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# RECIPROCAL EXPRESSIONS AND THE CONCEPT OF RECIPROCITY*

## INTRODUCTION

The English reciprocal expressions *each other* and *one another* vary in meaning according to the meaning of their scope and antecedent, as well as the context in which they are uttered. Variation in the reciprocal's meaning is not just pragmatically determined alteration in speaker's meaning but semantically determined change of literal conditions for strict truth. We will show how to parameterize the dramatic range of observed variation, and we will formulate a principle which predicts the reciprocal's literal meaning in any context of utterance: a reciprocal statement expresses the strongest candidate meaning that is consistent with certain contextually given information. This analysis explains a large collection of examples, including those with quantified antecedents.

The first two sections of this paper are descriptive, exploring a variety of examples to find whether their literal meaning changes or only the speaker's meaning. Section 3 gives formal definitions of the reciprocal meanings we have found and discusses previous claims about what reciprocals can mean and how reciprocal meanings can be formalized. Section 4

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provides a discussion of cases involving a relation holding among subgroups of a group rather than members of the group; since these examples are not the main focus of this paper, the discussion will be brief.

Section 5 presents parameters of variation in the meaning of the reciprocal and a generalization covering the meaning of each case considered. In Section 6, the Strongest Meaning Hypothesis is introduced and shown to give an analysis of the meaning of reciprocal expressions which explains observed shifts in their literal meaning. Section 7 discusses reciprocals with quantified antecedents, and spells out some surprising correct predictions that follow from the account proposed. The role of context in determining the meaning of the reciprocal expression is emphasized throughout the paper.

## 1. Exploring the Meaning of *Each Other*: Truth Conditions of Reciprocal Statements

Research on the syntax and semantics of reciprocity often centers on sentences such as:

(1) John and Bill saw/kicked/laughed at each other.

Examples in which the reciprocal antecedent denotes a group with two members – here, John and Bill – are particularly easy to analyze. Usually when groups of two members are considered, each group member is required to stand in the stated relation to the other member.

Generalizing to larger antecedent groups, this suggests that

(2) House of Commons etiquette requires **legislators** to address only the speaker of the House and **refer to each other indirectly**.

should mean that each legislator is required to refer to every other one indirectly, as diagram (3) depicts. In each diagram in this paper, the set $A$ is the group of entities which comprise the domain determined by the antecedent of the reciprocal, and the arrows represent the relation which is determined by the scope of the reciprocal.

(3)

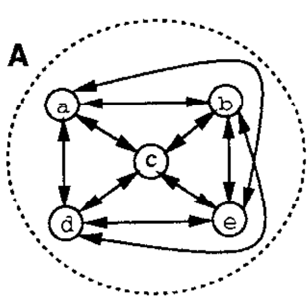
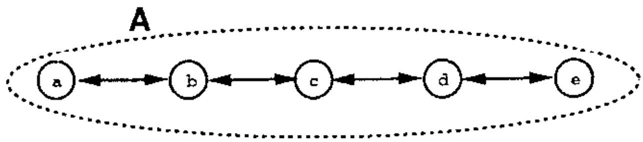


Diagram (3) shows that every House of Commons legislator (that is, every member of $A$) has to refer to every other one only indirectly in order for statement (2) to be true.

However, when reciprocal statements with antecedent groups larger than two members are considered extensively,[1] these truth conditions turn out to be the wrong ones for many cases. The following examples illustrate various meanings for reciprocal statements. For each statement, we give a diagram which depicts a typical situation described by it. Each sentence has different truth conditions, and we shall see that the variation is not random.

(4) As the preposterous horde crowded around, waiting for the likes of Evans and Mike Greenwell, **five Boston pitchers sat alongside each other**: Larry Andersen, Jeff Reardon, Jeff Gray, Dennis Lamp and Tom Bolton.

(5)

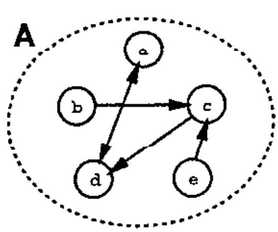



It is obvious that the reciprocal in (4) has a different meaning from that in (2). Its truth conditions are weaker; it does not require every member to be related to every other member by the relation of *sitting alongside*.

Statement (6), from J.M. Barrie's *Peter Pan*, exemplifies another meaning of the reciprocal: every member is claimed to relate to at least one other, and being passively related is not sufficient.

(6) "The captain!" said **the pirates, staring at each other in surprise**.

(7)



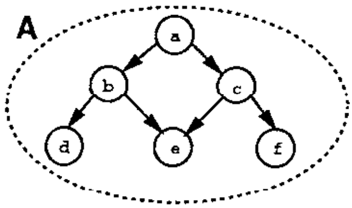

[1] We examined 1740 examples from the 'Hector' Corpus and 1579 examples from the New York Times. The authors are grateful to Oxford University Press for permission to study and use citations from the Oxford 'Hector' Corpus, a pilot corpus for the British National Corpus which was used for 'Hector', a research project in lexical computing by the Systems

In the next pair of examples, the relation holds asymmetrically. If one individual is related to another, the second is not related to the first by *giving measles to* or *being stacked on top of*.

(8) The third-grade students in Mrs. Smith's class gave each other measles.

(9) **They** climbed a drainpipe to enter the school through a high window and **stacked tables on top of each other** to get out again.

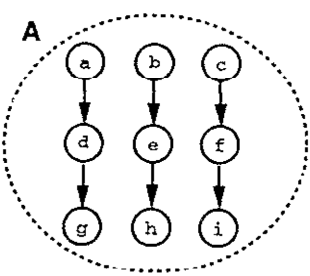
(10)




In statement (11), the reciprocal means something still different, allowing for multiple stacks of planks as compared with a single stack of tables.

(11) He and scores of other inmates slept on **foot-wide wooden planks stacked atop each other** – like sardines in a can – in garage-sized holes in the ground.

(12)




In all examples thus far, the antecedent denotes a group, which is taken as the domain of the reciprocal. Our data also include many examples with quantified antecedents. These exhibit variation in meaning of the reciprocal similar to what we have already seen. One difference to note

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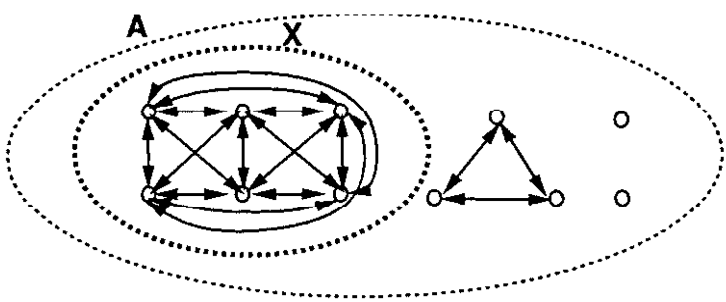
in the case of reciprocals with quantified antecedents is that in general the reciprocal is not claimed to hold of the whole group $A$ but rather of a subgroup $X$ of it; we will return to a discussion of reciprocals with quantified antecedents in Section 7.

(13) is a case where every member of the relevant set relates to every other member, similar to example (2).

(13) Accounts of watching football composed by ordinary spectators emphasize **how familiar many people were to one another**, the wide age-range, and the lively banter. You knew everybody. You never saw 'em between games. But we always stood roughly in the same place and we knew the forty or fifty people around us 'cos they were always there.

(14)

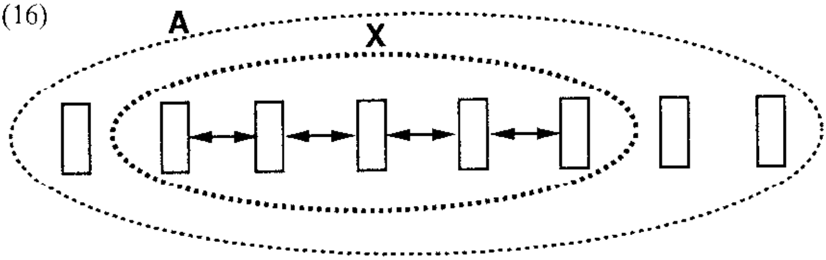



The group labeled $A$ is the group of football spectators, and the group labeled $X$ is a group consisting of many of those people. This example requires that each member of $X$ bear the *being-familiar-to* relation to each other member.

On the other hand, (15) has similar truth conditions to (4), requiring that every one of the many vertebrae in the group labeled $X$ be indirectly or directly related to every other one.

(15) The number of vertebrae varies from 39 to 63 (the larger number in long-necked species), with **many in the trunk fused to each other** and to other bony elements to form a rigid central framework for flight.

(16)

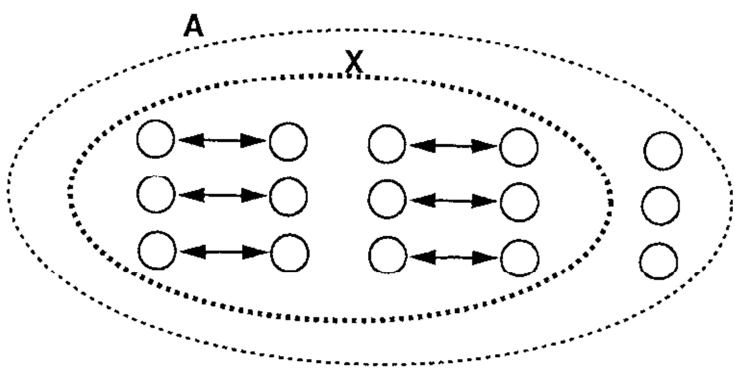



The statement

(17) Many people at the party yesterday are married to each other.

has notably weaker truth conditions, as shown below. It does not claim anyone in the group labeled *X*, representing a group of many people at the party, is married to more than one person.

(18)




## 2. Variation of Literal Meaning or Just Speaker's Meaning?

What are we to make of these variations in meaning of the reciprocal? It is well known that what a speaker means to communicate can differ in certain respects from the literal meaning of his or her utterance. The speaker's meaning can be stronger in some ways than the literal meaning due to factors such as Grice's Cooperative Principle (Grice, 1975), which entitles speakers to count on hearers to recognize conversational implicatures that are not entailed by the literal meaning of an utterance. Someone who says

(19) John is doing quite well in his new job working at the bank; he likes his colleagues, and he hasn't been to prison yet.

is ordinarily entitled to expect her hearer to understand she means John is the sort of person likely to yield to the temptation provided by working in a place with lots of money around.

On the other hand, the speaker's meaning can also be weaker in some ways than the literal meaning due to factors such as the speaker's indicating an intention not to be held strictly accountable for the truth of what he or she said, but rather to be understood as describing a situation somewhat loosely. As Austin (1962) pointed out, a general can truthfully state

(20) France is hexagonal.

in discussing a strategy for defense of the country's frontiers. But if a geometer were to assert (20), her statement would be false. Undulations in the 'sides' of French territory are irrelevant to the truth of the general's loose statement, but not the geometer's strict one.

