The Semantics of the English Comparative Prefix *out-* and the Ontology of Degrees and Differences

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1. Introduction

It is widely assumed that degrees are extents (intervals), not just points, on scales.[1] For example, the degree phrase *6 feet* in sentence *Andy is 6 feet tall* denotes the extent from the zero point to the point of 6 feet on the scale of height. This means that degrees are sets of points on a scale. Differential phrases such as *2 inches* in *Andy is 2 inches taller than Bill is* also denote extents on the height scale. The question that arises here is whether degrees and differentials are ontologically identical to each other, and if not, what the difference between them is. It will be argued in this paper that degrees and differentials are the same in terms of semantic type but different in sorts, providing new data concerning the semantics of the English comparative prefix *out-* as given in (1) and (2).[2]

(1) a. Mary outran Bill.

    b. Mary ran faster than Bill did.

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(2) a. *Mary outran Bill fast.
b. Mary outran Bill faster than Sue did.

As Frasier (1974) describes, verbs with the prefix *out-* can be paraphrased with comparatives. (1a) is roughly synonymous with (1b), which indicates that the *out*-prefixed verb *outran* contains the meaning of *faster than*. The ungrammaticality of (2a) appears to be able to be accounted for since adding the adverb *fast* to (1a) causes the semantic redundancy. Interestingly enough, however, if the adverb *fast* is used in the comparative form, the sentence becomes grammatical as shown in (2b), in spite of the fact that *outran* contains the meaning of *faster than*. This suggests that the ungrammaticality of (2a) does not come simply from the semantic redundancy.

I will claim that the ungrammaticality of (2a) should be attributed to the impossibility of comparison of two different sorts: degree extents and differential extents. In (2b) two differential extents of speeds are compared; the difference between Mary's speed and Bill's and the difference of speeds between Sue and Bill. On the other hand, in (2a) the main part of the clause denotes the difference between Mary's and Bill's speeds just like (2b), but the absolute form of the adverb *fast* introduces the contextually specified standard value, resulting in the interpretation "the difference between Mary's and Bill's speeds is greater than the contextually supplied degree," which makes no sense. This uninterpretability is due to the impossible comparison of sortally distinct extents: differential and degree extents.

The present paper is structured as follows. Section 2 briefly outlines the formal semantics of comparatives. In section 3, the semantics of the English comparative prefix *out-* is given to capture some characteristics of *out-V* sentences. Section 4 discusses the relation between the maximal event and its subevents with respect to extents denoted by gradable predicates. In section 5, it is shown that the ungrammaticality of (2a) can be accounted for without any other devices. Section 6 suggests that differential extents should be divided into positive and negative ones. Section 7 concludes this paper.

2. The semantics of comparatives

The truth conditions of a comparative sentence like *John is taller than Bill is* can be represented in several ways, and Heim (2000) gives the ones as in (3), where tall(j, d_1) is read as 'John is d_1-tall,' and max(λd_1[tall(j, d_1)]) stands for the maximal degree of John's tallness, namely John's height, and the whole truth conditions say that John's height is greater than Bill's height.

(3) $\max(\lambda d_1[\text{tall}(j, d_1)]) \geq \max(\lambda d_2[\text{tall}(b, d_2)])$

Based on the syntax of comparatives proposed in Bresnan (1973) as in (4), Heim (2000) assumes the LF representation as in (5).

(4) John is $[_{AP}$ $[_{DegP}$ -er [than Bill is $[_{AP}$ Op_2 tall]]]$_1$ tall]

(5) $[_{DegP}$ -er [Op_2 than Bill is $[_{AP}$ x_2 tall]]]$_1$ John is $[_{AP}$ x_1 tall]

The comparative morpheme *-er* and the *than*-clause make a constituent, DegP, which is generated in the specifier position of the AP headed by *tall*. At LF, the DegP undergoes QR, leaving behind the trace x_1. The *than*-clause contains the clause Bill is Op_2 tall, where Op_2 is degree operator, generated in the spec AP. This operator also moves to the clause initial position, leaving behind the trace x_2. The matrix clause 'John is $[_{AP}\ x_1$ tall]' is interpreted as the set of degrees to which John is tall. So is the embedded clause 'Bill is $[_{AP}\ x_2$ tall]'. The comparative morpheme is treated as generalized quantifier, which takes two sets of degrees, as in (6).

