Single Event Probabilities

By

Maile Yeats

Submitted to the Pomona College Department of Linguistics and Cognitive Science in partial fulfillment of the requirements of the degree

Bachelor of Arts
At
Scripps College

April 2009

ABSTRACT

This thesis seeks to present a linguistic analysis of statements of single-event probability. Such statements, which seem to be statistically vacuous, have been seen as a puzzle to cognitive psychologists, given their frequent and productive use in both casual language (*There is a 30% chance of rain tomorrow*) and technical predictions (*A woman has a 30% chance of developing cancer*). Despite clear systematic influences of linguistic form on such statements almost no linguistic analysis on single-event probabilities has been done to date. I have identified four linguistic factors – tense, scope, the nature of the determiner, and the nature of the predicate – that systematically influence the interpretation of single-event probabilities, forcing the expected absurd reading. Using situation semantics, I construct an analysis for these statements that accounts for three of the four factors – scope, determiner, and predicate.

ACKNOWLEDGMENTS

My experience with the linguistics and cognitive science department at Pomona has been as stimulating an academic experience as any undergraduate could ask for. Every class I have taken and every professor in the department has contributed in some way to my final product here. First and foremost I would like to thank my readers and advisors, Martin Hackl and Stephanie Harves. Any serious intellectual work evident in my written outcome occurred in my weekly meetings with Martin, and advising sessions and classroom discussions with Stephanie.

I would also like to thank the innumerable friends and classmates who for nearly a year have put up with my demanding for their intuitions on obscure sentences and provided consistent and invaluable feedback. Finally I thank my parents and sisters for their unflagging support over the past four years and for never once asking what exactly I plan to *do* with my linguistics major.

TABLE OF CONTENTS

1. Introduction....4
2. Linguistic Factors in Single-Event Probabilities....6
2.1 Tense....6
2.2 Scope....7
2.3 Individual vs. Stage Level Predicate....9
2.4 Weak and Strong Determiners....13
2.5 Summary....15
3. A Situation Semantics Analysis of Single-Event Probabilities....15
3.1 Situation Semantics....16
3.2 Situation Semantics Applied to Single-Event Probabilities....19
3.3 Accounting for the Indefinite....22
3.4 Individual and Stage Level predicates....26
3.5 Tentative account for effects of tense....31
4. Summary and Outlook....32
5. References....35

1. Introduction

Statements denoting the probability of a one time occurring event are common fixtures in modern English. They are seen in the medical field (*there is an 80% chance a woman has cancer)*, meteorology (*there is a 30% chance of rain tomorrow*) and, perhaps most frequently, gambling (*there is a 3% chance you will roll snake eyes*). However, such single-event probabilities are statistically vacuous. Probabilities reflected as percentages ought to be used productively only as normalized frequencies, predicting the likely outcome of a series of events. The statements above ought to be used to describe the following situations:

1)

a. Of 100 women with conditions such as hers, 80 are expected to have cancer.

b. Of 100 days with conditions like tomorrow, it is expected to rain on 30.

c. Of 100 dice rolls, 3 are expected to be snake eyes.

Though some accounts of the content of statements of single-event probability have been advanced, none adequately addresses the varying interpretations of such statements or the reasons for their frequent use in English. A study by Gigerenzer et al (2005) suggests that, because the reference class is not made explicit in statements like “There is a 30% chance of rain tomorrow”, the listener fills in the reference class spontaneously based on their understanding of the situation. The way in which the listener fills in the reference

class varies across cultures (some believe it will rain in 30% of a given area, that it will rain 30% of the time, or that on 30% of days with tomorrow's conditions it is expected to rain – this study will be discussed in further detail below). Though the reference class varies, Gigerenzer et al assume that the salient interpretation of single-event probabilities is as a normalized frequency. Such an assumption is surprising as frequencies, by definition, can only meaningfully refer to a sequence of events, as in the examples in 1 a-c. The frequency of a one-time occurrence is gibberish. The research by Cosmides and Tooby (1996) agrees that single-event probabilities are understood as frequencies, and that they are used to express a psychological degree of confidence in the likelihood of an event. This account does not, however, explain what linguistic properties of single-event probabilities allow listeners to derive meaning from what ought to be a nonsensical statement. This research paper will attempt to provide an account of the linguistic properties of statements of single-event probability that may reveal why such apparently nonsensical statements are used so frequently and productively.

Why the puzzle of single-event probabilities ought to be approached from a linguistic standpoint is not immediately apparent. However, there is ample evidence that linguistic factors affect our ability to interpret and construct single-event probabilities. By making subtle syntactic and semantic changes to traditional single-event probability constructions, the expected absurd reading can be forced. The sentences in (2) demonstrate the odd and less acceptable readings.

2)

a. #There is a 30% chance that the marble I have drawn is blue.

b. #The marble I drew has a 30% chance of being blue.

The intuition for these sentences corresponds to what a statistician or mathematician would expect the intuition to be. Namely, an intuition that the marble either is or isn't blue and the expressions in (2) do not effectively communicate any productive knowledge of the actual world. The interactions of four linguistic factors are recognized in this paper as having such an effect on the interpretation of single-event probabilities – tense, scope, individual vs. stage level predicates and weak vs. strong determiners. I then present an analysis using situation semantics that accounts for the interactions of three of the four factors – scope, predicate and determiner.