However, the situation with reciprocal sentences is not like either of these. Recall that example (2), repeated here, requires that each legislator address every other legislator indirectly:

(21) (=(2)) House of Commons etiquette requires **legislators** to address only the speaker of the House and **refer to each other indirectly**.

The following contradictory statement shows that the strong meaning of the reciprocal in (21) does not come from pragmatic strengthening, but is rather a genuine part of the reciprocal's conventional meaning.

(22) #House of Commons legislators refer to each other indirectly; the most senior one addresses the most junior one directly.

Note in contrast the felicity of the following example:

(23) House of Commons legislators refer to each other indirectly, except the most senior one addresses the most junior one directly.

In general, the exception construction is felicitous only in the presence of universal or negative universal quantification over appropriate $n$-tuples.[2] Witness the following contrast:

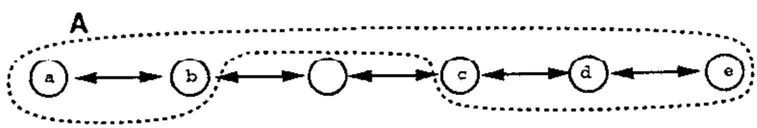
(24) a. Every legislator refers indirectly to every other legislator, except the oldest one addresses the youngest directly.
b. #Every legislator refers indirectly to some other legislator, except the oldest one addresses the youngest directly

Example (25) has a weaker meaning than example (21):

(25) (=(4)) Five Boston pitchers sat alongside each other; Larry Andersen and Tom Bolton sat on the ends, separated by Jeff Reardon, Jeff Gray and Dennis Lamp.

Unlike example (21), this sentence does not require that each pitcher sat alongside every other pitcher; indeed, such a situation could not obtain, since a pitcher can sit alongside only two other pitchers at one time. However, example (25) is false in a situation in which pitchers are separated by non-pitchers, as depicted in the following diagram:

(26)




The circle not included in the group labeled $A$ represents an individual who is not a Boston pitcher.

Similarly, example (27) would be false in a situation like the one depicted in (26). For the sentence to be true, adjacent exits should be within one mile of each other; larger gaps between adjacent exits are not tolerated.

(27) The exits on the Hollywood Freeway are within one mile of each other.

Example (28) has truth conditions that are weaker than either example (21) or example (25):

(28) (=(6)) "The captain!" said **the pirates, staring at each other in surprise.**

Again, arbitrary weakening of the truth conditions for the above examples

[2] See Moltmann (1995) although she suggests that universal quantification over pairs may be only implied, not asserted, by reciprocal sentences like (21).

does not preserve the truth of this example; the following example is contradictory:

(29) #The pirates were staring at each other in surprise; one of them wasn't staring at any pirate.

We conclude that the truth of the different reciprocal statements depends on meeting conditions of varying strength. These data show it would not be adequate to postulate some fixed, weak truth conditions for the reciprocal (e.g., what Langendoen 1978 called Weak Reciprocity) and rely on pragmatic strengthening to give a stronger speaker's meaning in cases where the speaker really means something stronger. Each of the reciprocal statements we have considered is literally false if the stronger conditions are not met; however, that would not be so in the case of pragmatic strengthening by means, e.g., of conversational implicature.

What about the converse strategy: relying on pragmatic weakening to loosen some fixed, strong truth conditions we might uniformly assign, thereby yielding a weaker speaker's meaning in cases where that is what we observed? For instance, we might appeal to Strong Reciprocity as the meaning of a reciprocal sentence, requiring each member of the relevant set to bear the stated relation to every other member. But this would not be adequate either because, as just pointed out, reciprocal statements can be strictly true even in conditions falling far short of those required by Strong Reciprocity.

Thus the literal meaning of the reciprocal really does vary across these statements. We must seek a semantic explanation of how it varies; we cannot claim that the literal meaning is fixed and only the speaker's meaning varies.

Related to issues of reciprocal interpretation in context is that some examples seem to have a strong meaning – for example, Strong Reciprocity – but are used in a loose way. Consider the following statement used to describe a bar-room brawl:

(30) The men were hitting each other.

This may be a perfectly acceptable description of this situation even if some men in the bar do not hit some other ones, as most likely would be the case. Thus it has been suggested (Fiengo and Lasnik, 1973) that (30) has truth conditions different from those of Strong Reciprocity. Nevertheless, we believe that (30), interpreted strictly, expresses Strong Reciprocity, but can be used in a loose way to describe a typical situation of a bar-room brawl. The possible 'looseness' or 'imprecision' we ascribe to (30) is not unlike that which may be found in a universal statement such as

(31) Everyone in the room was drunk.

Notice also that the degree of imprecision decreases when the antecedent denotes a relatively small group, as in

(32) The four men were hitting each other.

This sentence clearly claims that each pair is involved. Similarly, the reciprocal is interpreted more strictly when its antecedent group is referred to by listing the members.

(33) John, Paul, George, Ringo and Stu were hitting each other.

These observations are evidence that sentence (30) in fact means Strong Reciprocity but is used in a loose way.

## 3. Characterizing Reciprocal Meaning

We have seen a variety of examples exhibiting different meanings that the reciprocal can have. Here we provide a formal statement of these meanings, cataloging them where possible in terms of previous proposals for reciprocal meaning. For this purpose we draw primarily on the work of Langendoen (1978), who was the first to provide an extensive taxonomy of reciprocal meanings.

Langendoen discussed and compared six truth-conditions as candidates for the meaning of the reciprocal. We are aware of two other proposals for reciprocal meanings which Langendoen did not discuss; these two come from the work of Kański (1987). Of the eight proposals of Langendoen and Kański, we think that three are genuine meanings of the reciprocal, but at least some of the other five are not really things that the reciprocal can mean. We have also discovered examples exhibiting reciprocal meanings that have not been proposed in previous work: One-way Weak Reciprocity (Section 3.3) and Intermediate Alternative Reciprocity (Section 3.4).

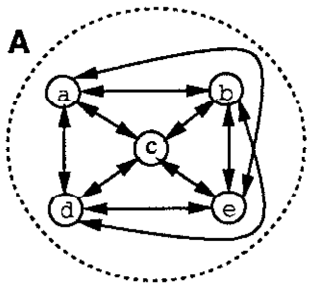
### 3.1. *Strong Reciprocity*

Above, we discussed the following sentence:

(34) (=(2)) House of Commons etiquette requires **legislators** to address only the speaker of the House and **refer to each other indirectly**.

We noted that this sentence is true in the situation depicted in the following diagram:

(35)




This example expresses a notion that has been called *Strong Reciprocity* (Langendoen, 1978). This condition – also called *each-the other* by Fiengo and Lasnik (1973) – is defined as:

(36) Strong Reciprocity (SR):
$|A| \geqslant 2$ and $\forall x,y \in A\ (x \neq y \rightarrow Rxy)$

$A$ represents the group denoted by the antecedent of the reciprocal, $R$ is the relation that is asserted to hold between members of the group and $|A|$ is the cardinality of the set $A$. Informally, SR says that every member of $A$ (in example (34), the group of legislators) is related directly by $R$ (the *refer-indirectly-to* relation) to every other member, as example (34) requires.

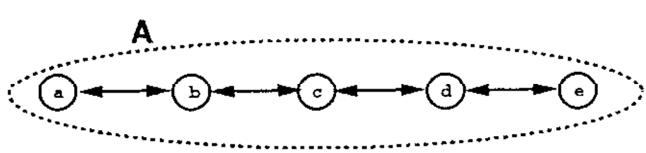
### 3.2. *Intermediate Reciprocity*

As noted above, the following statement from *The New York Times* can be true despite the impossibility of each group member sitting alongside every other one:

(37) (=(4)) As the preposterous horde crowded around, waiting for the likes of Evans and Mike Greenwell, **five Boston pitchers sat alongside each other**: Larry Andersen, Jeff Reardon, Jeff Gray, Dennis Lamp and Tom Bolton.

The situation in which sentence (37) is true is depicted in the following diagram:

(38)

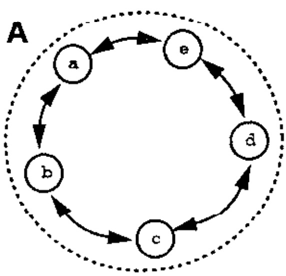


The truth conditions for sentence (37) are precisely characterized by *Intermediate Reciprocity* (Langendoen, 1978), defined as:

(39) Intermediate Reciprocity (IR):
$|A| \geqslant 2$ and
$\forall x,y \in A\ (x \neq y \rightarrow$
for some sequence $z_0, \ldots, z_m \in A$
$(x = z_0 \wedge Rz_0z_1 \wedge \cdots \wedge Rz_{m-1}z_m \wedge z_m = y))$

Informally, IR says that every member of $A$ is related directly or indirectly to every other member via the relation $R$.

Sentence (37) would thus literally be true in another type of situation, depicted in (40), in which the pitchers are sitting in a circle side by side:

(40)



If the situation being described were instead one in which the pitchers were sitting around a campfire, the diagram in (40) would correctly depict it. Since we know that benches at baseball stadiums are straight rather than circular, however, we assume that the situation described by example (37) is instead the one depicted in (38). In both cases, the literal truth conditions are simply Intermediate Reciprocity; specific knowledge and expectations about the different types of situation pragmatically add to the strength of the information communicated in each case.

Example (41) also exemplifies Intermediate Reciprocity:

(41) The telephone poles are spaced five hundred feet from each other.

This sentence is true of a situation in which every pole is five hundred feet from the nearest one or ones along the telephone line in either direction, and is false if any two adjacent poles are separated by a distance other than five hundred feet. Similar requirements hold for example (42), taken from *The New York Times*.

(42) "Technically there is enough energy along our coasts to power Britain," he said, "but at this point to deliver 1,000 megawatts to the consumer, you need a wave power plant with **machines spread out along 30 miles at some distance from each other**, much like underwater fenceposts."

The three examples above all involve symmetric relations. Unlike Strong Reciprocity and many other definitions offered in the literature, Intermediate Reciprocity can hold even when the relation $R$ is asymmetric. However, we have not found examples of reciprocal sentences that involve non-symmetric relations which have the truth conditions given by Intermediate Reciprocity.[3]

### 3.3. *One-way Weak Reciprocity*

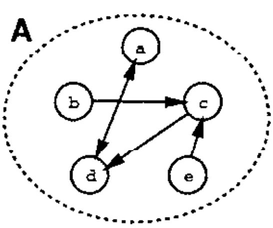
Another example which does not exhibit any of the truth conditions we have noted so far is example (43):

(43) (=(6)) "The captain!" said **the pirates**, **staring at each other in surprise**.

A pirate can stare at only one other pirate, and so it is impossible for each pirate to stare at every other pirate: Strong Reciprocity cannot hold.

Example (43) is true in the situation depicted in the following diagram:

(44)




Example (43) requires that each pirate stared at another one, although perhaps not every pirate was stared at by another one.

