufficient: we are interested in the position of x with respect to the reference object, in this case the house. However, in 'mereological' or 'pointal' ontologies of spatial expressions, the constituent *behind the house* in (5) is analyzed as the set of locations behind the house. Using this set alone it is impossible to compute the location of the house (note that the house itself is even not a member of the set of elements behind the house). Consequently, the analysis of MP modification using the structure in (5) is problematic for previous theories of spatial expressions.

In VSS, the measure phrase *ten meters* is treated as a set of (located) vectors that are ten meters long. The P' constituent *behind the house* is treated as a set of located vectors as well: those vectors that start on the house and end at a point behind the house. MP modification is treated simply as the *intersection* of these two sets, which in this case leads to the set of vectors that are ten meters long, start on the house and end at a point behind the house. In this paper I adopt the proposal in (Faller, 2000) that also the compositional analysis of MP modification with adjectives and comparatives, as in (2) and (3), is based on a similar intersective process. This section defines the denotations of these items, which will be used in order to analyze modification constructions. Since the main objective of this paper is also to account for the (un)acceptability of MP modification with various items, the proposed treatment of adjectives and comparatives will be slightly different from Faller's proposal.

3.1. Locative prepositions

All locative prepositions in (Zwarts and Winter, 2000) denote functions from sets of vectors to sets of located vectors. A set of vectors $A \subseteq V$ describes the location of an object (through the "end points" of its vectors). A locative preposition denotes a function P that sends such a set of vectors A to a set of located vectors $P(A)$, which describes other locations *relative to this location*. The located vectors in $P(A)$ are all *internally or externally closest* to A, in a sense that is formally defined in (Zwarts and Winter, 2000). Intuitively, a located vector $\mathbf{v}$ is internally (externally) closest to a set A when $\mathbf{v}$ starts at a boundary point of A, ends inside (outside) A, and is a shortest connection from the boundary of A to its ($\mathbf{v}$'s) end point. For instance, in figure 3 only the located vector $\mathbf{v}_5$ is externally closest to A. The located vectors $\mathbf{v}_1$ and $\mathbf{v}_3$ do not start at the boundary of A. The located vector $\mathbf{v}_4$ is not a shortest connection from A's boundary to its end point. The located vector $\mathbf{v}_2$ is internal to A – in fact, internally closest to A – hence it is not external to A.

The examples below illustrate the denotations of some locative prepositions:

- $\mathbf{inside}'(A)$ is the set of located vectors that are internally closest to A.
- $\mathbf{outside}'(A)$ is the set of located vectors that are externally closest to A.
- $\mathbf{near}'(A)$ is the set of located vectors that are externally closest to A, and v is of a length that is shorter than a certain contextually specified

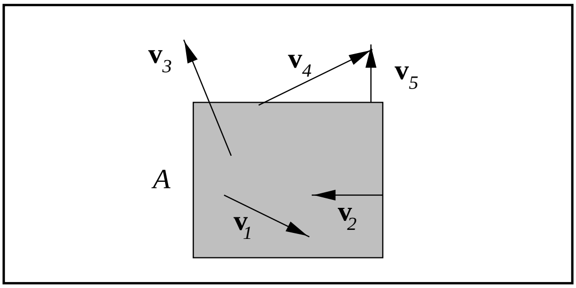

Figure 3: only $\mathbf{v}_5$ is externally closest to A

positive number.

- $\mathbf{above}'(A)$ is the set of located vectors that are externally closest to A, and v's projection on the vertical axis of A is longer than its projection on the horizontal axis of A.

In figure 3, the located vectors $\mathbf{v}_2$ and $\mathbf{v}_5$ are in the sets $\mathbf{inside}'(A)$ and $\mathbf{outside}'(A)$ respectively. If $\mathbf{v}_5$ is short enough, then it is also in the set $\mathbf{near}'(A)$. In figure 4, the located vector $\mathbf{v}$ is in the set $\mathbf{above}'(A)$, since its projection on the vertical axis from A is longer than its projection on the horizontal axis from A. For more formal details on the treatment of locative prepositions in VSS see (Zwarts and Winter, 2000).

