

Bound-Variable Pronouns and the Semantics of Number

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1. Introduction

In sentences like (1a,b) the plural pronoun *they* appears to function semantically as a bound variable ranging over singular individuals rather than pluralities.¹ Both sentences are truth-conditionally equivalent to (2a) in which the pronoun is morphologically singular. This suggests that semantically they involve universal quantification over an individual variable, as in the logical representation (2b).

- (1) a. All men₁ think they₁ are smart.
- b. The men₁ all think they₁ are smart.
- (2) a. Every man₁ thinks he₁ is smart.
- b. $\forall x[\text{man}(x) \rightarrow x \text{ thinks } x \text{ is smart}]$

The idea that a plural bound pronoun can represent a singular variable appears to be supported by examples such as (3) and (4a) in which the property predicated of the bound pronoun can only be true of one individual, either because of certain contingent facts (only one candidate can win a presidential election), or for logical reasons (only one person can be the smartest person in the world). Note that the embedded clause of (4a) is odd when used as an independent sentence in which *they* is not a bound variable, as in (4b).

- (3) All candidates thought they could win the presidential election.
- (4) a. All men think they are the smartest person in the world.
- b. #They are the smartest person in the world.

The conclusion that is commonly drawn from such facts is that plural bound pronouns can be semantically singular, and that the morphological number of a bound pronoun is the result of purely syntactic number agreement of the pronoun with its binder.² Although this conclusion seems plausible enough, I will argue that it is in fact incorrect, and that number agreement between a

bound pronoun and its antecedent is a matter of semantics rather than syntax.

One important problem for a purely syntactic account of pronominal number agreement is posed by sentences in which *they* is bound by more than one singular antecedent (in such examples I will use a set index like {1,2} to indicate that the semantic value of the pronoun is the plurality consisting of the value of index 1 and the value of index 2):

- (5) a. Mary₁ told John₂ that they_{1,2} should invest in the stock market.
- b. Every woman₁ told [her₁ husband]₂ that they_{1,2} should invest in the stock market.
- c. Every man₁ told [each of his₁ girlfriends]₂ that they_{1,2} were going to get married.

In (5a) *they* has two referential DPs as antecedents, so this example could be regarded as a case of accidental coreference; no such analysis is possible for (5b) and (c), however, in which one or both of the antecedents are quantifiers. A straightforward account of pronominal number based on purely syntactic agreement will fail in such cases, because in fact the bound pronoun “disagrees” in number with both of its antecedents.

2. Morphological Number and Semantic Number

In this paper I will propose a semantic account of pronominal number agreement based on the idea that the morphological number of a DP is transparently reflected in its semantics. In particular I will assume that singular DPs denote individuals, but plural DPs denote sets of individuals. (In the case of quantificational DPs or bound-variable pronouns, “denote” should be read as “quantify over” or “range over”, respectively.) Here I am extrapolating from Winter (2001, 2002), who proposes a similar correlation between morphological number and semantic number at the level of predicates, including common nouns. Unlike Winter, however, I will not view the semantic distinction between singular and plural expressions as a difference in semantic type (see also Bennett 1974 and Hoeksema 1983 for earlier type-theoretic treatments of the singular/plural distinction). The problem for a type-based approach to number is that it leads to a rampant multiplication of types for many expressions in the language. Intransitive verbs, for instance, would have to come in two types, $\langle e, t \rangle$ and $\langle et, t \rangle$, depending on whether they take a singular or plural subject. This could be regarded as an advantage in that it would encode subject-verb agreement for number in the semantic type of the verb. Note however that the same multiplication of types would apply to all other argument positions of a verb. Transitive verbs, for instance, would have to have at least four different types ($\langle e, \langle e, t \rangle \rangle$ or $\langle e, \langle et, t \rangle \rangle$ or $\langle et, \langle e, t \rangle \rangle$ or $\langle et, \langle et, t \rangle \rangle$), and there

would be a similar increase in the number of types for other expressions such as adverbs, prepositions, adjectives, etc., none of which is motivated by overtly expressed number agreement.