2. Linguistic Factors in Single-Event Probabilities

2.1 Tense

Tense appears to play an interesting role in determining the acceptability of such statements. For example, if you are one of one hundred people to buy a lottery ticket for which there is one winner, before the ticket is drawn it is acceptable to say, "There is a 1% chance that I will win". However, after the ticket has been drawn but the winner not yet revealed, it does not seem as acceptable to say, "There is a 1% chance that I have won". At this point, either you have won or you have not. Such a distinction in acceptability is evidence that the content of these statements is more complex than a mere psychological degree of confidence, as

proposed by Cosmides and Tooby (1996). Specifically, the perfect tense appears to have the strongest effect on acceptability. Interestingly, the perfect tense affects the acceptability of a single-event probability as the tense of the complement clause as noted above, but also as the tense of the relative clause contained within the complement clause as in “There is a 1% chance that the ticket that I have drawn is the winner”.

2.2 Scope

In addition to the questions raised by tense, scope also plays a role in determining the meaning of single-event probabilities. Consider the following sentences, given a bag of ten marbles, three of which are blue.

3)

a. Mary knows that a marble in this bag is blue
b. There is marble in this bag such that Mary knows it is blue
c. There is a 30% chance that a marble drawn from this bag is blue.
d. #There is a marble drawn from this bag such that there is a 30% chance it is blue.

Note that in the sentences (3)a and (3)b, the clefting of (3)a does not result in an altered truth condition or level of acceptability in (3)b. Both (3)a and (3)b are grammatical and not offensive to a speaker’s understanding of the world. However, when sentence (3)c undergoes an identical clefting, the result in (3)d is clearly unacceptable. It seems clear in (3)d that a marble must be either blue or not blue and a notion of chance is not appropriate. The apparent result is that *a*

marble must be under the scope, or c-commanded by, the probability phrase *30% chance that*.

When *a marble* is not under the scope of the probability phrase, a *de re* reading is forced where there *is* some marble drawn which cannot allow for the property "a 30% chance it is blue". While under the scope of the probability phrase, a *de dicto* reading is salient, which allows for an acceptable interpretation of the single-event probability as a frequency applying to the act of drawing marbles from the bag. It is still an interesting question as to how and why a *de dicto* reading derives a frequency from a single-event probability.

The effect of scope on single-event probabilities is also evident in the difference between the acceptability of such statements in raising and control structures. Consider the following sentences, using the same situation as (3)a-d.

4)

a. #[A marble drawn from the bag]$_i$ has a 30% chance of [PRO]$_i$ being blue.

b. ?[A marble drawn from the bag]$_i$ is 30% likely [t_i]to be blue.

Sentence (4)a demonstrates control structure, where *a marble* originates in the subject position, outside of the scope of statement of probability, which accounts for its lower level of acceptability from (4)b. There is no available interpretation where *a marble* is within the scope of the statement of probability. (4)b, however, represents a raising structure where *a marble* originates in the

subject position of the infinitival phrase *a marble to be blue*, then raises to the matrix subject position to receive nominative case. At the level of logical form, reconstruction allows for a reading where *a marble* is still under the scope of the statement of probability, yielding an acceptable reading. The unacceptable reading where *a marble* is outside the scope of the probability phrase is also available at LF, resulting in ambiguity between an acceptable and unacceptable interpretation of the raising structure. The control structure, on the other hand, has no accessible acceptable reading.

2.3 Individual vs. Stage Level Predicate

The effects of clefting and differences in acceptability of raising and control structures provide compelling evidence for concluding that the scope of the probability statement plays a primary role in determining the meaning of single-event probability statements. However, there is also evidence that acceptability is largely determined by the properties of the subordinate predicate. Consider the following sentences:

5)

a. There is a 30% chance that a woman in this house knows French.

b. #There is a woman in this house such that there is a 30% chance she knows French.

c. ?A woman in this house is 30% likely to know French.

d. #A woman in this house has a 30% chance of knowing French.

These sentences, which demonstrate the same patterns of acceptability as (3)c-d and (3)a-b, contain the individual-level predicate "knows French". Individual-level predicates are true of individuals throughout their existence or major portions of their existence. Predicates like *be blue* (in the marble's non-metaphorical case), *be intelligent, be Canadian* are all individual-level predicates. The predicates in sentences (5)a-b are known as stage-level predicates. Stage-level predicates express transitory properties of individuals. They are true not throughout an individual's existence but at certain stages, such as *be happy, be home, be arrested*. Now, contrast the acceptability of sentences in (5) with the sentences in (6).

6)

a. There is a 30% chance that a woman with such conditions develops cancer.

b. There is a woman with such conditions such that there is a 30% chance she develops cancer.

c. A woman with such conditions is 30% likely to develop cancer.

d. A woman with such conditions has a 30% chance of developing cancer.

Single-event probabilities appear to be acceptable in clefted and control sentences where the subject NP is not within the scope of the probability phrase. The preference for stage-level predicates in probability statements is supported by the properties of certain predicates that are ambiguous between stage-level and individual-level interpretations. In the following example, (7)a represents the individual-level interpretation and (7)b represents the stage-level interpretation.

7) Firemen are available.

a. Firemen are, by nature, available.

b. There are firemen who are available right now.