For the purposes of this paper, it is sufficient to keep in mind that the use of located vectors is motivated by the semantics of MP modification with PPs, where distances are measured with respect to a *syntactically overt* reference object. We will see that something quite similar happens with comparatives, but measures with absolute adjectives are with respect to a fixed point that does not overtly appear in the sentence.

3.2. Degree adjectives and comparatives

(Faller, 2000) observes that the same modification problem that motivates the VSS treatment of locatives appears with adjectives and comparatives. Consequently, Faller proposes that structures as in (6) and (7) below are analyzed using intersection of sets of vectors, similarly to the VSS analysis of the PP structure in (5) above.

(6) [$_{\text{MP}}$ two meters] [$_{A'}$ tall]

(7) [$_{\text{MP}}$ two meters] [$_{A'}$ taller than Mary]

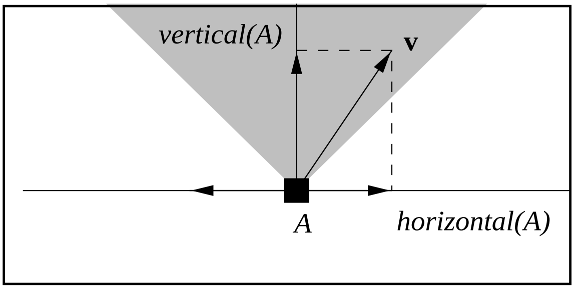

Figure 4: **v** is in the denotation of *above* A

The denotations that Faller proposes for degree adjectives and comparatives are based on the vector-based treatment of locatives in the proposal by Zwarts/Winter, and is similar in many respects to the interval semantics of adjectives in (Kennedy, 2000).[1]

The semantics of adjectives and comparatives that I adopt below is different at certain points from Faller's proposal. We first use VSS to define the notion of *scales*, which is useful in the semantics of adjectives. Recall that a unit vector is a vector of norm 1.

Definition 1 *Let V be a vector space over* **R** *with a norm function $|\ |$. Let $U \subset V$ be a (finite) set of unit vectors that are called* **scale units**. *A pair $S = \langle u_S, X_S \rangle$ where $u_S \in U$ and $X_S \subseteq$* **R** *is called a* **scale** *over V. The set of* **values** *of a scale S is the set of vectors $\{s \cdot u_S : s \in X_S\}$.*

Note that the vector space V is not necessarily the same vector space that is used for the denotations of spatial locative prepositions. Furthermore, degree adjectives such as *old*/*young* or *early*/*late* are not spatial but temporal. A scale is defined using a unit vector and a set of real values. For instance, the *height* scale for the adjectives *tall* and *short* is defined using a unit vector u_h and the set of *positive* real numbers, since anything that is tall or short has a positive height. A temporal scale for the adjective *early* and *late* is similarly defined using a unit vector u_t (different than u_h) and the set of real numbers excluding zero: something that happens just on time is never considered as early or late.[2]

1. Kennedy uses a notion of intervals that he calls *extents*, and argues that it is preferable to the more common ontology of *degrees*, which is similar to ontologies of points in spatial semantics. Interestingly, Kennedy's arguments for extents come from phenomena that are quite different from the ones that motivated VSS in the works of Zwarts/Winter and Faller.

2. For a recent work on scale structures that is motivated by different data than those discussed here, see (Kennedy and McNally, 1999).

One of the important properties of absolute adjectives is that the identity of their extension is sensitive to various, partly mysterious, factors. For instance, when two people are of the same height, one of them can be considered tall while the other is considered short. Whether a person is considered *tall* or *short* may depend on his/her sex, age, profession, point of view of the speaker and other extra-semantic factors.[3] For the purposes of this paper, these factors are not crucial, and as in many works on adjectives we can simply assume that the denotation of an absolute adjective is defined relative to a certain *standard value* in the relevant scale. The difference between pairs of adjectives such as *tall* and *short* is simply in the scale values that they allow with respect to the standard. In general, we traditionally distinguish between the denotations of *positive* and *negative* adjectives as follows.