Another example which shares these truth conditions is (45), from *The New York Times*:

[3] For this reason, Intermediate Reciprocity is not univocally attested to our present knowledge. All apparent examples of IR fall equally under the concept of Intermediate Alternative Reciprocity, which is univocally attested; there are examples in which the reciprocal expresses IAR and is not understood as IR or any other concept of reciprocity.

(45) A scant year ago, **heavily-armed men** stood in these towers day and night **training sophisticated military optics at each other** and reporting every move they saw.

This example means that each man is training military optics at some other man.

The following definition captures these truth conditions:

(46) One-way Weak Reciprocity (OWR):
$|A| \geq 2$ and $\forall x \in A\ \exists y \in A\ (x \neq y \wedge Rxy)$

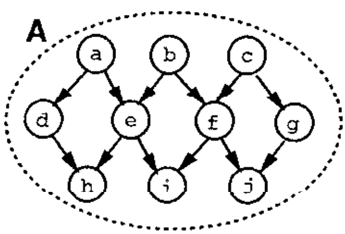
OWR says that every member $x$ of the set $A$ participates with some other member in the relation $R$ as the *first argument* of the relation. In example (43) above, OWR requires that each pirate stares at some other pirate.

### 3.4. *Intermediate Alternative Reciprocity*

Example (47), from The New York Times, exhibits truth conditions that are different from Strong Reciprocity, Intermediate Reciprocity, and One-way Weak Reciprocity:

(47) Instead, **countless stones** – each weighing an average of 300 pounds – **are arranged on top of each other** and are held in place by their own mass and the force of flying buttresses against the walls.

Sentence (47) is true in the situation depicted in the following diagram:

(48)



In the situation described by this sentence, the cathedral under discussion, the National Cathedral in Washington, is built of stones arranged in staggered, overlapping patterns like a brick wall. The sentence asserts that the stones form a single connected structure; it would be false if, for example, the stones were arranged in a multiplicity of piles, each pile separate from the others. These truth conditions are captured by the following definition of reciprocity, which we call Intermediate Alternative Reciprocity:

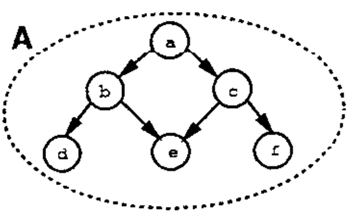
(49) Intermediate Alternative Reciprocity (IAR)

$|A| \geqslant 2$ and
$\forall x,y \in A\ (x \neq y \rightarrow$
for some sequence $z_0, \ldots, z_m \in A$
$(x = z_0 \wedge (Rz_0z_1 \vee Rz_1z_0) \wedge \cdots \wedge$
$(Rz_{m-1}z_m \vee Rz_mz_{m-1}) \wedge z_m = y))$

IAR requires that all pairs in $A$ be connected directly or indirectly via the relation $R$, ignoring the direction of the arrows. That is, each member $x$ of $A$ should be related to every other member $y$ via a chain of $R$-relations, where we ignore which way the pairs making up the chain are related via the relation R. This is unlike the stronger requirements of Intermediate Reciprocity, where directionality of arrows is taken into consideration.

A similar example is:

(50) (=(9)) **They** climbed a drainpipe to enter the school through a high window and **stacked tables on top of each other** to get out again.

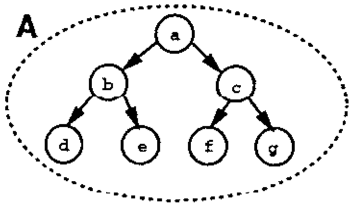
(51) 


Here the diagram depicting the real-world situation for example (50) is different from the diagram in (48) because of other properties of the described situation. The stack of tables is smaller, involving fewer individual tables, and each table must rest on more than one other table for the stack to be stable. Here again we see pragmatic strengthening of the literal truth conditions; nonetheless, the requirements of IAR must hold.

Another example of the same type is:

(52) (=(8)) The third-grade students in Mrs. Smith's class gave each other measles.

(53)




The nature of the relation *give measles to* makes the diagram in (53) different from diagrams (48) and (51): it is not possible to contract measles from more than one person. Nevertheless, the example is an equally good illustration of IAR as defined in (49). Example (52) would be false if some class member neither gave measles to any other member of the class nor got the disease from a fellow class member (thus, got it from outside the class if at all). Thus, the truth conditions of (52) are like those of (47) and (50).

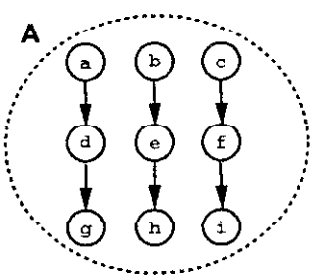
### 3.5. *Inclusive Alternative Ordering*

Example (54) is true in a situation in which there are multiple stacks of foot-wide planks in the holes in the ground:

(54) He and scores of other inmates slept on **foot-wide wooden planks stacked atop each other** – like sardines in a can – in garage-sized holes in the ground.

This example is true in the circumstances depicted in the following diagram:

(55)




These truth conditions are captured by what Kański calls Inclusive Alternative Ordering, defined as:

(56) Inclusive Alternative Ordering (IAO):
$|A| \geqslant 2$ and $\forall x \in A\ \exists y \in A\ (x \neq y \wedge (Rxy \vee Ryx))$

Informally, IAO says that every member $x$ of the set $A$ participates with some other member in the relation $R$ as the first *or* as the second argument, but not necessarily in both roles. Inclusive Alternative Ordering is the weakest relation that has been proposed as a meaning for the reciprocal.

### 3.6. *Unattested Definitions*

Two of the definitions of reciprocity we have looked at (viz., SR and IR) are discussed by Langendoen (1978), and one (IAO) is due to Kański (1987). Langendoen discussed four more definitions, and Kański proposed another definition that had not previously been proposed.[4] Despite earlier claims to the contrary, we are aware of no examples that univocally attest any of these other definitions. We will discuss them one by one below.

*Symmetric Reciprocity* (Langendoen, 1978) is defined as follows:

(57) Symmetric Reciprocity (SmR):
$$\forall x \in A\ \exists y \in A\ (x \neq y \wedge Rxy \wedge Ryx)$$

This requirement was also called the *unrestricted subsets* relation by Dougherty (1974) and *Conjunctive Ordering* by Kański (1987). Informally, this says that every member of $A$ has a 'partner' with whom the relation $R$ holds in both directions. Dougherty (1974) argues that Symmetric Reciprocity gives the proper truth conditions for example (58).

(58) John, Bill, Tom, Jane, and Mary had relations with each other.

He claims (1974, page 14) that this sentence can be true even if "only heterosexual relations are involved" – if (for example) Jane had relations with both John and Bill, but John and Bill did not have relations with each other.

We agree that the truth conditions for example (58) are as Dougherty describes; however, this and all other apparent examples of Symmetric Reciprocity that we have found involve relations that are inherently symmetric. In such cases, the truth conditions given by Symmetric Reciprocity turn out to be equivalent to Inclusive Alternative Ordering. Sentence (58) may well just attest the possibility of interpreting the reciprocal as Inclusive Alternative Ordering.

[4] In fact, Langendoen proposed yet another set of definitions, which involve relations among groups, rather than individuals. These definitions will be discussed in the next section.

*Weak Reciprocity* (Langendoen, 1978) is defined as:

(59) Weak Reciprocity (WR):
$\forall x \in A\ \exists y,z \in A\ (x \neq y \wedge x \neq z \wedge Rxy \wedge Rzx)$

Informally, WR says that every member of the group $A$ participates in the relation $R$ both as the first and as the second argument. Weak Reciprocity is the weakest of the relations discussed by Langendoen, but is stronger than Kański's Inclusive Alternative Ordering.

Langendoen (1978, page 183) offers the following example for Weak Reciprocity:

(60) They are at least as heavy as one another.

We are instructed to evaluate this sentence in a situation in which *they* refers to a group "consisting of five individuals, of whom two weigh 50 kg each, one weighs 60 kg, and two weigh 70 kg each". Langendoen judges the sentence to be true in this situation, and thus to exhibit the truth conditions that Weak Reciprocity would assign, although he states (and we agree) that the sentence is "bizarre independent of the truth or falsity of the assertion that it makes".

In fact, all examples in the literature we are aware of which have been proffered as attesting Weak Reciprocity have as their scope an inherently symmetric relation. When the scope relation $R$ is symmetric, Inclusive Alternative Ordering is equivalent to Weak Reciprocity as well as Symmetric Reciprocity. Thus, we believe that these examples are best regarded as exemplifying IAO and not WR or SmR, since IAO is also exemplified by nonsymmetric cases whose meaning is definitely not any of the other definitions.

Besides IAO and SmR, Kański (1987) proposes *Exclusive Alternative Ordering* as a candidate for reciprocal meaning, defined as:

(61) Exclusive Alternative Ordering (EAO):
$\forall x \in A\ \exists y \in A\ (x \neq y \wedge (Rxy \vee Ryx) \wedge \neg(Rxy \wedge Ryx))$

Informally, EAO says that every member of the group $A$ stands *asymmetrically* in the relation $R$ with some other member. This is a rather peculiar requirement.

Kański claims that Exclusive Alternative Ordering is exemplified by asymmetric relations $R$, such as:

(62) The students followed each other (into the room).

However, we do not believe that the *reciprocal* ever requires that the relation $R$ does not hold symmetrically. Of course, we agree with Kański that sentences containing reciprocals can be true even in case the relation $R$ is asymmetric, as in the case of example (62). As an account of the truth conditions of such sentences, FAO is equivalent to IAO.

In this connection, consider (63), called "the Geach-Kaplan sentence" by Boolos (1984). The example is of interest because, as Kaplan showed, its meaning cannot be represented by a formula of first-order logic. Boolos claims that the example entails that the *admire* relation must hold irreflexively – that each critic in question does not admire him/herself:

(63) Some critics admire only one another.

However, in this case we believe that it is the combination of *only* and *one another* (and not just the reciprocal) that gives rise to this alleged entailment.

The two remaining definitions proposed by Langendoen involve partitioning of the domain of the reciprocal. *Partitioned Strong Reciprocity* (Langendoen 1978, also called the *reciprocal relation* by Fiengo and Lasnik 1973 and the *distinct subsets* relation by Dougherty 1974) is defined as:

(PSR) There is a partition $A_1, \ldots, A_n$ of $A$ such that for all $i$, $|A_i| \geqslant 2$ and $\forall x,y \in A_i\ (x \neq y \rightarrow Rxy)$

This is simply Strong Reciprocity holding of disjoint subsets that cover the whole set $A$.

Fiengo and Lasnik claim that Partitioned Strong Reciprocity correctly represents the truth conditions of:

(64) The men are hitting each other.