This sentence on its own seems perfectly ambiguous, however, when used as the subordinate clause in single-event probability statement, a stage-level reading is forced.

8) There is a 30% chance that firemen are available

a. There is a 30% chance that firemen are available right now.

b. #There is a 30% chance that firemen are, by nature, available.

This forced stage-level reading of an ambiguous sentence presents additional evidence that stage-level predicates possess properties that allow them to be acceptably modified by a single-event probability operator. However, not all stage-level predicates have the same level of acceptability. As a class, those stage-level predicates expressing location have patterns of acceptability more analogous to those of individual-level predicates.

9)

a. There is a 30% chance that a friend from school is home.

b. #There is a friend from school such that there is a 30% chance she is home.

c. #A friend from school is 30% likely to be home.

d. #A friend from school has a 30% chance of being home.

Predicates that express temporal location demonstrate a parallel pattern of acceptability:

10)

a. There is a 30% chance that a friend from school left yesterday.

b. #There is a friend from school such that there is a 30% chance she left yesterday.

c. ?A friend from school is 30% likely to have left yesterday.

d. #A friend from school had a 30% chance of having left yesterday.

The generalization at this point is that with individual-level predicates in the subordinate clause, the subject must be within the scope of the probability phrase "30% chance", while stage-level predicates in the subordinate clause are acceptable regardless of scope, with the exception of stage-level predicates describing spatio-temporal location.

A discussion of stage and individual-level predicates in Kratzer (1989) argues that the differences in interpretation and distribution of these predicate types arise from a difference in argument structure. She argues that stage-level predicates have an extra argument for spatio-temporal location, allowing them to be modified by spatial and temporal expressions such as *this morning* and *in the room*. By this account, the extra argument position of stage-level predicates introduces an extra variable that is available to be bound by spatio-temporal expressions and quantifiers. The sentences in 10 are analogous to sentences 5 and 6, respectively.

11)

a. #A woman in this house always knows French

b. A woman with such conditions always develops cancer.

The difference in acceptability between sentences (11)a and (11)b are due to the prohibition against vacuous quantifiers, which states that for any quantifier (the quantificational adverb *always*) there must be some variable that it can bind. The individual-level predicate in (11)a does not contain the extra variable to be bound while the stage-level predicate in (11)b does. The similarity in acceptability judgments of (11)a-b and (5) and (6) suggest that the probability phrase *30% chance* bears a strong relation to other spatio-temporal operators that require an additional argument to bind. Such an explanation would also explain the pattern of acceptability seen in sentences (9) and (10). Although they are stage-level predicates, the extra argument for spatio-temporal location is already restricted by the content of the phrases *be home* and *yesterday*. However, this explanation does not account for the acceptability of individual-level predicates in structures like (5)a, which still suggest that scope of the probability phrase over the subject plays a crucial role in determining acceptability. For these sentences, we will see that the role of the determiner as well as scope are influential factors.

2.4 Weak and Strong Determiners

In most of the examples used above, the indefinite determiner *a* has been used. We will see later that the indefinite has certain properties that affect the domain of single-event probability operators. It is important to note that sentences that are expected to be acceptable based on their structure are rendered unacceptable due to a determiner forcing a *de re* reading.

12)

a. There is a 30% chance that a marble drawn from this bag is blue.

b. #There is a 30% chance that the marble in my hand is blue.

The sentences in 11 demonstrate a strong preference for the indefinite determiner with respect to the definite. The indefinite and definite determiners are representative of two groups of determiners, weak and strong, respectively. Strong determiners include demonstratives (*this, that*) and quantifiers that more strictly delineate the parameters of the NP such as *every* and *most*. Weak determiners, on the other hand, allow for more of a scale. They include quantifiers like *some* and *a few* as well as bare plurals. A convenient account of the distribution of determiners would be that all weak determiners are acceptable under a single-event probability and all strong determiners are unacceptable, as is suggested by (12). However, there are a few interesting points of deviation.

Both indefinite determiners and bare plurals are weak determiners, and are generally expected to have very similar, if not identical distribution patterns. However, under single-event probabilities, different readings arise.

13)

a. There is a 30% chance that a Pomona student is Hispanic.

b. #There is a 30% chance that Pomona students are Hispanic.

In addition to this odd distinction between indefinite determiners and bare plurals, the definite determiner appears to be acceptable depending upon the nature of the NP.

14)

a. #There is a 30% chance that the man in my store is Japanese

b. There is a 30% chance that the man who broke into my store is Japanese

When "the man in my store" describes a specific, known person, an unacceptable reading arises. However, when the definite determiner is used to describe an unknown person identifiable only be the description that is true of him, as in 13b, the statement seems fine.

2.5 Summary

At this point, there appear to be four major factors influencing the acceptability of statements of single-event probability. Those factors are tense, scope, the nature of the VP or predicate and the type of DP. Complement clauses in the past-perfect and DP's modified by relative clauses in the past perfect both result in unacceptable readings. The variables of scope include raising structures, control structures, and structures with the DP within the scope of the quantifier. The three variables of the VP that have been addressed are individual-level, stage-level and stage level with location restriction. The major variables of the DP are strong versus weak determiners. Weak determiners include indefinites, bare plurals, *some, a few*, etc. Strong determiners include definites, demonstratives, partitives, *every, most,* etc.