Definition 2 *Let* $S = \langle u_S, X_S \rangle$ *be a scale relative to a vector space* V *with norm* $|\ |$. *Let* $st_S \in \mathbf{R}$ *be a non-negative* **standard** *relative to* S.
The **positive adjective vector set** *over* S *relative to* st_S *is the set:*
$\{t \cdot u_S : t \in X_S \wedge t > st_S\}$.
The **negative adjective vector set** *over* S *relative to* st_S *is the set:*
$\{t \cdot u_S : t \in X_S \wedge 0 < t < st_S\}$.

How can we tell whether the denotation of a given adjective should be a positive or a negative vector set? In most theories of adjectives the answer to this question is based on judgments such as whether the adjective pertains to "small values" or to "big values" in the scale (cf. (Seuren, 1978)). However, it is possible to give a more theory-neutral test that distinguishes between negative and positive adjectives. Suppose that John's height is 170 cm. It follows that nothing is 170 cm. *short*er than John. However, it does not follow that nothing is 170 cm. *tall*er than John. I suggest that this kind of (un)boundedness test, in terms of entailments between sentences, qualifies the denotation of the adjective *short* as being negative and the denotation of the adjective *tall* as positive. The denotations of these adjectives are defined accordingly, relative to the height scale $H = \langle u_H, (0, \infty) \rangle$ and the height standard st_H:

(8) $[\![\text{tall}]\!] = \{t \cdot u_H : t > 0 \wedge t > st_H\}$
$[\![\text{short}]\!] = \{t \cdot u_H : t > 0 \wedge t < st_H\}$

The reason that degree adjectives in the proposed definition are treated as denoting sets of vectors, rather than sets of located vectors, is due to the semantics of MP modification as in (2). When a box is *10cm. wide*, it is invariably *10cm. wider than zero*. This is in contrast to what we observed about MP modification with prepositions, where an object that is *10m outside the*

3. See (Kamp, 1975) and (Klein, 1980) for classical works on these phenomena, and (Kennedy, 1999) for a recent theory, including a survey of relevant literature.

house is located relatively to the position of the reference object (the house). On the other hand, MP modification of adjectives in the *comparative* form is obviously relative: whether an object is in the denotation of the comparative *10 cm. wider than the door* depends on the width of the door. Consequently, and similarly to the case of prepositions, it is essential to include in the denotation of the comparative *wider than the door* an indication of the door's width. This is obtained by letting this comparative denote the set of located vectors $\langle w, v\rangle$ where w is a vector in the width scale that describes the door's width, and v is any vector pointing in the 'positive' direction of the scale (the direction of its unit scale).

More generally, the denotation of a comparative *more/less ADJ than x* is defined as a set of located vectors $\langle w, v\rangle$. The w vector is the dimension of *x* in the scale of the adjective *ADJ*. The v vector is any non-zero vector on this scale multiplied by 1 or by -1, depending on the polarity of the adjective (whether it is positive or negative) and the polarity of the comparative item (whether it is *more* or *less*). We use two functions for describing this polarity:

- The function *polarity*, which sends any set of vectors A to 1 (-1) if A is a positive (negative) vector set, and is undefined otherwise.[4]
- The function *sign*, which sends every real number to 1, -1 or 0, depending on whether it is positive, negative, or zero respectively.

We use these functions in the following definition for the denotations of the comparative words *more* (or the morpheme *-er*) and *less*.

Definition 3 (comparatives) *Let $S = \langle u_S, X_S\rangle$ be a scale relative to a vector space V with norm $|\ |$. Let A_S be a (negative or positive) denotation of an adjective relative to S, and let w be a value in S.*

The comparative $\mathbf{more}'(A)(w)$ *is defined as the set of located vectors* $\{\langle w, t\cdot u_S\rangle \in V\times V : t\in \mathbf{R} \wedge sign(t) = polarity(A)\}$.

The comparative $\mathbf{less}'(A)(w)$ *is defined as the set of located vectors* $\{\langle w, t\cdot u_S\rangle \in V\times V : t\in \mathbf{R} \wedge sign(t) = -polarity(A)\}$.

For example, consider the denotations that this definition derives for some comparatives with *tall* and *short*, where $h_{\mathbf{j}'}$ is John's height (a vector in the height scale).