(6) $\|$ [-er[D2]][D1] $\|$ is true iff max(D1) $\geq$ max(D2)

Incidentally, at PF the *than*-phrase is postposed to the sentence-final position with the AP deleted, and the DegP head *-er* and the AP head *tall* are phonetically realized as *taller*.

The syntactic derivation of adverbial comparatives like (1b) is identical to the one of adjectival comparatives. The LF representation of (1b) is given in (7). With event semantics, the truth conditions of (7) can be represented as (8), where the manner adverb *fast* takes the event argument introduced by the verb *run* and the degree variable, meaning 'the event is d-fast.'

(7) $[_{DegP}$ -er [Op_2 than Bill ran $[_{AdvP}\ x_2$ fast]]]$_1$ Mary ran $[_{AdvP}\ x_1$ fast]

(8) $\max(\lambda d_1 \exists e_1[\text{running}(e_1) \wedge \text{agent}(m, e_1) \wedge \text{fast}(e_1, d_1)])$
$\geq \max(\lambda d_2 \exists e_2[\text{running}(e_2) \wedge \text{agent}(b, e_2) \wedge \text{fast}(e_2, d_2)])$

Logical representation (8) is read: the maximal degree of the speed of Mary's running event is greater than the maximal degree of the speed of Bill's running event.

3. The semantics of the English comparative prefix *out-*

Sentences with *out*-prefixed verbs have several interesting properties. Bresnan (1981) shows that *out*- serves to transitivize intransitive verbs.

(9) a. Mary outlasted John.
 b. The lamp outshines the candle.
 c. Few people outgrin the Cheshire cat.

Last, *shine* and *grin* are all intransitive verbs, but when *out*-prefixed, they are used as transitive verbs as in (9). Transitive verbs, on the other hand, cannot be *out*-prefixed as in (10).

(10) a. *The Brownies outfound the Girl Scouts in the treasure hunt.
 b. *Extroverts outlike introverts.

She also points out that some transitive verbs are intransitivized (by object deletion) as in (11), and then the intransitivized verbs are transitivized by *out*-prefixation as in (12).

(11) a. Mary spends freely.
 b. Mary guessed correctly.
 c. A centerfielder must throw well.
 d. Mary reads well for a 5-year-old.

(12) a. Mary outspent John.

b. The Brownies outguesses the Girl Scouts in the contest.

c. Among ballplayers, the extroverts outthrow the introverts.

d. At all ages, Russian children could outdraw, outspell, and outread their American counterparts.

Semantically, interpretations of *out*-Vs are context-dependent to some extend. For example, (1a) also can be interpreted as 'Mary ran further than Bill did,' in addition to (1b). Sentence *Mary outjumped Bill* is paraphrased with 'Mary jumped higher than Bill did' but it also can be interpreted as 'Mary jumped more than Bill did' in the context of playing with Pogo stick. Interestingly, however, (1a) is never interpreted as 'Mary ran slower than Bill did' even in the context of the "slow-running" race where the slowest runner is the winner. It thus seems reasonable to assume that the adverbial interpretation associated with *out-* is a positive one (i.e. high, fast, great, well).

Given these properties, I would like to propose the semantics of the English comparative prefix *out-* as in (13).