3. A Situation Semantics Analysis of Single-Event Probabilities

To fully understand the nature of single-event probability operators, it will be necessary to understand the interactions between all variables of the four factors. For the purposes of this paper, however, the interactions are too varied and too complicated to be discussed in detail. The remainder of the discussion will be dedicated too developing an analysis of single-event probabilities based on the role of definite and indefinite DP's on domain restriction, the argument structure of individual and stage-level predicates and how both of these factors are affected by scope in raising and control structures.

3.1 Situation Semantics

Crucial to understanding how single-event probabilities work is understanding what, exactly, they are quantifying over. We know that when uttering (12a) the marble is necessarily either blue or not blue. The quantifier *30% chance* does not express any gradation of a characteristic of a marble. So, what kind of linguistic entity, if not the property of a given marble, is the quantifier ranging over? I propose that the domain of the quantifier consists of possible situations, as they are explained in Kratzer 2006.

Situation semantics proposes the idea that the truth of an utterance depends on the specific situation about which the utterance is made. The foundations of situation semantics come from the theory of topic situations as proposed by John L. Austin in 1950. The sizes of these situations vary; they can be very large or very small parts of the actual world. It is this variation in size that may allow situation semantics to account for implicit domain restriction. Implicit

domain restriction occurs when the domain of a quantifier is restricted based on the information available with a specific situation. For example, if a friend and I walk into a busy dining hall, looking for people we're supposed to meet and see that they haven't arrived, I could felicitously comment to my friend:

15) Nobody is here yet.

Although (15) is apparently contradictory given the context of the utterance, the relatively minimal topic situation restricts the domain of the quantifier. The topic situation involves only the people I am looking for, which allows me to use the quantifier *nobody*, even though I know that they are not the only people in the world.

Based on Austinian topic situations, my assertion in (12)a is not about the marble, but about a more maximal situation including the entire bag of marbles and my act of drawing one. What you are trying to communicate is not that the marble may or may not be blue, but that in thirty percent of the situations accessible from the actual world based on the information you have, the marble is blue. Kratzer 2006 provides discussion of situation semantics and domain restriction with reference to the modal operator *might*.

Kratzer uses the following example to defend the view that propositions are not made about individuals, but rather about the situation that contains them. Driving at night in a national park, you see a bear cross the road. Because

you are generally not familiar with bear classification and could not see the bear well you may exclaim (16) to your partner.

(16) The bear might be a grizzly

Sentence (16) is made in reference to the Austinian topic situation of "Bear Sighting" – a situation that involves the entire incident described above. Included in this situation is one specific bear, called Bruno. The topic situation, and the possible situations that are accessible from it, are different from possible worlds in that they contain partial information. Bruno is not the only bear in the world, but he is the only bear in the relevant situation. If the topic situation is required to restrict the domain of (16), then the domain is necessarily restricted to Bruno, the only bear in "Bear Sighting". This restriction may lead to the interpretation of the sentence as being a statement ascribing properties to Bruno, instead of describing the relation between the evaluation situation, "Bear Sighting" and the possible situation, compatible with our knowledge in "Bear Sighting", in which the bear is a grizzly.

Under the normal possible worlds analysis of modals, modal operators are said to express a relation between the evaluation world or real world, and all worlds accessible from the evaluation world that are compatible with our knowledge. The following lexical entry for *might*, still from Kratzer 2006, upholds this interpretation.

(17) $[[\textit{might}]]^c = \lambda s \lambda p \ \exists s' \ [Acc_c (s)(s') \ \& \ p(s')]$

This analysis states that in context c there is a situation s' that is accessible based on our knowledge from the situation s and a proposition p is true of the situation s'. As a modal operator, *might* is assumed to have a raising structure, meaning that the logical form for (16) is [might][s[the bear][be grizzly]]. The modal takes as its sister node a proposition that is true in a certain situation s. Using the lexical entry for *might* in (17), situation semantics gives the following interpretation of (16).

(18) $[[(26)]]^c = \lambda s \ \exists s'[Acc_c(s) (s') \ \& \ grizzley(ix\ bear(x)(s'))(s')]$

This interpretation says that the proposition in (16) is true of a situation s ("Bear Sighting") iff there is a situation s' that is accessible from s (compatible with our information) and the unique bear in s' is a grizzly in s'. In other words, the word *might* in the proposition introduces epistemic modality, in which we are considering situations that are possible alternatives to "Bear Sighting" given our limited knowledge. Statement (16) is true of "Bear Sighting" regardless of whether the bear is a grizzly or black bear, what makes it true is merely that it is a possible alternative.

3.2 Situation Semantics Applied to Single-Event Probabilities

Tweaking Kratzer's example to shed some light on single-event probabilities, let's say that though you know little about bears, you know that

grizzlies make up about 30% of the bears in the park, the remaining 70% being black bears. This is "Bear Sighting 2" You therefore may comment to your companion (19).

(19) There is a 30% chance the bear is a grizzly.

Once again, the topic situation "Bear Sighting 2" has apparently restricted the domain to one bear. It appears as though (19) is "about" Bruno. However, as in "Bear Sighting", the real domain over which the modal operator in (19) is ranging is the set of situations accessible from "Bear Sighting 2". Similar to the modal *might*, the presumed simplified logical form of (19) is [30% chance][(P)]. Following the example of partial situation semantics, the presumed lexical entry for [[30% chance]] may be as follows.