We disagree. We think this sentence means Strong Reciprocity but exhibits a certain amount of imprecision. Fiengo and Lasnik acknowledge (pages 452–3) "the impossibility of discrete partitioning in an unclear situation" such as a general brawl, and speculate on why reciprocals are somewhat vague. The one piece of evidence they offer for PSR as the correct meaning for example (64) is their intuition that it is false of a situation in which three men are hitting a fourth one, who is hitting them, and no other hitting is going on. We share this intuition, but note that it is fully compatible with Strong Reciprocity, since the set of four men is so small that vagueness or looseness leaves no latitude for counting this as enough hitting to make the reciprocal statement felicitous.

In fact, we believe that all examples that appear to illustrate Partitioned Strong Reciprocity instead involve Strong Reciprocity, some of them involving distribution to contextually-given sets along the lines proposed by Schwarzschild (1992). On this view, Partitioned Strong Reciprocity might better be termed Distributed Strong Reciprocity. Consider the following example from *The New York Times*:

(65) That heart debt is to the small-town society of her youth, which Bloodworth-Thomason describes as a "kind of microcosm of eccentric characters and Southern humor and familial love and extended family and everybody knows everybody and **their grandparents knew each other**."

This sentence describes a situation in which each citizen of a town satisfies two conditions: that his maternal grandparents knew his paternal grandparents, and vice versa. We can also imagine an example requiring distribution in a different way:

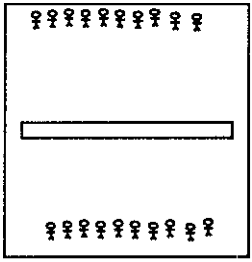
(66) Many years ago, arranged marriages were common in that town. As for the Smiths, their great-grandparents were complete strangers to each other when they got married. But that all changed 60 years ago; of course, **their grandparents knew each other** before they got married.

Here, the context requires a different interpretation: Mr. Smith's maternal grandparents knew each other, and so did his paternal grandparents; likewise for Mrs. Smith's grandparents. In this context, example (66) would be judged false if either grandparents of either Smith had an arranged marriage, even if it happened that (for example) the maternal grandmother knew the paternal grandfather, and the paternal grandmother knew the maternal grandfather. It is not sufficient that *some partition or other* satisfy SR. To make the sentence true, only the contextually salient partition will suffice.

Schwarzschild (1992) makes a similar point in his discussion of example (67) (Schwarzschild's (34)):

(67) The prisoners on the two sides of the room could see each other.

This example is to be evaluated in a context where there are prisoners on both sides of the room and an opaque barrier in the middle of the room, as represented in this diagram:

(68) 

As Schwarzschild points out, the sentence is false in this case, since the prisoners on one side of the room cannot see the prisoners on the other side. Even though there is a partition within each cell of which SR holds, this does not suffice to satisfy the truth conditions of (67).

*Partitioned Intermediate Reciprocity* (Langendoen 1978) is defined as:

(69) Partitioned Intermediate Reciprocity (PIR):
There is a partition $A_1, \ldots, A_n$ of $A$ such that
for all $i$, $|A_i| \geq 2$ and
$\forall x, y \in A_i\ (x \neq y \rightarrow$
for some sequence $z_0, \ldots, z_m \in A_i$
$(x = z_0 \wedge Rz_0z_1 \wedge \cdots \wedge Rz_{m-1}z_m \wedge z_m = y))$

Partitioned Intermediate Reciprocity bears the same relation to Intermediate Reciprocity that Partitioned Strong Reciprocity bears to Strong Reciprocity: Partitioned Intermediate Reciprocity requires Intermediate Reciprocity to hold within disjoint subsets covering $A$.[5]

We have found no example that illustrates Partitioned Intermediate Reciprocity.

## 4. Digression: Relations Among Groups

In all of the examples we have examined so far, the relation $R$ holds between individuals (i.e., atoms) in the group $A$. We have also mentioned cases in which the relation holds between subgroups, or groups, or "operative subsums" (Schwarzschild 1992; see also Moltmann 1992) of the group $A$; the Schwarzschild example (67), repeated here, is such an example:

(70) (=(67)) The prisoners on the two sides of the room could see each other.

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[5] PIR is equivalent to the requirement that each member of $A$ is involved in a non-trivial 'loop' of arrows, where each arrow goes from a member of $A$ to another via $R$.

The example means that the group of prisoners on side A of the room could see the group of prisoners on side B of the room, and vice versa. Many other such cases can be found:

(71) **The tanks facing each other across central Europe** are no longer the problem, in other words, but the economic and political tumult swirling about them can be every bit as lethal.

Here the participants in the relation *facing* are groups of tanks; the most likely interpretation in context is that there are two groups of tanks, each group facing the other one. Note that although the antecedent noun phrase apparently denotes a large set of tanks, the domain of the reciprocal is best regarded as having just two members.

We have also found cases that exhibit ambiguity:

(72) To muddy the ballot waters further, **at least four sets of propositions compete with each other**.

This sentence can be interpreted as SR with distribution to contextually salient groups, as discussed in Section 3.6. On this reading, each of the members of the first set of propositions on the ballot competes with every other individual proposition in that set, and similarly for the other three sets. (This is in fact the actual reading of the sentence, as becomes clear from inspection of the context in which it appears.) Interestingly, this is the linguistic opposite of the situation with example (71). Although the antecedent noun phrase apparently denotes a collection with four members, each a set of propositions, the domain on which strong reciprocity holds is each one of those sets separately.

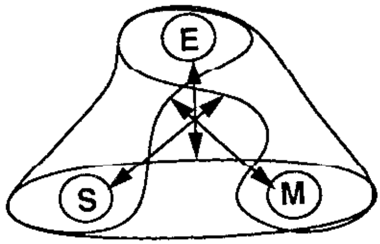
Alternatively, the sentence can be interpreted as asserting that the relation *compete* holds between sets of propositions on the ballot: that each of the four sets of propositions competes with the other three sets of propositions. Here, the reciprocal is interpreted as SR; again, the only difference from the cases discussed earlier is that the individuals related by relation $R$ are not atomic. The proper analysis of these examples involves us in the theory of group formation and collective predication, topics which we will not touch on further here.

We have also discovered examples of a different sort in which the relation $R$ holds between subsets of $A$. One such example is:

(73) The satellite, called Windsock, would be launched from under the wing of a B-52 bomber and fly to a "libration point" where **the gravitational fields of the Earth, the Sun and the Moon cancel each other out**.

In this example, the gravitational field of the Earth cancels out the combined gravitational fields of the Sun and the Moon, and so on. This situation is depicted in the following diagram:

(74)




Another example, brought to our attention by Yasunari Harada, is:

(75) The forks are propped against each other.

to describe a situation where three forks are in a tripod-like configuration, and each fork is supported by the other two.

These examples are different from the ones discussed earlier, since there is not a contextually-salient grouping of members of the set of forks or the set {Sun, Moon, Earth} into subgroups. Langendoen (1978), originally discussed examples like these under the general heading of Reciprocity for Subsets. Weak Reciprocity for Subsets can be defined as:

(76) Weak Reciprocity for Subsets (WRS):
Let $R_1$ be the following subset of the domain of $R$ on groups (including trivial groups, with just one member):

$$R_1 = \{X \subseteq A \mid \exists Y \subseteq A\ (Y \neq \emptyset \wedge X \not\subseteq Y \wedge RXY)\}$$

Similarly, let $R_2$ be the following subset of the range of $R$ on groups:

$$R_2 = \{X \subseteq A \mid \exists Y \subseteq A\ (Y \neq \emptyset \wedge X \not\subseteq Y \wedge RYX)\}$$

Then WRS holds of $A$ and $R$ iff

$$A \subseteq \left(\bigcup R_1\right) \cap \left(\bigcup R_2\right)$$

This definition makes sentences (73) and (75) true, but may be too weak for such examples in general. For instance, in a situation like (75) but where there are four forks, WRS would not require each fork to be supported by the other three forks. We do not have strong intuitions about this situation; however, if this is required for such examples, a definition like the following one is needed:

(77) $A \subseteq \{x \in A \mid Rx(A \setminus \{x\})\}$

We will not provide further discussion of such examples here, since our aim is the characterization of the meanings of basic reciprocal sentences, and we believe that the meanings of these examples should be characterized independently.

## 5. Parameterizing the Reciprocal's Truth Conditions

### 5.1. *The Reciprocal Expresses a Polyadic Quantifier*

Let us first be clear about how we view the 'logical form' of a simple reciprocal sentence like the following:

(78) Tom, Dick and Harry saw each other.

A sentence like this is naturally divided into three parts: the reciprocal expression *each other*, the reciprocal antecedent *Tom, Dick and Harry*, and the rest of the sentence, in this case *saw*. The semantic contribution of the second part (the reciprocal antecedent) is a group, i.e., a set of individuals (in this case {Tom, Dick, Harry}), and that of the third part is a binary relation (in this case $\lambda xy.\text{saw}(x, y)$). The reciprocal *each other* combines these two things to yield a truth value; its semantics can thus be thought of as a function that maps a set and a binary relation into a truth value. In other words, the semantic contribution of *each other* in a sentence like the above is a *type* $\langle 1, 2 \rangle$ *quantifier* in the sense of generalized quantifier theory (Westerståhl, 1989; van Benthem, 1989); a similar proposal was made by Keenan (1987), who analyzes the reciprocal as a quantifier over pairs.

Quantifiers like type $\langle 1, 2 \rangle$ ones that take $n$-ary relations ($n \geqslant 2$) as some of their arguments are called *polyadic quantifiers*. The above point, that the reciprocal contributes a polyadic quantifier, is neutral as to how the grammar of English treats the expression *each other*.[6] Our view is simply that

- Reciprocal expressions such as the English pronouns *each other* and *one another*, the Japanese adverbial *(o)tagai*, the Chichewa verbal affix *-an*, etc., are quantifiers.

We do not mean that reciprocals somehow give rise to two quantifiers –

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[6] Similarly, saying that the reflexive in a direct object position semantically contributes a function that maps a binary relation into a property does not affect the grammatical status of the reflexive as an anaphoric pronoun.

perhaps two universal quantifiers, or one universal and one existential quantifier. We mean rather that:

- Reciprocals express a single polyadic quantifier that binds two variables in its scope, both variables ranging over one set, the restricted domain of the quantification.

Thus a sentence like

(79) Tom, Dick and Harry saw each other.

expresses a proposition that might be symbolized

(80) $\textsc{recip}(\{\text{Tom, Dick, Harry}\}, \lambda xy.\ \text{saw}(x, y))$

using the quantifier symbol RECIP, with its restricted domain {Tom, Dick, Harry} and its scope. In this vein, a sentence like

(81) Tom, Dick and Harry think they are taller than each other.

which is ambiguous as regards the reciprocal's scope, would be symbolized by either of the following.