(13) Definition of *out-* (preliminary version)

$$\lambda P \lambda y \lambda x \exists df[\max(\lambda d_1 \exists e_1[P(x)(e_1) \wedge \Pi(e_1, d_1)])$$
$$= df + \max(\lambda d_2 \exists e_2\ [P(y)(e_2) \wedge \Pi(e_2, d_2)])]\text{, where } \Pi \text{ is positive.}$$

As observed above, *out-* can attach only to intransitive verbs. This fact can be captured by assuming that the prefix takes P of type <*e*, <*ev*, *t*>>. The variable Π is a contextually interpreted gradable adverbial predicate. If *out-* prefixes to *run*, the Π is interpreted as *fast* or *far*, depending on the context. The variables x and y correspond to the external and the internal arguments of the *out*-V sentence, respectively. Given that P is *run*, y *Bill*, x *Mary*, (1a) is represented as in (14), which says: there is a difference df such that the maximal speed of Mary's running event is greater than the maximal speed of Bill's running event by df.

(14) $\exists df[max(\lambda d_1 \exists e_1[running(e_1) \wedge agent(m, e_1) \wedge \Pi(e_1, d_1)])$
$= df + max(\lambda d_2 \exists e_2\ [running(e_2) \wedge agent(b, e_2) \wedge \Pi(e_2, d_2)])]$

Notice that the differential variable df is of type *d*, denoting an extent on the speed scale. In other words, df is no different from the usual degree variable type-wise, but they are different in sorts, which is very crucial in this paper.

The definition of *out-* given in (13) is not enough, however. The event argument associated with the host verb is bound by the existential quantifiers, but the eventuality of *out-V* sentences itself can be externally quantified, as shown in (15).

(15) a. Mary always outruns Bill.
b. Whenever Mary outruns Bill, she is happy.

(15a) for instance can be interpreted as follows: In all contextually relevant events, Mary outruns Bill and each of those events contains Mary's running event and Bill's running event. This suggests that the *out-V* actually owns an additional event argument, which contains subevents described by the host verb. Following Krifka (1989) among others, I introduce, as part of the definition of the definition of *out-*, the maximal event dominating subevents, as in (16). After existential closure on the event variable, we obtain the truth conditions of (1a) as in (17).

(16) Definition of *out-* (revised version)
$\lambda P \lambda y \lambda x \lambda e \exists df[MXE(e) \wedge max(\lambda d_1 \exists e_1[P(x)(e_1) \wedge \Pi(e_1, d_1) \wedge e_1 \subset e])$
$= df + max(\lambda d_2 \exists e_2[P(y)(e_2) \wedge \Pi(e_2, d_2) \wedge e_2 \subset e\ ])]$, where Π is positive.

(17) $\exists e \exists df[MXE(e) \wedge max(\lambda d_1 \exists e_1\ [running(e_1) \wedge agent(m, e_1) \wedge \Pi(e_1, d_1)$
$\wedge\ e_1 \subset e]) = df + max(\lambda d_2 \exists e_2\ [running(e_2) \wedge agent(b, e_2) \wedge \Pi(e_2, d_2)$
$\wedge\ e_2 \subset e\ ])]$

4. Extents of gradable predicates of the maximal event

The maximal event introduced in (16) serves as an argument of *fast(er)* in (2b), repeated as (18). This sentence undergoes LF derivation in the same way as the usual comparative sentences, as given in (19).

(18) Mary outran Bill faster than Sue did.
(19) $[_{DegP}$ -er [Op_6 than Sue outran Bill $[_{AdvP}\ x_6$ fast]]]$_3$ Mary outran Bill $[_{AdvP}\ x_3$ fast]

In this representation, the fastness of the maximal event denoted by the matrix clause and that denoted by the *than*-clause are compared. But what is the fastness of the maximal event? To consider this question, let me take an example as follows. Suppose someone says, “The car accident happened disastrously." That accident could consist of several subevents: cars clashed, some of the cars exploded, passersby were involved, some of the victims died in cruel ways, and so on. Each subevent is related to degrees: how many cars were involved, how many people were involved, how huge the explosion was, how cruel the passersby were killed, and so on. Suppose further that the cruelness of the way of the victims' dying in the accident is great enough to consider the accident disastrous. Then the sentence *The car accident happened disastrously* can be regarded as felicitously uttered, even though the other subevents are not disastrous. In this case, the speaker perceives the victims' dying event is the most prominent, and judges the disastrousness of the maximal event based on this subevent's cruelness. This can be schematized as follows.