To avoid this proliferation of types, I will make the singular/plural distinction one of sorts rather than types. Entities of type e come in two sorts: singular entities and plural entities, the latter being sets of singular entities. If SG is the set of singular entities, then the set of plural entities, PL , will be defined as the set of all non-empty subsets of SG ; that is, $PL = \text{Pow}^+(SG) = \text{Pow}(SG) - \{\emptyset\}$. The domain of type e can then be defined as the set of all singular and plural entities; i.e. $D_e = SG \cup PL$. Note that the set of plural entities PL includes singleton sets. This will be crucial for my explanation of why plural bound-variable pronouns may appear to be semantically singular.

This proposal avoids the type proliferation problem. Singular DPs denote elements of SG , whereas plural DPs denote elements of PL . Expressions that take DPs as arguments may be sensitive to the distinction between the two sorts (singular verbs, for instance, only take elements of SG as their subject argument, whereas plural verbs only accept elements of PL), or they may be indifferent to this distinction (transitive verbs, for instance, may take elements from both SG and PL as their object argument, and similarly for other expressions that do not show number agreement).

3. Plural Quantification

In the approach to the semantics of number just sketched, singular pronouns are treated as variables ranging over individuals (elements of SG), and plural pronouns are variables ranging over sets (elements of PL). But to account for the interpretation of sentences like (1a) we also need a semantics for plural quantifiers such as *all men*. In this I will again follow Yoad Winter's recent work (2001, 2002). There are two basic properties of plural quantification that need to be accounted for. First of all, in sentences with distributive predicates like *be at the party*, singular and plural quantifiers are equivalent. In (6)-(9) the (a) sentences have the same truth conditions as the (b) sentences.

- (6) a. All students were at the party.
b. Every student was at the party.
- (7) a. No students were at the party.
b. No student was at the party.
- (8) a. Many students were at the party.
b. Many a student was at the party.
- (9) a. At least two students were at the party.
b. More than one student was at the party.

Secondly, plural quantifiers can take collective predicates, but singular quantifiers can't (Morgan 1985, Winter 2001, 2002). By "collective predicates" I mean those predicates which Winter calls "set predicates", such as *swarm out of the stadium* or *meet after the game*; like Winter, I assume that these are predicates which can be true of sets (elements of PL), without being true of any of the members of those sets.³

- (10) a. All (the) / Many / No students swarmed out of the stadium / met after the game.
 b. *Every / Each / Many a / No student swarmed out of the stadium / met after the game.
- (11) a. At least two students met after the game.
 b. *More than one student met after the game.

Winter proposes a semantics in which singular determiners denote relations between sets, whereas plural determiners denote relations between sets of sets. He points out that there is a systematic relation between the meaning of a plural determiner (Det_{pl}) and that of the corresponding singular determiner of standard generalized quantifier theory (Det_{sg}) which is expressed by the schema in (12).⁴

$$(12) \quad \text{Det}_{\text{pl}}(A, B) \text{ iff } \text{Det}_{\text{sg}}(\cup A, \cup(A \cap B))$$

Take a sentence with a plural quantifier and a collective predicate such as *meet*. (13a) is true iff the condition specified in (13b) holds, where EVERY stands for the subset relation; these truth conditions are paraphrased in (13c).

- (13) a. All students met.
 b. $\text{EVERY}(\cup[[\text{students}]], \cup([\text{students}] \cap [\text{met}]))$
 c. "Every student is a member of a set of students that met."

To illustrate this, consider a simple scenario in which there are three students, a, b, and c, as well as two non-students, d and e. Suppose furthermore that two meetings took place: a and b met, and separately c, d, and e met. Let's first calculate the first argument of the determiner relation EVERY in (13b). The denotation of the singular noun *student* is $[[\text{student}]] = \{a, b, c\}$. I will assume that a plural noun denotes the set of all non-empty subsets of the denotation of the corresponding singular noun; therefore $[[\text{students}]] = \text{Pow}^+([[\text{student}]]) = \{\{a\}, \{b\}, \{c\}, \{a, b\}, \{a, c\}, \{b, c\}, \{a, b, c\}\}$. So $\cup[[\text{students}]] = \{a, b, c\} = [[\text{student}]]$. Next, let's turn to the second argument of EVERY in (13b). In the scenario just described $[[\text{met}]] = \{\{a, b\}, \{c, d, e\}\}$. This means that $[[\text{students}]] \cap [[\text{met}]] = \{\{a, b\}\}$, and therefore $\cup([\text{students}] \cap [\text{met}]) = \{a, b\}$. In this scenario (13a) is false, because it is not the case that every student is a member of a set of students that met. However, in the same scenario the sentence *Most*

students met will be true, because it is true that a majority of students participated in a student meeting.