(82)(a) $\text{think}(\{\text{Tom, Dick, Harry}\},$
$\qquad\qquad \textsc{recip}(\{\text{Tom, Dick, Harry}\}, \lambda xy.\ \text{taller}(x, y)))$
(b) $\textsc{recip}(\{\text{Tom, Dick, Harry}\}, \lambda xy.\ \text{think}(x, \text{taller}(x, y)))$

A formula $\textsc{recip}(A, \lambda xy.\phi)$ is true iff the relation RECIP holds between the set $A$ and the binary relation of which $\lambda xy.\phi$ is the characteristic function. Like type $\langle 1, 1\rangle$ generalized quantifiers of natural languages, RECIP is required to be conservative, in the sense that

$$\textsc{recip}(A, R) \quad \text{iff} \quad \textsc{recip}(A, R \cap (A \times A))$$

holds for all $A$ and $R$.

Moltmann (1992) argues against treating RECIP as a polyadic quantifier, pointing out that such an analysis predicts scope interactions between RECIP and other quantifiers, and claiming that such interactions are not found. She discusses the following two sentences:

(83)a. John and Mary gave each other some present.
b. John and Mary called each other ten times.

Moltmann claims that these sentences do not have a reading where the other quantifier in the sentence scopes inside RECIP; that is, that the following readings are unavailable:

(84) a. $\textsc{recip}(\{John, Mary\}, \lambda xy.some(present, \lambda z.give(x, y, z)))$
b. $\textsc{recip}(\{John, Mary\}, \lambda xy.ten\_times(call(x, y)))$

The reading in question for example (84a) is that John gave Mary some present, and Mary gave John some present. The relevant reading for example (84b) means that John called Mary ten times, and Mary called John ten times.

We disagree with Moltmann's intuitions concerning example (83a); we find that the reading represented in (84a) is in fact readily available. For example (83b), on the other hand, the preference may be stronger for the cumulative reading of RECIP and the adverb, in which neither takes scope over the other. Even if the reading in (84b) were completely unavailable, however, the availability of the reading in (84a) for example (83a) in itself constitutes evidence that the reciprocal is a quantifier, since it shows that quantifiers can scope in various relationships with RECIP. To see this, consider the following pair of examples:

(85) a. John doesn't like everybody.
b. John doesn't like anybody.

Even if one claimed that each of these sentences is unambiguous, with "not" taking wide scope in example (85a) and narrow scope in example (85b), this would not constitute evidence against "not" as a scope-taking operator: in fact, it must be analyzed as scope-taking to account for the presence of both the wide scope reading for (85a) and the narrow scope reading for (85b).

Further, we find that both of the examples Moltmann presents actually do exhibit ambiguity as to scope. For example (83a), we also find available another reading, although pragmatically not the most plausible one, on which a single present was exchanged between John and Mary:

(86) $some(present, \textsc{recip}(\{John, Mary\}, \lambda xy.give(x, y, z)))$

Similarly, given the proper context, the reading of (83b) in which RECIP takes wide scope (and there are a total of twenty calls) does in fact become available:

(87) The detective noticed ten calls to New York on John's phone bill, and ten calls to Los Angeles on Mary's bill. He decided that they must have been desperate to get in touch with each other, since they called each other ten times.

We believe, then, that Moltmann has misconstrued the data she presents, and that her data show that the reciprocal must be treated as a quantifier.

In fact, it is not possible to capture this ambiguity within an analysis in which RECIP does not take scope.

### 5.2. *The Reciprocal is not an Iteration of Two Quantifiers*

Following a suggestion of Emmon Bach's, Roberts (1987) proposes that reciprocal meaning can be defined in terms of an iteration of two occurrences of the context-sensitive generalized quantifier ENOUGH (Roberts, 1987, page 142):

(88) $$\text{ENOUGH}_1\ x \in A.\ \text{ENOUGH}_2\ y, z \in A.\ x \neq y \wedge x \neq z \wedge R(x, y) \wedge R(z, x)$$

Here, $\text{ENOUGH}_1$ is a type $\langle 1, 1\rangle$ quantifier, and $\text{ENOUGH}_2$ is a type $\langle 2, 2\rangle$ quantifier. Roberts notes that varying the interpretation of ENOUGH yields Strong Reciprocity and Weak Reciprocity as subcases. Interpreting both instances of ENOUGH as universal quantification gives Strong Reciprocity, while interpreting the first instance of ENOUGH as universal quantification and the second as existential quantification gives Weak Reciprocity.

In fact, Roberts' formula (88) does not quite achieve the intended effect. To get Strong Reciprocity by interpreting $\text{ENOUGH}_1$ and $\text{ENOUGH}_2$ as universal quantifiers, the conditions $x \neq y$ and $x \neq z$ must appear in the restriction of the second universal quantifier. This problem can easily be repaired by modifying (88) as follows:

(89) $$\text{ENOUGH}_1\ x.(x \in A,\ \text{ENOUGH}_2\ y, z.(y \in A \wedge z \in A \wedge x \neq y \wedge x \neq z,\ R(x, y) \wedge R(z, x)))$$

We agree with Roberts that it is necessary to appeal to contextual factors to determine the semantic contribution of the reciprocal. Her definition of reciprocal meaning correctly ensures that the reciprocal can make different semantic contributions depending on the context in which it appears. However, the particular appeal to context that she makes is insufficient to capture the variety of reciprocal meanings that are found. For instance, there is no way to vary the interpretation of ENOUGH to produce the truth conditions required for Intermediate Reciprocity, though, as we have seen, some reciprocal sentences impose these requirements:

(90) The freeway exits are spaced five miles from each other.

Intuitively, the difficulty with Roberts's proposal for reciprocal meanings is that it assumes that varying the force of quantification over individuals is sufficient to distinguish different reciprocal meanings. Examples such as (90) show that to properly distinguish different reciprocal meanings, it is necessary to quantify over *pairs* of individuals standing in the relation $R^+$,[7] which comes from the polyadic quantifier RECIP.[8]

We turn now to a precise statement of the definition of RECIP, showing that the reciprocal meanings attested in previous sections can be stated in terms of a set of simple relations. This allows for a specification of entailments among these meanings. We will make crucial use of these entailments in our definition of RECIP.

### 5.3. *Concepts of Reciprocity*

Parameterizing the differences between the various definitions of RECIP identified by Langendoen and others, as suggested by Dag Westerståhl (p.c.), is useful in understanding the logical relations among these definitions.

The first parameter of variation relates to how the scope relation $R$ should cover the domain $A$. One of the following three requirements might be relevant:

1. each pair of individuals in $A$ may be required to participate in the relation $R$ directly (FUL);
2. each pair of individuals in $A$ may be required to participate in the relation $R$ either directly or indirectly (LIN); or
3. each single individual in $A$ may be required to participate in the relation $R$ with another one (TOT).

[7] $R^+$ is the transitive closure of $R$, i.e., the smallest transitive relation which includes $R$.

[8] Under reasonable assumptions, one can prove that no choice of $\text{ENOUGH}_1$ and $\text{ENOUGH}_2$ allows (89) to capture the truth conditions of Intermediate Reciprocity. Since the variables $y$ and $z$ in (89) vary independently, (89) must be equivalent to the following formula on models where $R$ is symmetric:

(i) $\text{ENOUGH}_1\ x.(x \in A,\ \text{ENOUGH}_3\ y.(y \in A \wedge x \neq y,\ R(x, y)))$,

Here, $\text{ENOUGH}_1$ is as before, and $\text{ENOUGH}_3$ is a suitable quantifier of type $\langle 1, 1\rangle$. Now it is easy to prove that Intermediate Reciprocity (IR) cannot be equivalent to (i) on all models where $R$ is symmetric, provided that $\text{ENOUGH}_1$ and $\text{ENOUGH}_3$ are *permutation invariant*, as all 'logical' quantifiers are (see van Benthem 1986 or Westerståhl 1989). It suffices to observe that while IR distinguishes the following two models, (i) cannot:

(ii)  (iii) 

(Here, all individuals are in $A$ and arrows indicate that $R$ holds in both directions.) Since (89), but not IR, is equivalent to (i) on all symmetric models, (89) and IR cannot be equivalent.

We can state these requirements more formally as:

$$\mathrm{FUL}(A, R) \overset{\mathrm{df}}{\longleftrightarrow} R\restriction A = A \times A$$

$$\mathrm{LIN}\,(A, R) \overset{\mathrm{df}}{\longleftrightarrow} (R\restriction A)^{-} = A \times A$$

$$\mathrm{TOT}\,(A, R) \overset{\mathrm{df}}{\longleftrightarrow} \mathrm{dom}(R\restriction A) = A$$

$R\restriction A$ is $R \cap (A \times A)$, and $(R\restriction A)^{-}$ is the transitive closure of $R\restriction A$.

As discussed above, we believe that the meaning of a reciprocal sentence is never dependent on whether or not an individual bears the relation $R$ to itself, so we would like our parameterization of RECIP to ignore those pairs where the first and second members are the same. The definitions of FUL$\backslash I$, LIN$\backslash I$ and TOT$\backslash I$, where $I$ is the identity relation, capture this fact by ignoring such pairs:

$$\mathrm{FUL}\backslash I(A, R) \overset{\mathrm{df}}{\longleftrightarrow} \mathrm{FUL}(A, R \cup I) \text{ and } |A| \geqslant 2$$

$$\mathrm{LIN}\backslash I(A, R) \overset{\mathrm{df}}{\longleftrightarrow} \mathrm{LIN}\,(A, R \cup I) \text{ and } |A| \geqslant 2$$

$$\mathrm{TOT}\backslash I(A, R) \overset{\mathrm{df}}{\longleftrightarrow} \mathrm{TOT}\,(A, R\backslash I) \text{ and } |A| \geqslant 2$$

Thus, for $Q$ = FUL$\backslash I$, LIN$\backslash I$, TOT$\backslash I$:

$$Q(A, R) \leftrightarrow Q(A, R\backslash I)$$

We analyze RECIP$(A, R)$ as $Q(A, R^{\dagger})$, where $Q$ is FUL$\backslash I$, LIN$\backslash I$ or TOT$\backslash I$ and † is the second parameter of variation in the meaning of the reciprocal, described in the next paragraph. Since these concepts are used in defining possible meanings for RECIP, we place the additional requirement that the set $A$ must have at least two members. We turn now to the second parameter of variation in the meaning of the reciprocal.

The second parameter concerns how the reciprocal's scope determines the argument $R$ of FUL$\backslash I$, LIN$\backslash I$, TOT$\backslash I$: whether the relation $R$ that reciprocity requires between individuals in the domain $A$ is in actuality the extension of the reciprocal's scope, or is obtained from the extension by ignoring the direction in which the scope relation holds (i.e., by adding inverse pairs).

$$R^{\vee} \overset{\mathrm{df}}{\longleftrightarrow} R \cup R^{-1}$$

Thus we define the schema RECIP$^{\#\dagger}$ as:

$$\mathrm{RECIP}^{\#\dagger}(A, R) \overset{\mathrm{df}}{\longleftrightarrow} \mathrm{RECIP}^{\#}(A, R^{\dagger})$$

where RECIP$^{\#}$ is one of FUL$\backslash I$, LIN$\backslash I$ and TOT$\backslash I$, and $R^{\dagger}$ is either $R$ or $R^{\vee}$.