(20) Condition on the Extent of Gradable Predicates of the Maximal Event (CEGME): Let δ_S be the function from events to extents on scale S, $F_{S' \to S}$ the function from extents on S' to extents on S, e_{max} the maximal event, e_n its subevent. Then
$\delta_S(e_{max}) = F_{S' \to S}(\delta_{S'}(e_n))$, if $\delta_{S'}(e_n)$ is the most prominent.

In the scenario above, δ_S corresponds to *disastrous*, and $\delta_{S'}$ to *cruel*. Since (the speaker recognizes) the victims' dying event e_4 is the most prominent, the CEGME gives us $\delta_{disastrous}(e_{max}) = F_{cruel \to disastrous}(\delta_{cruel}(e_4))$, which says the cruelness of the victims' dying event is identical to the disastrousness of the maximal event.

Now let us go back to (18). In the matrix clause *Mary outran Bill (faster)*, there are at least three extents involving its subevents: Mary's speed, Bill's speed, and the difference between them. It is reasonable to regard the differential extent as the most prominent in the *out-V* sentence since it asserts a difference. Then by the CEGME, we get (21), where the function F is trivial, and the event variables e_1, e_2, and e_3 stand for Mary's running event, Bill's running event, and the maximal event, respectively.

(21) $\delta_{fast}(e_3) = F_{fast \rightarrow fast}(\delta_{fast}(e_1) - \delta_{fast}(e_2))$

By the same token, the CEGME guarantees that the fastness of the maximal event in the *than*-clause is equal to the difference between Sue's speed and Bill's speed.

LF representation (19) illustrates that the degree operators $DegP_3$ and Op_6 λ-abstract over the set of extents of the maximal events' speeds. But (21) says based on the CEME that the speed of the maximal event is equal to the differential extent denoted by the *out-V* sentence. In (22), the most prominent extents, the differential extents in the case, are represented with superscripts: 3 in the matrix clause and 6 in the *than*-clause.

(22) $[_{DegP}$ -er $[Op_6^6$ than Sue out^6-ran Bill $[_{AdvP}\ x_6$ fast$]]]_3^3$ Mary out^3-ran Bill $[_{AdvP}\ x_3$ fast$]$

LFs like (22) translate into logical representations in (23i), where df^n is the variable of the most prominent extent. (23i) is rewritten as in (23ii), in which the existential quantifier binding df^n is "wiped off" and instead the extent/degree variable d_n created via DegP movement is existentially bound. This is guaranteed by the CEGME.

(23) $\text{DegP/Op}_n{}^n[\text{IP}] \quad \rightsquigarrow \quad \lambda d_n \exists df^n[\phi]$ (i)

$\Rightarrow \lambda df^n \exists d_n[\phi]$ (ii)

Equipped with these assumptions, (22) is first represented as (24), where the maximal speed of the maximal event e_3 is compared with that of the maximal event e_6. And then it is rewritten as (25), where the maximal difference of Mary's and Bill's speeds and that of Sue's and Bill's speeds are compared.

(24) $\max(\lambda d_3 \exists df^3 \exists e_3[\text{MXE}(e_3) \wedge \text{fast}(e_3, d_3)$

$\wedge \max(\lambda d_1 \exists e_1[\text{running}(e_1) \wedge \text{agent}(m, e_1) \wedge \Pi(e_1, d_1) \wedge e_1 \subset e_3])$

$= df^3 + \max(\lambda d_2 \exists e_2 [\text{running}(e_2) \wedge \text{agent}(b, e_2) \wedge \Pi(e_2, d_2) \wedge e_2 \subset e_3])\ ])$

$\geq \max(\lambda d_6 \exists df^6 \exists e_6[\text{MXE}(e_6) \wedge \text{fast}(e_6, d_6)$

$\wedge \max(\lambda d_4 \exists e_4[\text{running}(e_4) \wedge \text{agent}(s, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$