(20) $[[30\%\ \text{chance}]]^c(S)(P) = 1$ iff $\lambda P.\ \lambda S.\ |P \cap S| = 30\% \mid S|$

This proposed lexical entry for *30 % chance* says that the number of situations in which the proposition P is true is equal to 30% the set of situations epistemically accessible from the topic situation[1]. Where P is the set of situations where [[the bear]] [be grizzly]] is true, and the set of situations compatible with your knowledge of the world are S, (21) should be an appropriate analysis for (19)

[1] I ignore here whether bare numerals, which 30% is an example of, have an "at least" or an "exact" semantics. i.e., whether (19) an accurate description of a situation where P is true in 50% of situations epistemically accessible from the topic situation.

(21) $[[(19)]]^c = 1$ iff $\lambda S. |(grizzley(bear(x)) \cap S| = 30\% \mid S|$

However, the quantifier *30% chance* is trickier to get right than *might* for one important reason. Where *might* only requires that the proposition be true in at least one situation that is consistent with our knowledge of the world, a single-event probability operator has much more specific, numerically quantified parameters. The sentences we have worked with so far, (16) and (19), both use the definite determiner *the*, which contains a uniqueness condition, automatically restricting possible situations to those situations that contain exactly one bear. Situations containing no bears or multiple bears are not accessible because they are not consistent with our knowledge of the world in the context within which the sentence was uttered. The analysis provided in (18) works fine for such sentences. However, when the indefinite quantifier is used, the analysis predicts a false sense, when the intuition is that it is true. Consider, for example, (6)a reprinted below:

(22) A woman with such conditions has a 30% chance of developing cancer.

The topic situation in (22) is extremely inclusive, effectively including every situation of every possible size that is consistent with your knowledge of the world. Situations that are accessible from the topic situation do not necessarily contain *a woman with such conditions*. Effectively, accessible situations are

infinite. However, as a brief diagnostic to demonstrate why (20) predicts a false reading, let's say there are exactly 100 possible situations that are consistent with my knowledge of the world. Only 10 of those situations contain *a woman with such conditions*. The other 90 are situations that vary wildly from something like "my bed room between 9:15 and 9:30 PM 3 April 2009" to "The Revolutionary War" or "Bear Sighting". Of the ten situations that contain *a woman with such conditions*, in three of them *a woman with such conditions develops cancer*.

Using the analysis in (20), the predicted intuition is that (22) is false. Where P is the set of situations where the proposition is true and S is the set of situations consistent with my knowledge of the world, $|P \cap S| = 30\% |S|$.

However, the intuition for this sentence is fine. (22) is consistent with the idea that the proposition is true of 30% of the situations containing *a woman with such conditions*, not every situation compatible with my knowledge of the world.

3.3 Accounting for the Indefinite

This thesis is supported in Percus (1998) in which he presents evidence that adverbial quantifiers such as *always, usually* and *rarely*, though quantifying over situations, appear to quantify over individuals.

23)

a. A blue eyed bear is usually intelligent.

b. Most blue eyed bears are intelligent.

The puzzling intuition that 22a seems to express the same thing as (23)b is roughly analogous to the puzzle of single-event probabilities, where (24)a expresses the same thing as (24)b.

24)

a. There is a 30% chance that a blue eyed bear is intelligent.

b. 30% of blue eyed bears are intelligent.

In 23, the adverbial quantifier that ought to have a domain of situations instead appears to quantify for individuals. In 24, the probability statement that ought to express the outcome of a series of events, expresses the composition of a set of individuals.

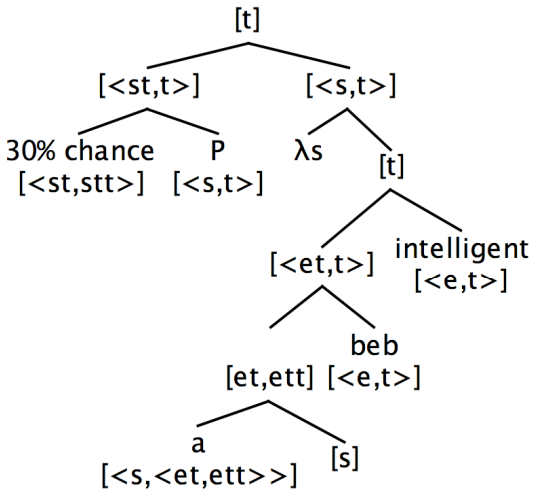
Percus (1998) suggests that sentences that contain indefinite DP's (*a*) and adverbial quantifiers with no contextually salient domain of situations, a covert "propredicate" is present. This propredicate functions as the restrictive scope of the adverbial quantifier. Interpreted in the same way as a pronoun, the propredicate must have an antecedent. Finding this antecedent is tantamount to finding the domain of the quantifier. Percus asserts that the indefinite determiner in 22a carries a presupposition that the set of situations in the propredicate antecedent holds a one-to-one relation with the set of *blue eyed bears*. So, every situation in the domain of *usually* in 22a contains exactly one *blue eyed bear*, and every *blue eyed bear* is contained by exactly one situation. Given this

interpretation, 23a is true if and only if most of the situations in the domain of *usually* are such that *a blue eyed bear is intelligent*. Because the domain of *usually* holds a one-to-one relation to the set of *blue eyed bears*, 23a entails 23b.