Semantic rules are supposed always to set $R$ equal to the extension of the reciprocal's scope, and A equal to the set denoted by the reciprocal's antecedent when the antecedent is set-denoting.

This way of defining RECIP$^{\#\dagger}$ gives rise to six non-equivalent possible definitions, of which three are new possibilities that have not previously been considered in the literature: Strong Alternative Reciprocity (SAR), One-way Weak Reciprocity (OWR), and Intermediate Alternative Reciprocity (IAR). The reciprocal means OWR in examples (43) and (45), and IAR in examples (47), (50) and (52). These definitions can be ordered according to the implications among them; in the following diagram, the implications are represented by arrows:

(91)

$$\begin{tikzcd}
& & \text{SR: FUL}\backslash I(A,R) \arrow[dl] \arrow[dr] & \\
& \text{IR: LIN}\backslash I(A,R) \arrow[dl] \arrow[dr] & & \text{SAR: FUL}\backslash I(A,R^{\vee}) \arrow[dl] \\
\text{OWR: TOT}\backslash I(A,R) \arrow[dr] & & \text{IAR: LIN}\backslash I(A,R^{\vee}) \arrow[dl] & \\
& \text{IAO: TOT}\backslash I(A,R^{\vee}) & &
\end{tikzcd}$$

The attested definitions discussed in Section 3 are expressible in these terms. Because there apparently are reciprocal sentences whose meaning is a previously unattested definition – IR, IAR and OWR – we provisionally assume that SAR, which also arises from this parameterization, may turn out also to be a possible meaning for reciprocals.

Partitioned Strong Reciprocity, Partitioned Intermediate Reciprocity, Symmetric Reciprocity,[9] Weak Reciprocity,[10] and Kański's Exclusive Alternative Ordering are not definable in these terms. We reiterate that no examples have been given to our knowledge which unequivocally attest any of these definitions.

[9] Symmetric Reciprocity can be expressed as follows, using intersection and the relational converse: TOT$\backslash I(A, R \cap R^{-1})$.

[10] Weak Reciprocity can be expressed as follows, using conjunction and the relational converse: TOT$\backslash I(A, R) \wedge$ TOT$\backslash I(A, R^{-1})$.

### 5.4. *Dependence of Partial Ordering on Special Properties of Scope*

Under certain circumstances, some of the definitions discussed in the previous section become equivalent. In case the scope relation $R$ is transitive and symmetric, for example, the six possible reciprocal meanings collapse to only two separate cases. Care must be taken to control for these factors in considering evidence for the potential reciprocal meanings under discussion.

**Symmetric** $R$. If $R$ is symmetric $R = R^{-1} = R^{\smile}$ and the partially ordered possibilities reduce to:

(92)
$$\begin{array}{ccc} \mathrm{FUL}\backslash I(A,R) & & \mathrm{SR, SAR} \\ \downarrow & & \downarrow \\ \mathrm{LIN}\backslash I(A,R) & \text{i.e.,} & \mathrm{IR, IAR} \\ \downarrow & & \downarrow \\ \mathrm{TOT}\backslash I(A,R) & & \mathrm{IAO, OWR} \end{array}$$

**Transitive** $R$. If $R$ is transitive, $R{\restriction}A = (R{\restriction}A)^{+}$, so $\mathrm{FUL}(A,R) \leftrightarrow \mathrm{LIN}(A,R)$. This reduces the partially ordered possibilities to:

(93)
$$\begin{tikzcd}
& \mathrm{SR, IR} \arrow[dl] \arrow[dr] & \\
\mathrm{OWR} \arrow[dr] & & \mathrm{SAR} \arrow[d] \\
& \mathrm{IAO} & \mathrm{IAR} \arrow[l]
\end{tikzcd}$$

**Transitive and symmetric** $R$. If $R$ is transitive and symmetric, the partially ordered possibilities reduce to:

(94)
$$\begin{array}{ccc} \mathrm{FUL}\backslash I(A,R),\ \mathrm{LIN}\backslash I(A,R) & \text{i.e.,} & \mathrm{SR, IR, SAR, IAR} \\ \downarrow & & \downarrow \\ \mathrm{TOT}\backslash I(A,R) & & \mathrm{IAO, OWR} \end{array}$$

## 6. Generalizing about which Parameter Settings Yield the Observed Truth Conditions: The Strongest Meaning Hypothesis

We spoke informally in preceding sections of the reciprocal's meaning, reading, interpretation or truth conditions varying with context. To be slightly more precise, we were saying that because of what it means, the reciprocal can give different truth conditions to different statements. It is time to get more precise still. We have come to the main point of this paper: systematic investigation of the factors underlying the shifts in the truth conditions of reciprocals.

On one important issue – whether the reciprocal itself is ambiguous – let us disclose our conclusion in advance. Do we claim *each other* is ambiguous, somewhat as the adjective *light* means bright (the opposite of dark) and also means low in weight (the opposite of heavy) according to a speaker's choice? Or do we claim *each other* has a single meaning that exploits an utterance's context in determining the utterance's truth conditions, somewhat as *here* unambiguously means this place, and refers on each occasion to wherever it is uttered?

We believe the latter: the reciprocal has just one meaning, a flexible or context-sensitive one in virtue of which it makes varying contributions to a statement's truth conditions depending on the context in which it appears. The variation is not just in 'fudge factor' or in quantificational force; the reciprocal's meaning is actually capable in appropriate contexts of giving rise to the forms of truth conditions discussed in the previous sections. What, precisely, is that context-sensitive meaning?

Given our parameterization of the reciprocal's meaning, and the partial ordering of the resulting interpretations under entailment, an empirical generalization emerges underlying the examples we discussed. We start from the simpler case: reciprocal sentences with group-denoting antecedents. We then deal with cases having quantified antecedents, which involve the added complication of combining the antecedent quantifier with the $\text{RECIP}^{\#\dagger}$ quantifier and its scope. The examples with quantified antecedents are crucial, for they confirm that the generalization this section derives about the meaning of the reciprocal concerns the combination of the reciprocal with its scope and antecedent. The parameters of reciprocal meaning are set so that the reciprocal statement, not just the reciprocal expression, has the strongest possible candidate meaning.

### 6.1. *Interpreting RECIP in Context*

Recall example

(95) (=(2)) House of Commons legislators refer to each other indirectly.

The reciprocal in statement (95) is interpreted as Strong Reciprocity. This meaning is the strongest candidate in the partial ordering. Furthermore, this interpretation is consistent with the meanings of *House of Commons* *legislators* and *refer indirectly to*; it also is not contradicted by any contextually given information. This simple case is typical of a great many examples.

Next consider

(96) (=(4)) As the preposterous horde crowded around, waiting for the likes of Evans and Mike Greenwell, **five Boston pitchers sat alongside each other**: Larry Andersen, Jeff Reardon, Jeff Gray, Dennis Lamp and Tom Bolton.

The reciprocal in statement (96) is interpreted as Intermediate Reciprocity. We note first that the reciprocal's scope in (96) is the symmetric relation of *sitting alongside*. So the six truth conditions under discussion collapse to three: SR(=SAR), IR(=IAR), and IAO(=OWR).

Notice further that when the group $A$ of pitchers contains as many as five members, SR cannot hold, as people have only two sides. Thus, the meaning of the words in this sentence, together with the nonlinguistic fact that (baseball) pitchers, being people, have only two sides, is inconsistent with any stronger truth conditions than IR. And in fact, the reciprocal is interpreted as IR, the strongest truth condition consistent with these facts. IAO is of course also consistent with these facts; but so is the logically stronger Intermediate Reciprocity, which is what the reciprocal in statement (96) means.

Now consider:

(97) (=(9)) **They** climbed a drainpipe to enter the school through a high window and **stacked tables on top of each other** to get out again.

This sentence means that the tables were piled into a stack, i.e., the reciprocal in statement (97) means IAR. Note that the relation of *stacking on top of* is necessarily asymmetric, so SR cannot hold. If there are finitely many tables, OWR entails that a table on the bottom is stacked on top of a table above, which is impossible; so OWR cannot hold, and the stronger IR cannot hold either. SAR entails that every pair of the tables is in direct physical contact, which is possible only if there are exactly two tables, in which case SAR is equivalent to IAR and IAO. So if there are more than two tables, all interpretations stronger than IAR are unavailable.

This leaves only IAR and the weaker interpretation IAO as consistent interpretations of (97). IAR entails there is one stack, while the weaker condition IAO allows multiple stacks. In the given context, it is clear that one stack is the right interpretation, i.e., the reciprocal has the strongest

meaning IAR of the meanings that are consistent with the acy
the scope relation and the finiteness of the domain.

The scope of

(98) (=(8)) The third-grade students in Mrs. Smith's class g
other measles.

is the relation of giving measles to. First, consider the relation
measles. This relation is necessarily asymmetric, so that SR cann
In fact, even OWR cannot hold, since interpretation OWR of (9
it entail

(99) Each third grader gave another third grader measles.

A person can only have measles once; however, if there are finite
third graders, (99) entails the existence of a collection of third
who passed measles around in a circle, which is impossible with
or more of them getting measles twice. So interpretation OWR
which entails (99), is necessarily false. It is also easy to see that t
fact makes SAR necessarily false if there are three or more third

This leaves IAR and IAO as the only possible meaning for REC
entails that

(100) any two third graders are connected by a chain of third
each of whom either gave measles to or got measles f
next one.

Together with the impossibility of getting measles twice, this ent
there is one third grader from whom all the others got measle
directly or indirectly. This disease transmission pattern is actually p
What are our intuitions about the truth conditions of (98)? In t
actual truth conditions may be weaker than those given by IA
seems to be compatible with there being more than one third gra
got measles from outside of the class of third graders. On the oth
it is not clear whether IAO, which allows as many as half of t
graders to get measles from outside, captures the truth conditions

We believe that example (98) actually does mean IAR, but th
is some vagueness in its meaning. While IAR requires that a sing
grader was the only point of entry of measles into the class, w
allow that there might be a few more points of entry, but still only
number, if the class is large enough. Evidence for this comes f
interpretation of sentences such as:

(101) Those six children gave each other measles.

which does not seem to allow for multiple entry points for the measles virus, in accordance with IAR. This is analogous to the observation that sentence (30) means Strong Reciprocity, with vagueness allowing some men not to hit some other ones when the sentence is true of a bar-room brawl, as discussed in Section 2. Again, then, the sentence has the strongest meaning that is consistent with properties of the relation and the domain.