$= df^6 + \max(\lambda d_5 \exists e_5[\text{running}(e_5) \wedge \text{agent}(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])\ ])$

(25) $\max(\lambda df^3 \exists d_3 \exists e_3[\text{MXE}(e_3) \wedge \text{fast}(e_3, d_3)$

$\wedge \max(\lambda d_1 \exists e_1[\text{running}(e_1) \wedge \text{agent}(m, e_1) \wedge \Pi(e_1, d_1) \wedge e_1 \subset e_3])$

$= df^3 + \max(\lambda d_2 \exists e_2 [\text{running}(e_2) \wedge \text{agent}(b, e_2) \wedge \Pi(e_2, d_2) \wedge e_2 \subset e_3])\ ])$

$\geq \max(\lambda df^6 \exists d_6 \exists e_6[\text{MXE}(e_6) \wedge \text{fast}(e_6, d_6)$

$\wedge \max(\lambda d_4 \exists e_4[\text{running}(e_4) \wedge \text{agent}(s, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$

$= df^6 + \max(\lambda d_5 \exists e_5[\text{running}(e_5) \wedge \text{agent}(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])\ ])$

In (25), two differences are compared, which reflects our intuition about the interpretation of (18). The full derivation of (18) is given in Appendix.

5. Absolute forms

Before showing the derivation of the ungrammatical sentence (2a), repeated as (26), let me remind you the semantics of a sentence with the absolute form of adjectives/adverbs, like *Mary ran fast*. It is widely assumed (cf. von Stechow (1984) and Kennedy (1997) among many others) that as shown in (27), the absolute form accompanies with the null degree morpheme *pos*, which translates into the variable d_P of type *d*, degree-sort, as in (28).

(26) *Mary outran Bill fast.

(27) Mary ran *pos*-fast.

(28) $\|pos\|$ ~> d_{pos}

Given the morpheme *pos*, the truth conditions of (27) are represented as in (29), and the fastness of the event is defined as in (30).

(29) $\exists e_1[\text{running}(e_1) \wedge \text{agent}(m, e_1) \wedge \text{fast}(e_1, d_{pos})]$

(30) $\text{fast}(e, d_{pos}) = 1$ iff d_{pos} is greater than the contextually specified degree.

Thus (29) means that Mary's running event is faster than the contextually given degree.

With the definition of *pos* in (28), the truth conditions of (26) are represented as (31), which translates into (32) by the CEGME.

(31) $\exists df\exists e_3[\text{MXE}(e_3) \wedge \text{fast}(e_3, d_{pos})$

$$\wedge\ \max(\lambda d_1 \exists e_1[\text{running}(e_1) \wedge \text{agent}(m, e_1) \wedge \Pi(e_1, d_1) \wedge e_1 \subset e_3])$$
$$= df + \max(\lambda d_2 \exists e_2\ [\text{running}(e_2) \wedge \text{agent}(b, e_2) \wedge \Pi(e_2, d_2) \wedge e_2 \subset e_3\ ])\ \ ]$$

(32) $\exists df^3 \exists e_3[\text{MXE}(e_3) \wedge \text{fast}(e_3, d_{pos})$
$$\wedge\ \max(\lambda d_1 \exists e_1[\text{running}(e_1) \wedge \text{agent}(m, e_1) \wedge \Pi(e_1, d_1) \wedge e_1 \subset e_3])$$
$$= df^3 + \max(\lambda d_2 \exists e_2\ [\text{running}(e_2) \wedge \text{agent}(b, e_2) \wedge \Pi(e_2, d_2) \wedge e_2 \subset e_3\ ])\ \ ]$$

This logical representation amounts to saying that the difference between Mary's speed and Bill's speed is greater than the standard value contextually given. This comparison is impossible since differences and the contextually provided values are ontologically different objects. Thus (26) is ungrammatical.