Winter shows that with distributive predicates (or, to be more precise, “atom predicates” in his terminology), plural quantification is equivalent to singular quantification. For instance, (14a) and (14b) have the same truth conditions.

- (14) a. All students were at the party.
- b. Every student was at the party.

To see why this is so, again consider a simple scenario with students a, b, and c; this time, suppose that a, b, and d were at the party (and no one else was). So $[[\text{was at the party}]] = \{a, b, d\}$. The corresponding plural VP will denote the set of all non-empty subsets of its singular counterpart; that is $[[\text{were at the party}]] = \text{Pow}^+([[\text{was at the party}]]) = \{\{a\}, \{b\}, \{d\}, \{a,b\}, \{a,d\}, \{b,d\}, \{a,b,d\}\}$. Now the second argument of the universal quantifier will be $\cup([[\text{students}]]) \cap [[\text{were at the party}]] = \cup\{\{a\}, \{b\}, \{a,b\}\} = \{a,b\}$. This means that (14a) is false, but *Most students were at the party* would be true in the same situation.

Winter (2001) adds a condition (the “witness condition”) to the effect that for *All/Most students met* to be true there must be one meeting which involves all/most students. Although this does seem to be the preferred interpretation for sentences like (13a), this condition is too general, because of examples of plural quantification of the sort discussed by Link (1987) and Roberts (1987a):

- (15) a. All competing companies have common interests.
- b. Between many houses, there stood a picket fence.
- c. Most students wore matching sweaters.

(15a), for instance, does not require that all companies which compete with any other company compete with each other and have common interests (which is what Winter’s witness condition would come down to). Examples like (15a-c) seem to involve a partitioning of the set of companies/houses/students which is either induced by a symmetric predicate like *compete* or *between* in the restriction of the quantifier, or by context (see Roberts 1987a). I believe that the semantics in (12) does give the right truth conditions for (15a-c) as well as for (13a), but that there probably is a pragmatic preference for sentences with plural quantifiers to describe situations in which either the witness condition holds, or there is the kind of partitioning we see in (15a-c). I will leave this as an unresolved issue, and will continue to assume that (12) captures the truth conditions of plural quantifiers.

Above I assumed without argumentation that the denotation of a plural noun such as *students* includes not only sets of two or more members, but also singletons. Although this assumption may seem counterintuitive it is in fact necessary to get the right truth conditions for sentences with downward entailing

determiners (Roberts 1991, Schwarzschild 1996, Winter 2001, among others). Consider (16), and suppose that there is exactly one student and that he or she was at the party. If singleton sets were not included in the denotation of plural nouns, *students* would denote the empty set, and as a result (16) would come out as true, which surely is an unwanted result. As we will see in the next section the assumption that the range of plural quantifiers includes singleton sets is the key for explaining why *they* sometimes seems to behave as if it were a variable ranging over singular individuals.

(16) No students were at the party.

4. Plural Pronouns as Variables Ranging over Sets

Why does *they* appear to be an individual variable in sentences like (17)?

(17) All candidates thought they could win the election.

(18) $\cup[[\text{candidates}]] \subseteq \cup([\text{candidates}] \cap [[\lambda X[X \text{ thought } X \text{ could win}]]])$

According to the schema in (12), (17) has the truth conditions stated in (18). (As a typographical convention I use upper case letters for plural variables, i.e. variables ranging over sets of individuals.) To take a concrete example, suppose that three candidates ran in the election: Al, George, and Ralph. Furthermore, let's assume that each candidate thought that he could win, but of course no candidate thought that more than one candidate could win. We thus have the following facts: Al thought Al could win; George thought George could win; and Ralph thought Ralph could win; but not: Al and George thought Al and George could win, etc. Let's calculate the truth conditions of (18) in this scenario. $\cup[[\text{candidates}]] = \cup(\text{Pow}^+([\text{candidate}])) = [[\text{candidate}]] = \{a, g, r\}$. The denotation of the λ -term $\lambda X[X \text{ thought } X \text{ could win}]$ is $\{\{a\}, \{g\}, \{r\}\}$, because the singleton sets are the only ones of which the open predicate '*X thought X could win*' is true. Thus, $\cup([\text{candidates}] \cap [[\lambda X[X \text{ thought } X \text{ could win}]]]) = \cup(\text{Pow}^+([\text{candidate}]) \cap [[\lambda X[X \text{ thought } X \text{ could win}]]]) = \cup\{\{a\}, \{g\}, \{r\}\} = \{a, g, r\}$. Therefore, (18) is true. It is easy to see that (17) will in effect be equivalent to *Every candidate thought he could win the election*.