A simplified tree structure for the logical form of (24)a is provided in (25). The structure here is assumed to be analogous to that proposed in Percus 1998 for (23)a.

(25)

a. [30% chance][a beb][be intelligent]



Observing the sister node of *30% chance*, the "propredicate" P functions as the quantifier's restrictive argument. Because no contextually salient set of situations is available, the antecedent for the "propredicate", and therefore the domain of the *30% chance*, is a set of situations in a one-to-one relation with the set of blue-eyed bears. It is not clear how the antecedent of P could contain information that

P can't "see", as the set of blue-eyed bear is embedded within the right side of the tree within the nuclear argument, λs which represents the set of situations in which the proposition is true.

The notion of presupposition projection as developed in Heim 1983 explains how the set of P-situations is in a one-to-one relation with the set of *blue-eyed bears*. A generalized approach says that if a sentence assigns a property Z to an entity, which presupposes a property Z', and an additional sentence says a certain proportion of entities with property Y also have property Z, then the sentence presupposes that all entities with property Y also contain property Z'. Because of a uniqueness condition in [[a]], [[a]]([[s_1]])([[beb]]) is defined iff [[s_1]] contains exactly one beb, composition rules therefore require that the proposition [*a* s_1 *blue-eyed bear is intelligent*] presupposes that [[s_1]] contains one beb. Therefore, every situation within the domain of *usually* is also presupposed to contain exactly one beb.

The same process likely accounts for the paraphrase of 23a as 23b. There is no explicit domain over which *30% chance* ranges. In fact, there is no explicit reference to a set or series that ought to license the use of a statement of probability. However, a perfectly natural paraphrase is one where the probability ranges over individuals. Even if *there is a 30% chance that* is replaced with *30% of the time*, the overwhelming intuition is that a set of individuals are quantified. Even with this explicit reference to quantifying time, the individual-level predicate *be intelligent* does not present a free temporal variable to be bound, precluding a reading where blue eyed bears are intelligent for 30% of the time.

3.4 Individual and Stage Level predicates

That the individual-level predicate is constricted exclusively to giving rise to a reading of quantifying over individuals, even when the quantifier is changed to explicitly reference time is surprising. Kratzer's 1989 discussion of the differing argument structure between stage and individual-level predicates explains both that rigid reading as well as the effects of stage and individual-level predicates on control structures of single-event probabilities.

Interestingly, Percus' analysis of adverbial quantifiers parallels that of single-event probabilities with individual-level predicates such as "be intelligent" and "be blue" when the predicate and subject are both within the scope of the modal operator. However, the analogy between sentences like (23)a and (24)a breaks down when stage-level predicates are used. Consider the following sentences.

26)

a. A blue eyed bear is usually asleep.

b. ?Most blue eyed bears are asleep.

c. Blue eyed bears are asleep for most of their lives.

The rough paraphrase that holds between (23)a and (23)b with the individual-level predicate "be intelligent" does not hold between (26)a and (26)b. A preferred paraphrase would be (26)c, where the adverbial quantifier clearly binds the temporal variable of the stage-level predicate. However, when a statement of single-event probability is made in reference to a stage-level

predicate, the paraphrase that holds between (24)a and (24)b goes through, indicating that the domain of *30% chance* consists of a set of situations with a one-to-one relation with the set of *blue eyed bears*. Interestingly, the paraphrase (27)c is also accessible, suggesting that *30% chance* has access to both the temporal variable on the predicate, as well as a presupposed domain of situations containing exactly one *blue eyed bear*.

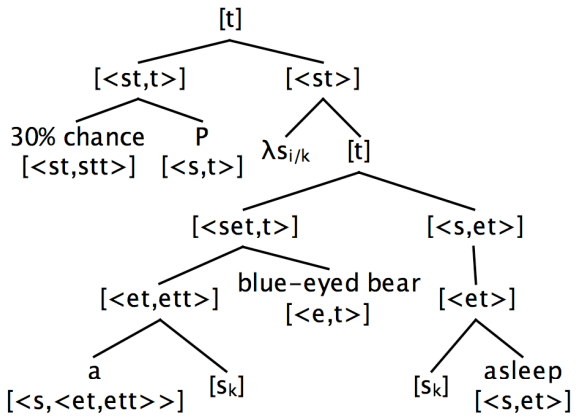
27)

a. There is a 30% chance that a blue eyed bear is asleep.

b. 30% of blue eyed bears are asleep.

c. Blue eyed bears are asleep for 30% of their lives.

d.



The logical form structure shown in (27)d demonstrates the two available sets of situations over which the single-event probability operator may quantify. When the lower set of available situations is quantified over (S_k, the external argument of *asleep*), the reading in (27)c arises. When the higher set of situations is quantified over (S_i, the internal argument of *a*), the reading in (27)b arises.