6. Positive and negative differential extents

Gradable predicates can be divided into positive and negative, and in most cases, they constitute antonym pairs such as *high-short*, *fast-slow*, *expensive-cheap*, and so on. Kennedy (2001) argues that positive and negative degrees should be regarded as being sortally different, and examples like (33), known as cross-polar anomaly, are ungrammatical because of the impossibility of comparison of different sorts.

(33) a. *John is taller than Mary is short.
b. *Mars is closer than Pluto is distant.

One might claim that these are ungrammatical since two different scales such as the tallness scale and the shortness scale are used for comparison. This claim is not correct, however. The antonym pair should be dealt with on an identical scale. The bidirectional relation between two sentences in (34) must be captured in any theory of gradable predicates, and this is possible if *tall* and *short* are related to extents on the same scale (cf. Kennedy (2001)).

(34) a. John is taller than Mary is. ↔ Mary is shorter than John is.
b. Mars is closer than Pluto is. ↔ Pluto is more distant than Mars is.

The difference between positive and negative degrees is the matter of perspectives. For example, in (35) the extent from the zero point to *J* stands for John's tallness, which is a positive extent, and the rest of the extent on that scale denotes John's shortness, which is a negative extent.

(35)
$$\text{height: } 0\overbrace{\text{————————————}}^{\text{John's tallness (positive extent)}}J\overbrace{\text{————————————}}^{\text{John's shortness (negative extent)}}> \infty$$

The bidirectional relation in (34) can be captured as illustrated in (36), where the extent of John's tallness is greater than the extent of Mary's tallness (*John is taller than Mary is*), and the extent of Mary's shortness is greater than the extent of John's shortness (*Mary is shorter than John is*).

(36)
John's tallness John's shortness
height: 0——————*M*——————*J*——————————————> ∞
Mary's tallness Mary's shortness

Kennedy (2001) attributes the ungrammaticality of the cross-polar anomaly in (34) to the impossibility of comparison of two degrees which are different in sort: John's tallness cannot be compared with Mary's shortness because the former is positive while the latter negative.

It is interesting to ask if there is a positive-negative distinction as such in differential extents. In other words, is the deferential phrase 2 *inches* in (37a) the same as the one in (37b) with respect to the polarity of extents?

(37) a. John is 2 inches taller than Mary is.
b. Mary is 2 inches shorter than John is.

Suppose differential extents are polar-neutral. Then, it is predicted that (38) is grammatical just like (2b)/(18). But this is not the case.

(38) *Mary outran Bill more slowly than Sue did.

The logic of this (wrong) prediction goes as follows. The intended reading of (38) is 'the slowness of the maximal event denoted in the matrix clause is greater than the slowness of the maximal event of *than*-clause.' The CEGME requires that the former is identical with the difference between Mary's and Bill's speeds, and the latter is with the difference between Sue's and Bill's speeds, since those differences are the most salient extents among the extents concerning the subevents. If differential extents were polar-insensitive, the differential extents of slowness could be identified with the differential extents of fastness. Nothing seems wrong, but the sentence is ungrammatical.

It should be thus concluded that differential extents bear the positive-negative dichotomy as well as degrees. A differential extent derived by subtracting a positive extent from another is also positive, and the same is applied to a negative differential extent. To account for the ungrammaticality of (38), I slightly revise the CEGME as in (39), where a gradable predicate of the maximal event and that of the most salient subevent are required to share the polarity direction.

(39) Condition on the Extent of Gradable Predicates of the Maximal Event (CEGME) (revised):
Let δ_S be the function from events to extents on scale S, $F_{S'\rightarrow S}$ the function from extents on S' to extents on S, e_{max} the maximal event, e_n its subevent. Then
$\delta_S(e_{max}) = F_{S'\rightarrow S}(\delta_{S'}(e_n))$, if $\delta_{S'}(e_n)$ is the most prominent, where the polarities of δ_S and $\delta_{S'}$ are the same.