The analysis can naturally be extended to sentences in which *they* is bound by a floated quantifier, such as (19). Following much of the literature (for instance, Roberts 1987a,b) I will assume that there is a silent counterpart to floated *each* in the form of a distributivity operator *Dist* which accounts for the distributive interpretation of sentences with plural subject. The semantics for the floated quantifier *each* and *all* as well as the implicit distributivity operator is given in (20). When applied to a VP, *each/all/Dist* first selects all the singleton sets from the denotation of the VP, and then applies closure under union.⁵ The result is the

set of all sets S of individuals such that the property expressed by the VP is true of all singleton subsets of S.⁶

- (19) The candidates (each/all/Dist) thought they could win the election.
 (20) $[[\text{each/all/Dist VP}]] = *([\text{VP}] \cap \text{SING})$
 where SING is the set of all singleton sets (i.e. $\{\{x\} \in \text{PL} \mid x \in \text{SG}\}$)
 and * is closure under union.

To get the bound-variable interpretation of the pronoun in (19), the floated quantifier or distributivity operator has to be applied to the predicate obtained by λ -abstraction over the variable corresponding to the pronoun (see also Roberts 1987b). In the situation just sketched, the resulting VP denotation will be $[[\text{each/all/Dist } \lambda X[X \text{ thought } X \text{ could win}]]] = *([\lambda X[X \text{ thought } X \text{ could win}]] \cap \text{SING}) = *(\{\{a\}, \{g\}, \{r\}\} = \{\{a\}, \{g\}, \{r\}, \{a,g\}, \{a,r\}, \{g,r\}, \{a,g,r\}\})$. Thus, assuming that *the candidates* denotes $\{a,g,r\}$, (19) will come out as true. Again *they* seems to be a variable ranging over individuals but in reality it ranges over sets, including singletons. In this case it is the floated quantifier or distributivity operator that forces the distribution of the predicate down to the singleton sets.

In addition to cases like the ones just discussed, there are also examples in which it is crucial that the plural pronoun ranges not just over singleton sets, but also over non-singleton sets. Consider (21), which is similar to the examples of plural quantification discussed by Link (1987) and Roberts (1987a).

- (21) Most people who think they have common interests become friends.

The interpretation of the relative clause is $\lambda X[X \text{ think } X \text{ have common interests}]$. Since the predicate *have common interests* can only be true of non-singleton sets, this λ -term will denote a set of non-singleton sets.

Although the data in (17), (19), and (21) can be handled elegantly by a unified account which treats all plural bound pronouns as variables ranging over sets, they would also be compatible with an alternative analysis which treats *they* as ambiguous between a variable ranging over individuals (for cases like (17) and (19)) and a variable ranging over (non-singleton) pluralities (for examples like (21)). However, this ambiguity analysis would not only be less economical but also empirically untenable, because there are cases in which *they* must crucially be able to range over both singleton and non-singleton sets at the same time. Imagine a situation in which a class gets a homework assignment on which the students can work either individually or in groups. Now consider:

- (22) None of the students think they can solve the problem.

This sentence should be false if there is one student, say Jane, who works on the assignment individually and who thinks that she by herself can solve the

problem. However, (22) would also be falsified by the existence of a set of students who work together and who believe that collectively they can solve the problem. Note that the truth conditions assigned to the sentence need to exclude both these possibilities at the same time, something which is captured nicely by the account I have proposed. The ambiguity analysis cannot adequately deal with (22). It would have to claim that in the situation where only Jane thinks she can solve the problem (that is, there are no other individual students or groups of students who think they can solve the problem), (22) would be false in one sense (the individual variable reading), but true in another sense (the plural variable reading). But that clearly does not capture the intuition that the sentence is plain and simply false in such a situation. We can conclude, then, that *they* is not ambiguous between a semantically singular reading and a semantically plural reading. *They* can be said to be “number neutral” in the sense that it ranges over both singleton and non-singleton sets.⁷

5. Binding by Multiple Antecedents

As pointed out in the introduction, examples such as (5b,c), repeated here as (23a,b), are problematic for any purely syntactic account of pronominal number agreement, because they contain a plural pronoun that is bound by two singular antecedents.