(9) $[\![\text{taller than John}]\!] = \mathbf{more}'(\mathbf{tall}')(h_{\mathbf{j}'}) = \{\langle h_{\mathbf{j}'}, t\cdot u_H\rangle : t > 0\}$

(10) $[\![\text{shorter than John}]\!] = \mathbf{more}'(\mathbf{short}')(h_{\mathbf{j}'}) = \{\langle h_{\mathbf{j}'}, t\cdot u_H\rangle : t < 0\}$

4. Formally, A is a positive vector set iff it is non-empty and closed under lengthening, and it is a negative vector set iff it is non-positive, non-empty and closed under shortening (see below).

(11) $[\![\text{less tall than John}]\!] = \mathbf{less}'(\mathbf{tall}')(h_{\mathbf{j}'}) = \{\langle h_{\mathbf{j}'}, t \cdot u_H \rangle : t < 0\}$

(12) $[\![\text{less short than John}]\!] = \mathbf{less}'(\mathbf{short}')(h_{\mathbf{j}'}) = \{\langle h_{\mathbf{j}'}, t \cdot u_H \rangle : t > 0\}$

Note that these four denotations, illustrated in figure 5, account for the equivalences between *taller* and *less short* and between *shorter* and *less tall*.

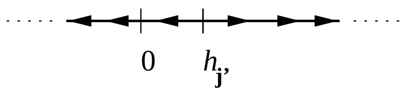

Figure 5: taller (less short) and shorter (less tall) than John

3.3. Measure phrases and modification

Given a vector space V, we assume that a measure phrase such as (*at least*/*at most*) *ten meters* is a subset of vectors with a norm that satisfies the corresponding requirement on its length. Measure units such as *meter* or *year* are assumed to specify constant real numbers, defined relative to the norm of the vector space. The exact way these constants are determined is not our main concern here. However, it is important to note that as sets of vectors, denotations of MPs have a special property that qualifies them as *measure* sets:

Definition 4 *Given a vector space* V *with a norm* $|\ |$, *we call a set of vectors* $M \subseteq V$ *a* **measure set** *iff for all* $v, v' \in V$*: if* $v \in M$ *and* $|v'| = |v|$ *then* $v' \in M$.

Intuitively, whether a vector is in a measure set or not depends only on its length. Consider for example the denotation of the measure phrase (*exactly*) *two meters*:

(13) $\mathbf{two\_meters}' = \{v \in V : |v| = 2m\}$

Whether a vector v is in this set, any vector v' s.t. $|v'| = |v|$ is obviously also in this set.

All MPs denote measure sets of vectors in an underlying vector space V, not located vectors in $V \times V$. However, let us assume that any set W of vectors can be lifted into the set of located vectors $lift(W) = V \times W$: the set of all located vectors with a vector from W in their right coordinate. This assumption allows us to use intersection for MP modification with both adjectives, which denote sets of vectors, and PPs or comparatives, which denote sets of *located* vectors. The following examples illustrate this intersection process with degree adjectives and comparatives.

(14) *two meters tall*:
$\mathbf{two\_meters'} \cap \mathbf{tall'}$
$= \{v \in V : |v| = 2m\} \cap \{t \cdot u_H : t > 0 \wedge t > st_H\}$
$= \{t \cdot u_H : t = 2m \wedge t > st_H\}$

(15) *two meters taller than John*:
$\mathit{lift}(\mathbf{two\_meters'}) \cap \mathbf{more'}(\mathbf{tall'})(h_{\mathbf{j'}})$
$= (V \times \{v \in V : |v| = 2m\}) \cap \{\langle h_{\mathbf{j'}}, t \cdot u_H \rangle : t > 0\}$
$= \{\langle h_{\mathbf{j'}}, t \cdot u_H \rangle : t = 2m\}$

With modified PPs, the analysis is similar to the analysis of comparatives:

(16) *two meters above the house*:
$\mathit{lift}(\mathbf{two\_meters'}) \cap \mathbf{above'}(H)$,
where $H \subseteq V$ is the location of the house.