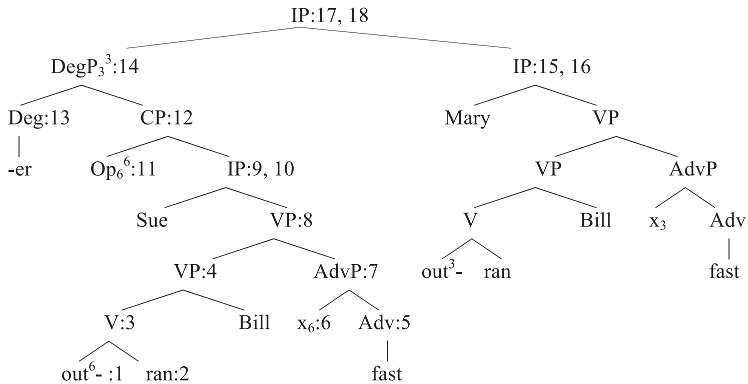
The definition of *out-* given in (16) contains the free variable Π, which is interpreted as positive. In the *outrun*-context, it denotes positive extents on the speed scale. Thus Mary's and Bill's speeds are both positive, and the difference between the two positive extents is also positive. On the other hand, the extent denoted by *(more) slowly* is negative, so the CEGME in (39) does not allow the slowness of the maximal event to be regarded as being identical with the difference between Mary's and Bill's speeds because of the difference of polarity.

7. Conclusion

This paper has argued that differential extents are not compared with degree extents due to the sortal difference, and it has been shown that the ungrammaticality of (2a) follows from this claim. It has been also shown that the truth conditions of the new data in (2b) is derivable with the supplemental condition requiring that the fastness of the maximal event is identical to the most prominent extent among the subevents' fastnesses. The present paper has also claimed that differential extents have the positive-negative distinction as well as degrees.

Appendix: Derivation of (18) with the CEGME

(18) Mary outran Bill faster than Sue did.



1. $\lambda P\lambda y\lambda x\lambda e\exists df^6[\text{MXE}(e) \wedge \max(\lambda d_4\exists e_4[P(x)(e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e])$
$= df^6 + \max(\lambda d_5\exists e_5[P(y)(e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e])]$
2. $\lambda x\lambda e[\text{running}(e) \wedge \text{agent}(x, e)]$
3. $\lambda y\lambda x\lambda e\exists df^6[\text{MXE}(e) \wedge \max(\lambda d_4\exists e_4[\text{running}(e_4) \wedge \text{agent}(x, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e])$
$= df^6 + \max(\lambda d_5\exists e_5[\text{running}(e_5) \wedge \text{agent}(y, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e])]$
4. $\lambda x\lambda e\exists df^6[\text{MXE}(e) \wedge \max(\lambda d_4\exists e_4[\text{running}(e_4) \wedge \text{agent}(x, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e])$
$= df^6 + \max(\lambda d_5\exists e_5[\text{running}(e_5) \wedge \text{agent}(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e])]$

5. $\lambda d\lambda P\lambda x\lambda e_6[P(x)(e_6) \wedge fast(e_6, d)]$

6. d_6

7. $\lambda P\lambda x\lambda e_6[P(x)(e_6) \wedge fast(e_6, d_6)]$

8. $\lambda x\lambda e_6\exists df^6[MXE(e_6) \wedge max(\lambda d_4\exists e_4[running(e_4) \wedge agent(x, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$
$= df^6 + max(\lambda d_5\exists e_5[running(e_5) \wedge agent(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])] \wedge fast(e_6, d_6)]$

9. $\lambda e_6\exists df^6[MXE(e_6) \wedge max(\lambda d_4\exists e_4[running(e_4) \wedge agent(s, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$
$= df^6 + max(\lambda d_5\exists e_5[running(e_5) \wedge agent(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])] \wedge fast(e_6, d_6)]$

10. (by existential closure)
$\exists e_6\exists df[MXE(e_6) \wedge max(\lambda d_4\exists e_4[running(e_4) \wedge agent(s, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$
$= df + max(\lambda d_5\exists e_5[running(e_5) \wedge agent(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])] \wedge fast(e_6, d_6)]$

11. (λ-operator binding d_6)