- (23) a. Every woman₁ told [her₁ husband]₂ that they_{1,2} should invest in the stock market.
 b. Every man₁ told [each of his₁ girlfriends]₂ that they_{1,2} were going to get married.

Such cases can be given a semantic treatment by providing an explicit semantics for set indices, which I have used so far only for expository reasons. So let us assume that the index of a plural pronoun can be a set expression such as {1, 2}, where 1 and 2 themselves are simple indices borne by singular DPs. However, at the same time we need to allow for plural pronouns to have a simple index in examples such as (24).

- (24) All men₃ think they₃ are smart.

To make the indexing system semantically transparent, I will from now on underline the indices in examples like (24) to indicate that they stand for variables ranging over sets. Three kinds of indices should thus be distinguished:

- simple singular indices (non-underlined integers: 1, 2, 3, ...);
- simple plural indices (underlined integers: 1, 2, 3, ...);
- set indices, which consist of a sequence of simple (singular or plural) indices

that are separated by commas and enclosed in curly brackets { and }.

We can now regard the morphological number of a pronoun as something that is determined by the kind of index it has. Singular pronouns can only bear a simple singular index, while plural pronouns can bear either a simple plural index or a set index. Semantically, we will require that for any assignment g , simple singular index n , and simple plural index \underline{m} , it be the case that $g(n) \in \text{SG}$ and $g(\underline{m}) \in \text{PL}$. Singular pronouns have the usual semantics given in (25) (ignoring gender). The interpretation of plural pronouns with a simple plural index is also straightforward (see (26a)), but that of plural pronouns with a set index is bit more complicated; (26b) is a first attempt, restricted to cases in which the set index has two members, each of which is a simple singular index.

- (25) Interpretation of singular pronouns: $[[\text{he/she/it}_n]]^g = g(n)$
 (26) Interpretation of plural pronouns
 a. with a simple plural index: $[[\text{they}_{\underline{n}}]]^g = g(\underline{n})$
 b. with a set index: $[[\text{they}_{\{n,m\}}]]^g = \{g(n), g(m)\}$ (to be revised)

(26b) has to be generalized in two ways. First, it is possible for a plural pronoun to have three or more singular antecedents, as in (27).

- (27) Every woman₁ asked [one of her₁ children]₂ to tell [her₁ husband]₃ that they_{\{1,2,3\}}} should get together.

Secondly, an antecedent of a plural pronoun with multiple antecedents may itself be plural:

- (28) Every man₁ told [all his₁ girlfriends]₂ that they_{\{1,2\}}} were going to get married.

A generalization of (26b) that will deal with such cases is given in (26b').

- (26b') Interpretation of a plural pronoun with set index S :
 $[[\text{they}_S]]^g = \{d \in \text{SG} \mid \text{either } d = g(n) \text{ for some } n \in S, \text{ or } d \in g(\underline{m}) \text{ for some } \underline{m} \in S\}$

With this system of indices and their interpretation, there is no need for an additional purely syntactic rule requiring a pronoun to agree in number with its binder, because the relevant cases will automatically be excluded. Take for instance (29a). The quantifier and the pronoun cannot be coindexed, because the quantifier is plural and can therefore only have a simple plural index or a set index, whereas the pronoun is singular and can only have a simple singular index. This leaves only one theoretically possible indexing that needs to be taken into consideration, namely the one given in (29b).

- (29) a. All men think he is smart.
 b. All men_{1} think he₁ is smart.

Does (29b) give rise to a bound-variable interpretation? The answer is no. Recall Winter's semantics for plural quantification, according to which a plural determiner denotes a relation between two sets of sets. To get a bound-variable interpretation, the second argument of this relation would have to be obtained by λ -abstraction over the individual variable represented by the pronoun *he*. This would give us the property denoted by $\lambda x[x \text{ thinks } x \text{ is smart}]$, which is a set of individuals rather than a set of sets, and can therefore not be the second argument of *all*. Hence, (29b) is semantically uninterpretable.