See (Zwarts and Winter, 2000) for the precise definition in VSS of denotations of locative prepositions such as *above*, hence of the MP modification process with locative PPs as in (16).

4. The modification condition

So far, only the compositional analysis of MP modification has been addressed, with no account of facts (F1)-(F3) from the introduction concerning the distribution of this process and the way it affects the meaning of absolute adjectives. In this section I show that these facts can be accounted for using the assumptions that underly the compositional process above, together with an additional general requirement of non-empty denotations. To facilitate the exposition of this principle, consider the following two definitions concerning order and monotonicity in VSS, adopted from (Zwarts and Winter, 2000).

Definition 5 (vector order) *For any two vectors v, w in a vector space V over* $\mathbf{R}$, *$v \leq w$ iff there is $s \geq 1$ in* $\mathbf{R}$ *s.t. $w = s \cdot v$.*

Thus, two vectors v and w are comparable when they "point in the same direction". In this case w is considered "greater" than v if it is a lengthening of v. Using this natural partial ordering of vectors, we can standardly define the notion of upward (downward) monotone sets of vectors as being sets that are closed under lengthening (shortening) of their members. Formally:

Definition 6 *A set of vectors $A \subseteq V$ is* **upward (downward) monotone** *iff for all vectors $v \in A$ and $w \in V$, if $v \leq w$ ($v \geq w$) then w is in A.*

As shown by (Zwarts, 1997), upward monotonicity of prepositions is the relevant factor for the possibility to modify them using MPs. In VSS, those prepositions that appear felicitously with MPs have denotations that lead to upward monotone sets of vectors, and vice versa. (Zwarts and Winter, 2000) capture this observation using the following *modification condition* (MC).

Definition 7 (modification condition) *A set of vectors $W \subseteq V$ satisfies MC iff it is non-empty and for every non-empty measure set M: $M \cap W$ is not empty.*

It is easy to verify that a set of vectors satisfies MC if and only if it is non-empty and both upward and downward monotone. In this paper, I propose the following application of MC for MP modification:

(17) Any expression that denotes a set of vectors A can be modified by an MP only if A satisfies MC.

The idea behind this rule is that modification using MPs is possible only if the modified set of vectors guarantees that for *any* MP that denotes a non-empty set of vectors, the modification process (=intersection of the two sets) would not lead to an empty set. Consider for instance the contrast between the acceptable prepositional phrase *two meters outside the house* and the unacceptable prepositional phrase **two meters near the house*. The denotation of the P' *outside the house* is closed under lengthening: any lengthening of a vector that points from the house outwards leads to another such vector. By contrast, this is not the case for *near the house*: if v is a vector that points from the house outwards to a point that is in proximity to the house, there are still lengthenings of v that do not have this property. Thus, even though the intersection of *two meters* and *near the house* might be non-empty (depending on the standard of "nearness"), it is guaranteed that *some* MP can nullify this intersection (e.g. *two hundred kilometers*). Consequently, MP modification is ruled out. Note that both sets of vectors that are denoted by *outside the house* and *near the house* are closed under *shortening*.[5] For further elaborations on the MC and the semantic restrictions on MP modification of PPs see (Zwarts and Winter, 2000).

Moving on to degree adjectives, the MC straightforwardly account for the contrast between positive and negative adjectives in allowing for MP modification (fact F1). For instance, if the negative adjective *short* denotes a non-empty set then it is downward but not upward monotone for any finite standard. That is: if x is short, then anything shorter than x is short as well, but there can always be something that is taller than x and not considered short. By contrast, the positive adjective *tall* is upward but not downward

5. In fact, (Zwarts, 1997) argues that <u>all</u> locative prepositions are downward monotone in this sense.

monotone only for positive standards. For the zero standard, the denotation of *tall* is both upward and downward monotone. Since zero is the *only* non-negative standard that makes *tall* downward monotone, we expect the adjective to be acceptable with MPs only if it is evaluated with respect to a zero standard, which explains why positive adjectives do not make any value judgment when they appear modified by MPs (fact F2). As for comparatives, note that the definitions of *taller than x* and *shorter than x* are completely symmetrical. Both kinds of comparatives are upward as well as downward monotone, independently of the standard or the legitimate values in the scale. Consequently, we do not expect them to show any contrast in the acceptability of MP modification (fact F3).