### 6.2. *The Strongest Meaning Hypothesis*

In each of the examples discussed in the previous section, the reciprocal is interpreted as having the logically strongest candidate meaning which is consistent with the meanings of the reciprocal's scope and antecedent as well as with relevant nonlinguistic information. But what exactly should be interpreted in the strongest way: the reciprocal proper (i.e., RECIP$^{**}$) or the combination of it with its antecedent and scope? Since one must take into account the combined meaning of reciprocal, scope and antecedent in order to determine whether the meaning of a given reciprocal statement is consistent with contextually relevant information, the most natural hypothesis is that the reciprocal is interpreted so as to maximize the strength of this combined meaning. These empirical and theoretical observations indicate that the parameters of the linguistic meaning of reciprocal expressions are set by the following general principle, which we call the *Strongest Meaning Hypothesis*:

> **Strongest Meaning Hypothesis (SMH):** A reciprocal sentence $S$ can be used felicitously in a context $c$, which supplies non-linguistic information $I$ relevant to the reciprocal's interpretation, provided the set $\mathcal{S}_c$ has a member that entails every other one:
> $\mathcal{S}_c = \{p \mid p$ is consistent with $I$ and $p$ is an interpretation of S obtained by interpreting the reciprocal as one of the six quantifiers in (91)$\}$
> In that case, the use of S in $c$ expresses the logically strongest proposition in $\mathcal{S}_c$.

### 6.3. *Evaluating SMH*

Examining a wider variety of examples shows that SMH is successful in predicting which of the various alternative meanings a reciprocal sentence will have, given the context in which the reciprocal appears.

Consider the following example:

(102) The children followed each other.

This sentence exhibits different RECIP meanings, depending on what is permitted by the context. First, consider:

(103) The children followed each other into the church.

In this situation, the children are traversing a path which begins outside the church and ends inside the church. Thus, the relation *follow into the church* is asymmetric and intransitive, disallowing SR and SAR, the relations defined in terms of FUL. Additionally, IR is disallowed, since children who go into the church first cannot even indirectly be said to follow children who go into the church later.

Notice too that if the group of children is finite, then OWR is excluded as a possible meaning for RECIP: it is not possible for each child to be a follower in this situation. Some child or children must be the first to go into the church.

This leaves IAR and IAO as possible meanings for RECIP in this situation. IAR entails that the children entered in a single group while IAO allows more than one group of children to enter the church at the same time through different doors. In a situation where the context supplies the additional information that the children enter the church in multiple groups, IAO is the strongest possible meaning, and it is the one that is chosen. When the context does not supply this information, the stronger meaning IAR is chosen; in fact, this is the meaning of example (104), which does not permit entry of the treehouse by multiple children at once:

(104) The children followed each other into the treehouse.

Consider now the similar sentence (105):

(105) The children followed each other around the Maypole.

Unlike the context described above, the path traversed by the children is circular, and the meaning of RECIP changes accordingly: here, it is possible for every child to bear the *follow* relation to every other child indirectly.[11] This is the requirement of the stronger meaning IR, and this is the meaning

[11] If we assume that the *follow* relation is transitive in this situation – that if child $a$ follows child $b$, and child $b$ follows child $c$, then child $a$ also follows child $c$ – then SR is not ruled out. In that case, as predicted by the SMH, SR is the meaning of the sentence: every child follows every other child around the Maypole.

that the sentence has: every child follows every other child either directly or indirectly around the Maypole.

In statement (106), the reciprocal means IAO:

(106) (=(11)) He and scores of other inmates slept on **foot-wide wooden planks stacked atop each other** – like sardines in a can – in garage-sized holes in the ground.

Like example (97), discussed above, the relation *stacked atop* in example (106) is necessarily asymmetric; in fact, by the reasoning outlined for that example, all interpretations stronger than IAR are unavailable. IAR and IAO are the only interpretations possible.

However, unlike example (97), it is impossible for IAR to hold in this situation. IAR entails there is one stack, while the weaker condition IAO allows multiple stacks. But it would not be possible for scores of sleeping inmates to fit in a single stack of wooden planks in a hole described as "garage-sized"; instead, multiple stacks of planks are required. The example has, as expected, the strongest meaning available in the given context.

The following example also shows the effect of context in the interpretation of the reciprocal:

(107) The inspector found peach fruit flies at four different locations within a mile of each other.

Again, the relation of *being within a mile of* is symmetric, so the six possible reciprocal definitions reduce to three: SR(=SAR), IR(=IAR), and IAO(=OWR). In a context where it was clear that the inspector was systematically criss-crossing the area he was searching, this example would mean SR: each of the locations is within a mile of every other location. But in a context where it was clear that the inspector was making a sweep in a straight line through a large area to collect a sample of fruit fly traps, the stronger interpretation SR is ruled out, and the statement would mean the strongest of the remaining candidates, IR: no two consecutive finds of fruit flies were more than a mile apart.

The SMH also successfully predicts that sentence (108), discussed by Kański (1987), means IAO rather than SR even though the group consists of only two members.

(108) Their bunk beds are on top of one another.

This successful prediction of the SMH is unfortunately accompanied by an incorrect one, however, namely that any reciprocal sentence will mean IAO if all stronger candidates are unsatisfiable, So, for instance, the following example should mean that John and Bill are not the same height – that one of them is taller than the other:

(109) #John and Bill are taller than each other.

The SMH seems to make an overly strong prediction here: the SMH rules out all but the weakest meaning, and allows that meaning as the predicted meaning for the sentence. This example suggests that it may be necessary to revise the SMH so as to preserve the prediction that the reciprocal means whatever option yields the strongest possible interpretation overall, but drop the insistence that only satisfiable interpretations are possible.

The SMH also makes an incorrect prediction for the meaning of example (110), which has the meaning OWR:

(110) (=(6)) "The captain!" said **the pirates, staring at each other in surprise**.

A pirate can stare at only one other pirate, and so SR cannot hold if there are more than two pirates, nor SAR if there are more than three. The SMH thus predicts that the sentence means IR: that each pirate is related directly or indirectly to every other pirate via the *stare* relation. The only way IR can hold for a single-valued relation like *stare* is for there to be no eye contact; if any pirate stares back at one who stares at him, some pirate would have to get left "out of the loop".

However, we don't believe that example (110) has these strict requirements, since it actually allows all of the pirates or none of them to be involved in eye contact, or any number in between. What it requires is something weaker, namely OWR: each pirate stares at another one, although perhaps not every pirate is stared at by another one. For this example, we do not have an explanation of why the sentence does not have the stronger meaning IR.

### 6.4. *Other Applications of SMH*

The SMH is prefigured in work by Schmerling (1978) on verbs such as *allow*, which seem to behave both as equi and as raising verbs. Sentences with *allow* are acceptable with complement verbs having pleonastic and idiom subjects:

(111) a. The new regulations allow there to be intolerable situations like this all the time.

b. The administration allowed unfair advantage to be taken of the embargo by the big oil companies.

In these examples, *allow* appears to be a raising verb. However, the sentences in (112) do not appear to be synonymous, and in these examples, *allow* appears to be an equi verb:

(112)a. I allowed the doctor to examine John.
b. I allowed John to be examined by the doctor.

Schmerling notes that the equi/'give permission' interpretation of *allow* in examples like (112) entails the raising/'do nothing to prevent' interpretation found in examples like (111), and proposes the following principle to explain the pattern of interpretations that is found (Schmerling, 1978, page 304):

(113) Informants assign the most complex interpretation possible to a stimulus sentence.

According to this principle, the stronger equi interpretation for sentences with *allow* is chosen where possible; in other cases, the raising interpretation is chosen. Although this principle is similar to the SMH, Schmerling gives it a very different status: she proposes that it constitutes a pragmatic strategy which informants use in dealing with example sentences, and not a general principle that can be used in determining the meaning of linguistic input.

We claim that the SMH is a semantic principle determining the literal meaning of utterances of certain expressions in any context appropriate for the expression. As employed here, the SMH is not a pragmatic principle – for example, for listeners to use in divining which reading of an ambiguous expression a speaker might intend on a given occasion. It does not concern how the speaker's meaning can diverge from literal meaning of an utterance. Thus its generality should not be expected to be the kind associated with pragmatic principles such as Grice's.

For instance, the SMH is not one of the principles used to work out which meaning of donkey pronouns the speaker has in mind between a 'strong' and a 'weak' reading.[12] When a donkey pronoun has as antecedent a $\uparrow$MON$\uparrow$ quantifier, the 'strong' reading ("beat every donkey they own") is logically stronger than the 'weak' reading; but the weak reading is the one people actually get (Kanazawa, 1994).

(114) Some farmers who own a donkey beat it.

And with $\uparrow$MON$\downarrow$ quantifiers as antecedent, the 'weak' reading ("beat

[12] We base this claim on the work of Kanazawa (1994). See, however, Krifka (1995) for an alternative view.

some donkey he owns") is logically stronger; but the 'strong' reading is the one people actually get.

(115) Not every farmer who owns a donkey beats it.

However, we believe that the SMH does apply more generally than just to reciprocals. Another case where the SMH operates semantically to explain variation in literal meaning is presuppositions of implicative verbs. Coleman (1971) observed (even earlier than Schmerling's work) that the presupposition of, e.g., *manage* varies with context, as (116), (117) and (118) show.

(116) a. John managed to cash the check.
b. John tried to cash the check.

(117) a. He managed to run up a room service bill for \$80,000.
b. It is difficult to run up a room service bill for \$80,000.

(118) a. Our neighbors managed to schedule their wild party of the year the night before my German exam.
b. It is unlikely that our neighbors would schedule their wild party of the year the night before my German exam.

These cases have progressively weaker presuppositions, and each has as its presupposition the strongest candidate consistent with information supplied in the context of utterance. A single sentence like (119) can have any of the three presuppositions, depending on context.

(119) Harry's dog manages to wake him up whenever he dozes off on the couch.

Coleman, unlike Schmerling, presented her proposal as concerning how hearers interpret speech acts.

## 7. Quantified Antecedents

So far we have only looked at reciprocal sentences with group-denoting antecedents like conjoined proper names and definite plurals. We now turn to an examination of reciprocal sentences with quantified antecedents. These provide striking additional support for the SMH, since the SMH also successfully predicts the meaning of reciprocal sentences with quantified antecedents, given certain assumptions about how quantifiers and RECIP can combine.

Consider the following example, in which the antecedent of the reciprocal is the quantified NP 'many people':

(120) (=(13)) Accounts of watching football composed by ordinary spectators emphasize **how familiar many people were to one another**, the wide age-range, and the lively banter. You knew everybody. You never saw 'em between games. But we always stood roughly in the same place and we knew the forty or fifty people around us 'cos they were always there.