The readings on 23 and 27 suggest the following generalizations about sentences containing indefinite articles and adverbial quantifiers or single-event probabilities. When no spatio-temporal variable is available, both adverbial quantifiers and probability operators range over a presupposed domain of situations with the shared property of containing exactly one of the set of individuals selected by the indefinite determiner. For this reason, they appear to quantify over individuals. When an adverbial quantifier has access to a spatio-temporal variable, it only has access to that variable and there is no accessible reading of quantifying over the individual. When a probability operator has access to a spatio-temporal variable, and both the variable and the DP are within the scope of the probability (of the structure *There is a 30% chance that…*) it can bind either the spatio-temporal variable, or the presupposed domain of situations containing exactly one of the set of individuals selected by the indefinite article. As a result, there are two salient paraphrases; one that expresses a proportion of individuals (27)b and one that expresses a proportion of situations (27)c.

Based on these observations, and following Percus' account of the indefinite determiner's role in adverbial quantification, a tentative generalization may be made that accounts for the affects of scope and tense. With an individual-level predicate, there is no extra argument for spatio-temporal location variable. Because there is no variable to be bound, the single-event probability operator acts as an adverbial quantifier and ranges over the set of situations presupposed to be the antecedent of the propredicate. Because the content of the antecedent is

determined by the indefinite determiner, the single-event probability operator must c-command the DP containing the indefinite determiner.

Stage-level predicates, on the other hand, do present the spatio-temporal variable available to be bound by the single-event probability operator. Because there is a variable available as an argument on the predicate to be bound by the single-event probability, the DP may scope out from under the single-event probability and the statement still has an acceptable reading. The sentences in (28) demonstrate that when the DP scopes out, only one reading is available, unlike (27) where an ambiguity arises.

28)

a. A blue-eyed bear has a 30% chance of being asleep

b. Blue eyed bears are asleep for 30% of their lives.

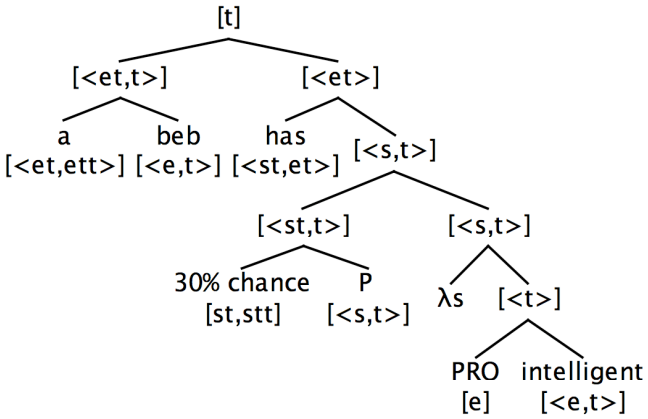
c. #30% of blue-eyed bears are asleep.

Unlike (27), (28)c does not seem to be an acceptable paraphrase of (28)a. Because the DP in (28)a is not c-commanded by the single-event probability operator, the interpretation of the single-event probability ranging over a presupposed antecedent of situations determined by the indefinite determiner is not available. The tree structures in (29) show the proposed simplified logical form for control structures with both individual and stage level predicates. As demonstrated in (29), because the spatiotemporal argument is still available with stage-level predicates in control structures, (28)a is still interpretable, but has

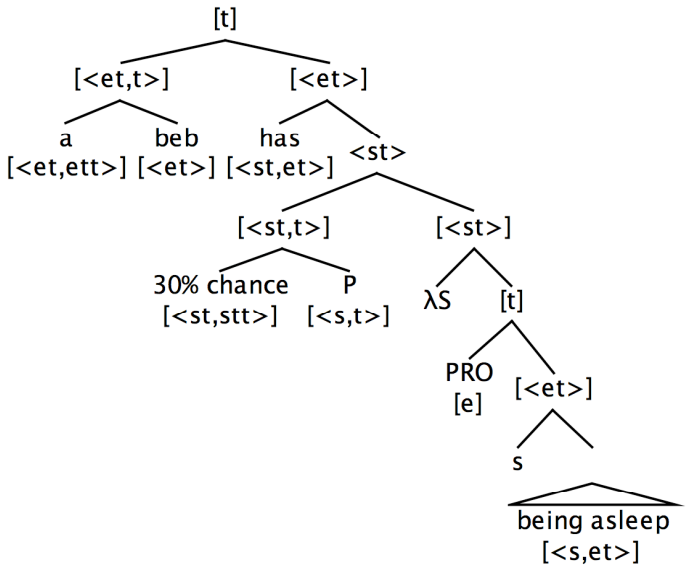
only one remaining salient interpretation. Because in (29)a the individual-level predicate has no spatiotemporal argument, the statement violates the prohibition against vacuous quantification, as there is no available variable to bind and no interpretation is available.

(29)

a. #[a beb][[30% chance][be intelligent]]



b. [a beb][[30% chance][be asleep]]



The structure in (29)a fails, as its restrictive argument P, does not have a defined antecedent. However, as proposed in Kratzer 1989, the stage-level predicate has an abstract spatiotemporal external argument available to be bound as a variable by an operator. If this variable is thought of a set of situations that contain the set of the VP *be asleep* at varying intervals of time, this set may be bound by the probability operator and would predict the reading that we get in (28)b.

3.5 Tentative account for effects of tense

The generalization outlined above may also explain the effects of tense on the acceptability of statements of single-event probability. Relative clauses in the perfect tense modifying the DP as in (30) result in unacceptable statements.

30)

a. There is a 30% chance that a painting from the gallery is beautiful.

b. A painting from the gallery is usually beautiful.

b. #There is a 30% chance that a painting that I have bought is beautiful.

d. #A painting that I have bought is usually beautiful.