That comparatives are insensitive to scale structure is also implied by the following well-known observation (cf. (Seuren, 1978), (Kennedy, 2000)). Many pairs of degree adjectives do not allow MP modification at all, with both the positive and the negative adjective. Consider for instance the following unacceptable examples.

(18) a. *This car goes 100 kmh. fast/slow.
b. *This parcel is two pounds heavy/light.
c. *This pen is five dollars expensive/cheap.

However, the comparative form of these adjectives can be modified by MPs, as the following example illustrate.

(19) a. This car goes 100 kmh. faster/slower than that car.
b. This parcel is two pounds heavier/lighter than that parcel.
c. This pen is five dollars more expensive/cheaper than that pen.

What can be the reason for this contrast between the acceptability of the degree adjectives in (18) and those in (2)? A possible explanation, discussed by Seuren and Kennedy, is that adjectives such as *fast* and *expensive* cannot exhaust all the legitimate values in the corresponding scale even when the standard is set to zero. Thus, motionless physical objects may exist, but they cannot qualify as being *fast* or *slow* for any non-negative standard. Similarly, things that are given for free cannot be classified as being very cheap, and objects that are weightless (e.g. in space) are not simply very light. This property of the speed, price and weight scales is opposed to the scales of the other adjectives that were given in (2). For instance, an object that has no height or a person that has no age do not exist in a physical sense. Hence, the adjectives *tall* and *old*, unlike *fast*, *heavy* or *expensive*, exhaust all the values in their scales when the standard is set to zero. I believe that similar claims can be made for other adjectives, thus strengthening the above Modification Condition into an ‘if and only if’ condition. Substantiating the details of such a proposal requires further research.

5. Conclusions

This paper has shown that using fairly simple assumptions, which slightly modify ideas from (Faller, 2000) and other accounts of adjectives, it is possible to extend the empirical coverage of the modification condition that is proposed by (Zwarts and Winter, 2000) for locative prepositions. The extended principle also governs the acceptability of Measure Phrase modification with absolute and comparative adjectives. As I see it, the main advantage of this proposal is that zero standard effects with modified degree adjectives are treated as simple epiphenomena of general restrictions on MP modification. Hopefully, further ongoing research into scale structure may lead to further simplification of theories in this challenging domain.

References

Faller, Martina. 2000. Dimensional adjectives and measure phrases in vector space semantics. In M. Faller, S. Kaufmann and M. Pauly, editors, *Formalizing the Dynamics of Information*. CSLI Publications, Stanford.

Kamp, J. A. W. 1975. Two theories about adjectives. In E. Keenan, editor, *Formal Semantics of Natural Language*. Cambridge University Press, Cambridge.

Kennedy, Christopher. 1999. *Projecting the Adjective: the syntax and semantics of gradability and comparison*. New York: Garland Press. A published version of a 1997 UCSC PhD thesis.

Kennedy, Christopher. 2000. Polar opposition and the ontology of 'degrees'. *Linguistics and Philosophy*, 24:33–70.

Kennedy, Christopher and Louise McNally. 1999. From event structure to scale structure: degree modification in deverbal adjectives. In *Proceedings of Semantics and Linguistic Theory, SALT9*.

Klein, Ewan. 1980. A semantics for positive and comparative adjectives. *Linguistics and Philosophy*, 4:1–45.

Lang, Serge. 1977. *Linear Algebra*. second edition. Reading, Massachusetts: Addison-Wesley.

Seuren, Pieter A. M. 1978. The structure and selection of positive and negative gradable adjectives. In D. Farkas *et al.*, editors, *Papers from the Parasession on the Lexicon, CLS14*. University of Chicago.

Zwarts, Joost. 1997. Vectors as relative positions: a compositional semantics of modified PPs. *Journal of Semantics*, 14:57–86.

Zwarts, Joost and Yoad Winter. 2000. Vector Space Semantics: a model-theoretic analysis of locative prepositions. *Journal of Logic, Language and Information*, 9:169–211.

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