It may seem that all cases of binding in which the pronoun and the binder differ in number will similarly be excluded by the proposed account. However, this is not the case, and the type of number "disagreement" that is predicted to occur is actually attested in English.

6. *They* with a Singular Antecedent

In colloquial registers of English, singular quantifiers can bind plural pronouns:

- (30) a. %Someone left their coat on the table.
 b. %Every student thinks they're smart.

At first sight this might appear to be a major problem for the account of pronominal number agreement I have proposed; however, this phenomenon can actually be accommodated without any adjustments to the analysis, if the plural pronoun is given a singleton set index as in (31).

- (31) Someone₈ left their_{8} coat on the table.

Abstracting over the variable with index 8 gives the property $\lambda x_8[x_8 \text{ left } \{x_8\}'\text{s coat on the table}]$ to which the singular quantifier *someone* can perfectly well be applied. In fact, my account is in danger of being too successful at this point. If plural pronouns can have a singleton set index, then how can cases like (32) and (33) be excluded?

- (32) *John₈ left their_{8} coat on the table.
 (33) *They_{8} are sick. (referring deictically to a single person)

Moreover, there are varieties of English in which (30a) and (b) are ungrammatical (and if you think this might be due purely to the influence of

prescriptive grammar, consider the fact that there are languages like Dutch in which the equivalent of (30a,b) is always ungrammatical, no matter how informal the register). Some limits therefore need to be put on the use of singleton set indices. Dialects (or languages) in which sentences like (30a,b) are ungrammatical have a blanket prohibition against plural pronouns with singleton set indices.⁸ (But of course a plural pronoun with a simple plural index must still be allowed to range over singleton sets, as argued in the preceding section.) In varieties which accept (30a,b) but reject (32) and (33), the situation is more complicated. One possible conjecture would be that singleton set indices are allowed for bound-variable pronouns, but not for referential pronouns. However, consider a situation in which several speech samples of three patients known only as A, B and C are analyzed. In such a context, a sentence like (34) would be perfectly natural for many speakers,⁹ but this is clearly not a case of a pronoun bound by a quantifier.

(34) Patient A has a lot of pauses in their speech sample.

Another possibility is that *they* can only have a singleton set index if the gender of the individuals involved is unknown. But examples like (35), pointed out to me by Sarah Cummins (p.c.), show that this explanation is not tenable either.

(35) Someone left their jockstrap in the locker room.

What seems to tie cases like (34) and (35) together with bound-variable examples is that there is no single identified referent for the pronoun. Somewhat tentatively I therefore conclude that in dialects in which (30) is grammatical (but (32) and (33) are not), there is a constraint to the effect that a singleton set index is allowed only if the pronoun does not refer to an identified individual.

Notes

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² I believe this is often assumed implicitly. Authors who have explicitly made this point include Roberts (1987b), Heim, Lasnik and May (1991), Carpenter (1997), and Beck and Sauerland (2000).

³ Note however that these predicates may also be true of certain singular entities such as the groups (“impure atoms”) denoted by DPs like *the crowd* or *the committee*.

⁴ In Winter’s account this systematic relation between plural determiners and their singular counterparts is the result of an operation that he calls “determiner fitting”, but that aspect of his theory is not crucial for our present purposes.

⁵ (20) is equivalent to Roberts’ semantics for the distributive operator. Thanks to Youri Zabbal for making me aware of that fact.

⁶ For simplicity I ignore readings in which *all* does not distribute all the way down to singletons, but to larger subsets in a contextually determined cover of the subject denotation (Schwarzschild 1996).

⁷ This conclusion finds additional support in recent work by Kanazawa (2001) who argues for much the same point on the basis of data involving donkey anaphora. McCawley (1968) has suggested for independent reasons that plural is the unmarked member of the singular-plural opposition.

⁸ There may be a plausible explanation for the existence of such a constraint. A plural pronoun with a singleton index is for all intents and purposes equivalent to a singular pronoun with a simple singular index. The constraint may therefore be subsumed under a more general principle which requires linguistic expressions to have the simplest possible semantic type or sort.

⁹ Many such examples were attested in an assignment I gave in an introductory linguistics class.

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