The examples in (30) having individual-level predicates, the anticipated reading is of the single-event probability and the adverbial quantifier ranging over a set of situations presupposed to be in a one-to-one relation with all paintings. In (30)a and (30)b, the set of situations containing one painting is restricted to the number of all possible paintings in the gallery and the quantifiers in each case successfully range over these sets. In sentences (30)b and (30)d the set of

situations containing one painting should be restricted to the number of paintings I have bought. However, the perfect tense in the relative clause limits the set of available situations to one situation containing *a painting I have bought*. If there is only one specific painting, then the set of situations in the antecedent of the adverbial quantifier and the single-event probability operator is restricted to one possible situation. The restriction on vacuous quantification bans the adverbial quantifier and single-event probability from ranging over a set of situations that has already been restricted to one.

There is also a strong intuition that the perfect tense is related to individual-level predicates. Given the sentence, "I have been kicked" there is an intuition that having been kicked is a property that will belong to you for the rest of your life, similar to an individual-level predicate. However, a possible similarity in structure would not account for why the perfect tense results in less acceptable sentences in structures where the individual-level predicate has no effect, as in sentences where the modal operator has scope over the predicate.

4. Summary and Outlook

By using situation semantics, I have constructed an analysis of single-event probabilities that accounts for the interactions of three of the four factors I recognize as influencing the interpretation of such statements. Single-event probabilities are modals that quantify over situations; they do not do not quantify over or make any proposition about the entity that appears as the subject. Properties of predicate argument structure and indefinite articles give rise to the appearance of quantifying over individuals instead of sets of situations. However, this is merely an illusion that results in the statistical confusion about statements

that appear to make nonsensical observations of the world yet are perfectly interpretable by competent speakers. What is most evident in the analysis presented here is that there are systematic linguistic properties of these statements that give rise to the meaning we take from them. The system of interpretation is observable and analyzable unlike the dismissive assertion of the "psychological degree of certainty" explanation given by past cognitive psychologists such as Cosmides and Toobey (2004).

The analysis presented here finds some empirical support in the surprising findings of Gigerenzer et al (2005). In this study, Gigerenzer studies the interpretation of *There is a 30% chance of rain tomorrow,* reconfigured in 30 as a near minimal pair of 22a and 23a.

31) There is a 30% chance that it will rain tomorrow.

As noted above, because the reference class is not made explicit in statements like (19), or any statement of single-event probability, Gigerenzer believes the listener fills in the reference class spontaneously based on their understanding of the situation. For most Americans, the natural paraphrase for (31) is (32)a, while (32)b-c seem highly unintuitive.

32)

a. On 30% of days like tomorrow, it rains.

b. It will rain 30% of the time tomorrow

c. It will rain in 30% of a given area tomorrow.

However, in four European cities, Amsterdam, Athens, Berlin and Milan, 21b was judged as most appropriate, followed by (32)c and, finally, (32)a as the least appropriate paraphrase. It is not clear that (32) has parallel structure to (23)a and (24)a, as it is the properties of the indefinite determiner that allow for the ambiguities. However, as weather-verbs are clear stage level predicates, it should be anticipated that, depending upon a given language and culture's pragmatic tendencies, both readings with bound spatial and temporal variables arise as well as the reading binding a domain of situations containing exactly one instantiation of tomorrow.

It is also important to note that cognitive psychologists in the field of risk analysis conducted the study, not linguists. A critical reading of the methods of the study may present challenges to the findings or other causes that forced the unexpected readings of (21). However, if the findings can be repeated in another study, and this pattern of ambiguous interpretation of single-event probabilities holds constants, it is strong evidence in favor of the analysis presented here.

5. References

Cosmides, L., & Tooby, J. 1996: “Are humans good intuitive statisticians after all? rethinking some conclusions from the literature on judgment under uncertainty.” *Cognition, 58*(1), 1-73.

Diesling, M. 1994: *Indefinites*. Cambridge: MIT Press

von Fintel, K. 1996: “A Minimal Theory of Adverbial Quantification.” In H. Kamp and B. Partee, eds., *Context in the Analysis of Linguistic Meaning*. Stuttgart/Prague: IMS/UFAL.

von Fintel, K., & Heim, I. 2005: *Intensional Semantics Lecture Notes*, MIT

Gigerenzer, G., Hertwig, R., van den Broek, Eva, Fasolo, B., & V. Katsikopoulos, K. (2005): "A 30% chance of rain tomorrow": How does the public understand probabilistic weather forecasts? *Risk Analysis, 25*(3), 623--629.

Kratzer, A. 1989. “Stage-Level and Individual-Level Predicates” In E. Bach, ed., *Papers on Quantification*, 2-73. UMass Amherst.

Kratzer, A. 2006: “Situation Semantics” in Stanford Encyclopedia of Philosophy

Percus, O. 1998: “A Somewhat more Definite Article” in D Strolovitch and A. Lawson (eds.), *Proceedings of SALT III*. CLC publications, Cornell University, Ithaca, N.Y.

Stowell, T. 2007: “Sequence of Perfect” in L. de Saussure, J. Moeschler and G. Puskas (eds.) *Recent advances in syntax and semantics of tense, mood and aspect*. Berlin: Mouton De Guyter, 123-146.