12. $\lambda d_6\exists e_6\exists df^6[MXE(e_6) \wedge max(\lambda d_4\exists e_4[running(e_4) \wedge agent(s, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$
$= df^6 + max(\lambda d_5\exists e_5[running(e_5) \wedge agent(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])] \wedge fast(e_6, d_6)]$

13. $\lambda D_2\lambda D_1[max(D_1) \geq max(D_2)]$

14. $\lambda D_1[max(D_1)$
$\geq max(\lambda d_6\exists e_6\exists df^6[MXE(e_6) \wedge max(\lambda d_4\exists e_4[running(e_4) \wedge agent(s, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$
$= df^6 + max(\lambda d_5\exists e_5[running(e_5) \wedge agent(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])]$
$\wedge fast(e_6, d_6)])]$

15. $\exists e_3\exists df^3[MXE(e_3) \wedge max(\lambda d_1\exists e_1[running(e_1) \wedge agent(s, e_1) \wedge \Pi(e_1, d_4) \wedge e_1 \subset e_3])$
$= df^3 + max(\lambda d_5\exists e_2[running(e_2) \wedge agent(b, e_2) \wedge \Pi(e_2, d_5) \wedge e_2 \subset e_3])] \wedge fast(e_3, d_3)]$

16. (λ-abstraction of d_3)
$\lambda d_3\exists e_3\exists df^3[MXE(e_3) \wedge max(\lambda d_1\exists e_1[running(e_1) \wedge agent(s, e_1) \wedge \Pi(e_1, d_4) \wedge e_1 \subset e_3])$
$= df^3 + max(\lambda d_5\exists e_2[running(e_2) \wedge agent(b, e_2) \wedge \Pi(e_2, d_5) \wedge e_2 \subset e_3])] \wedge fast(e_3, d_3)]$

17. $max(\lambda d_3\exists df^3\exists e_3[MXE(e_3) \wedge max(\lambda d_1\exists e_1[running(e_1) \wedge agent(s, e_1) \wedge \Pi(e_1, d_4) \wedge e_1 \subset e_3])$
$= df^3 + max(\lambda d_5\exists e_2[running(e_2) \wedge agent(b, e_2) \wedge \Pi(e_2, d_5) \wedge e_2 \subset e_3])$
$\wedge fast(e_3, d_3)])$
$\geq max(\lambda d_6\exists df^6\exists e_6[MXE(e_6) \wedge max(\lambda d_4\exists e_4[running(e_4) \wedge agent(s, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$
$= df^6 + max(\lambda d_5\exists e_5[running(e_5) \wedge agent(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])$
$\wedge fast(e_6, d_6)])$

18. (by the CEGME)

$$\max(\lambda df^3 \exists d_3 \exists e_3[MXE(e_3) \wedge \max(\lambda d_1 \exists e_1[running(e_1) \wedge agent(s, e_1) \wedge \Pi(e_1, d_4) \wedge e_1 \subset e_3])$$
$$= df^3 + \max(\lambda d_5 \exists e_2[running(e_2) \wedge agent(b, e_2) \wedge \Pi(e_2, d_5) \wedge e_2 \subset e_3])$$
$$\wedge fast(e_3, d_3)])$$
$$\geq \max(\lambda df^6 \exists d_6 \exists e_6[MXE(e_6) \wedge \max(\lambda d_4 \exists e_4[running(e_4) \wedge agent(s, e_4) \wedge \Pi(e_4, d_4) \wedge e_4 \subset e_6])$$
$$df^6 + \max(\lambda d_5 \exists e_5[running(e_5) \wedge agent(b, e_5) \wedge \Pi(e_5, d_5) \wedge e_5 \subset e_6])$$
$$\wedge fast(e_6, d_6)])$$

Notes

1. This claim dates back to Sauren (1978) and von Stechow (1984), and most recently it is advocated by Kennedy (2001), among many others.
2. Not all native speakers of English accept (2b), but even for those who do not think (2b) perfectly grammatical, the difference in grammaticality between (2a) and (2b) is very clear.

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