In such examples, the antecedent NP expresses a type $\langle 1\rangle$ quantifier $\mathcal{Q}$ constructed from the type $\langle 1, 1\rangle$ determiner quantifier $Q$ and the common noun phrase set $A$.

$$\mathcal{Q} = \{X \mid Q(A, X)\}$$

The quantifier $\mathcal{Q}$ over members of $A$ must combine with the collective predicate $\mathcal{P}$ that the VP expresses, which is composed in turn from the type $\langle 1, 2\rangle$ polyadic quantifier $\textsc{recip}^{\#\dagger}$ and its scope $R$.

$$\mathcal{P} = \{X \mid \textsc{recip}^{\#\dagger}(X, R)\}$$

For statement (120), the type $\langle 1\rangle$ quantifier and the collective predicate are as follows.

$$\mathcal{Q} = \{X \mid \textsc{many}(\textsc{people}, X)\}$$
$$\mathcal{P} = \{X \mid \textsc{recip}^{\#\dagger}(X, \lambda xy.\ x \text{ is familiar to } y)\}$$

The question is: how are these meanings composed to yield the meaning of a reciprocal sentence containing a quantified antecedent, and what does the SMH predict about these cases?

## 7.1. *Previous Proposals*

Higginbotham (1980) addressed the question of how meanings of collective predicates combine with meanings of quantifiers such as *all*, *some* and *no*,[13] proposing that the antecedent quantifies over pluralities, rather than over individuals as usual.

According to this view, when an antecedent NP whose determiner means the type $\langle 1, 1\rangle$ quantifier $Q$ and whose $\bar{N}$ denotes the set $A$ combines with the rest of a reciprocal sentence, the whole expresses the proposition

$$Q(\text{PLU}(A), \{X \sqsubseteq A \mid \text{PSR}(X, R)\})$$

where $X \sqsubseteq A$ means $X$ is a subset of $A$ having at least two members, and

[13] He also considered the case of *only* plus a bare plural as antecedent, treating this as a quantified NP.

$\text{PLU}(A) = \{X \mid X \subseteq A\}$. That is, Higginbotham takes the antecedent NP to quantify over plural groups of $A$s, and the statement to assert that Partitioned Strong Reciprocity holds of the quantity of such groups that $Q$ requires.

However, his proposal fails to extend to the full range of quantifiers. Roberts (1987) credits Kratzer with pointing out that Higginbotham's analysis wrongly gives the truth value false for the quantifier *few* in case only small subsets satisfy $\textsc{recip}^{\#\dagger}$ but many of them do. The dual problem is found for the quantifier *many*. The quantifier *most* presents the same problem as *few*.

(121) Most couples in the apartment complex babysit for each other.

Example (121) is intuitively true if six of the complex's eight couples babysit for each other (pairwise). Nevertheless, sentence (121) is incorrectly predicted to be false since just 57 of the 247 sets of two or more couples have the property of the set's members babysitting for each other.

For a failure of the opposite sort, note that if $A$ is any set with an even number $n \geqslant 4$ of members, its subsets with between two and $n/2$ members – i.e., plural groups that are no more than half as big as the entire set $A$ – constitute a majority of the plural groups of $A$s. Higginbotham's analysis thus incorrectly predicts that reciprocal sentences with the antecedent quantifier *most A* can be true under conditions when no subset of $A$ that satisfies $\textsc{recip}^{\#\dagger}$ contains more than half of $A$'s members.

These defects were partially addressed by Roberts (1987), who proposed treating determiners as cardinal adjectives, making (120) assert that the largest set of people who were familiar to each other contains many members. Her approach is largely successful for determiners such as *at least/most three* and cardinal *few* and *many*. However, Roberts's proposal does not apply to proportional quantifiers such as *most*. Moreover, it is unsuccessful in dealing with cases where the domain of quantification is infinite; in these cases, there may be no largest set in the domain satisfying the reciprocal.

### 7.2. *Bounded Composition*

It seems clear that as antecedents of reciprocals, quantifiers still quantify over members of their domain rather than over groups of domain members. If we temporarily simplify matters by restricting attention to monotone increasing antecedent quantifiers, it is simple to formulate a semantic rule that gives the right results:

$$\exists X \subseteq A(\textsc{recip}^{\#\dagger}(X, R) \wedge Q(A, X))$$

For example, statements (120) and (121) are true iff there is a subset $X$ of the domain $A$ containing many (respectively, most) members and $\textsc{recip}^{\#\dagger}$ holds of that set $X$ for the scope relation $R$.[14]

However, when the antecedent quantifier is monotone decreasing, as in (122)

(122) At most five men hit each other.

the mere existence of a subset of which $\textsc{recip}^{\#\dagger}$ holds is not a sufficient condition for truth. For instance, if all members of a set of six men hit each other (pairwise), that set must have a subset of five men all members of which hit each other (pairwise). But in this case the statement (122) is false. However, an equally simple, different semantic rule accounts naturally for cases where the antecedent quantifier is monotone decreasing:

(MD) $\forall X \subseteq A(\textsc{recip}^{\#\dagger}(X, R) \rightarrow Q(A, X))$

Indeed, (122) is true just in case every set of men who hit each other has at most five members.

Of course, we would not be satisfied with a multiplicity of semantic rules, each applicable only in restricted cases. Instead, we propose the following semantic rule, which does not suffer from the problems of the Higginbotham or the Roberts proposals; we term this mode of combination *Bounded Composition*.[15]

**Bounded Composition** is defined as:

$$\begin{aligned} BC(Q, A, \textsc{recip}^{\#\dagger}, R) &\overset{\text{df}}{\longleftrightarrow} \\ \forall Y \subseteq A(\textsc{recip}^{\#\dagger}(Y, R) \rightarrow \\ &\exists X \subseteq A(|X| \geqslant |Y| \wedge |A \setminus X| \leqslant |A \setminus Y| \wedge \\ &\textsc{recip}^{\#\dagger}(X, R) \wedge Q(A, X))) \\ &\wedge (\exists X \subseteq A\ \textsc{recip}^{\#\dagger}(X, R) \vee Q(A, \emptyset)) \end{aligned}$$

where $|X|$ denotes the cardinality of the set $X$.[16]

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[14] A minor complication arises from the possibility of vacuous truth. To reckon the statement *All the marbles in the bag are the same color as each other* true when no marbles are in the bag, the rule needs to be

(MI) $\exists X \subseteq A(\textsc{recip}^{\#\dagger}(X, R) \wedge Q(A, X)) \vee (Q(A, \emptyset) \wedge \neg\exists X \subseteq A\ \textsc{recip}^{\#\dagger}(X, R))$

[15] This formulation is different from the proposal that appeared under the same name in Kim and Peters (1995). We thank Jan-Tore Lønning for pointing out to us a problem with that version.

[16] This semantic rule is not strictly compositional, as separate reference is needed to the denotation of the antecedent's common noun subphrase, i.e., to the set $A$. When the quantifier $Q$ is permutation invariant (as well as conservative) and $\{X \mid Q(A, X)\}$ is nontrivial (i.e., $Q(A, X_1)$ and $\neg Q(A, X_2)$ hold for some sets $X_1$ and $X_2$), then $A$ is the least live-on set if there is a minimal one: $A$ is included in every set $B$ satisfying

Bounded Composition combines the reciprocal quantifier and its scope $R$ with the antecedent quantifier $Q$ and its domain $A$ to produce the proposition that

- however big a subset of $A$ there is satisfying $\text{RECIP}^{\#\dagger}$ for $R$, you can find a subset of $A$ which is at least that big and satisfies the quantifier $Q$ as well as the reciprocal, and
- some subset of $A$ satisfies the reciprocal unless the empty set satisfies the quantifier.

As Lønning and Peters (1996) show, this rule is equivalent to (MI) when $Q$ is monotone increasing and equivalent to (MD) when $Q$ is monotone decreasing, provided the quantifier $Q$ is permutation invariant and not trivially empty.

### 7.3. *Monotone Increasing Quantifiers*

Let us now examine what values of the parameters of $\text{RECIP}^{\#\dagger}$ are involved in each of various cases with quantified antecedents. The reciprocal in example (120) is interpreted as Strong Reciprocity; (120) is true iff there is a set $Y$ of many people such that every person in $Y$ is familiar with every other one. These truth conditions result when Bounded Composition combines the antecedent quantifier with Strong Reciprocity.

While Strong Reciprocity is the reciprocal's strongest meaning, as the partial ordering in (91) shows, does it yield the strongest combined meaning when Bounded Composition combines it with an antecedent quantifier? The answer is positive if that quantifier is monotone-increasing and permutation invariant.

PROPOSITION 1. For monotone increasing, permutation invariant $Q$:
if $\text{RECIP}^{\#_1\dagger_1} \Rightarrow \text{RECIP}^{\#_2\dagger_2}$
then $\text{BC}(Q, A, \text{RECIP}^{\#_1\dagger_1}, R) \Rightarrow \text{BC}(Q, A, \text{RECIP}^{\#_2\dagger_2}, R)$.

Proposition 1 says that with a monotone increasing quantifier such as *many* or *most*, the logical relationship among the various $\text{RECIP}^{\#\dagger}$ meanings is preserved. Thus, the statement in (120), whose reciprocal is interpreted

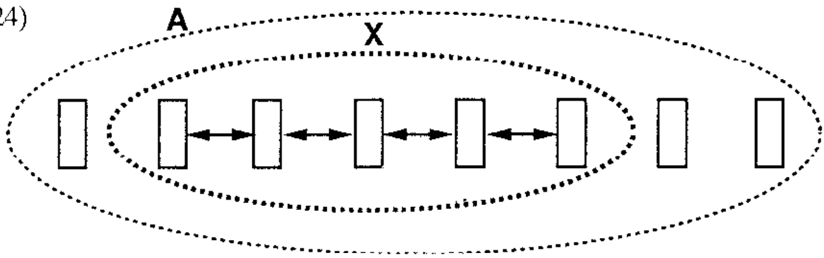
$\forall X(Q(A, X) \longleftrightarrow Q(A, X \cap B))$ if any set is minimal among such sets $B$. In this case, it is possible to formulate a fully compositional semantic rule combining the meaning $\{X \mid Q(A, X)\}$ of the quantified antecedent NP and that of the reciprocal plus its scope $\{X \mid \text{RECIP}^{\#\dagger}(X, R)\}$.

as SR, has the strongest possible interpretation, as predicted by the Strongest Meaning Hypothesis.

Not surprisingly, reciprocals with quantified antecedents can mean something weaker than SR. Consider, for example,

(123) (=(15)) The number of vertebrae varies from 39 to 63 (the larger number in long-necked species), with **many in the trunk fused to each other** and to other bony elements to form a rigid central framework for flight.

(124)




The relation of *being fused to* is symmetric, so only three of the six definitions of RECIP$^{++}$ are distinguishable. The nonlinguistic knowledge that vertebrae are arrayed in a line contradicts the possibility that any set of more than two vertebrae could satisfy SR(=SAR), and two is too few to constitute many. So only IR(=IAR) and IAO(=OWR) yield consistent interpretations of statement (15). IR is the stronger interpretation, in light of Proposition 1; and, as the SMH predicts, IR is what the reciprocal means in (123).

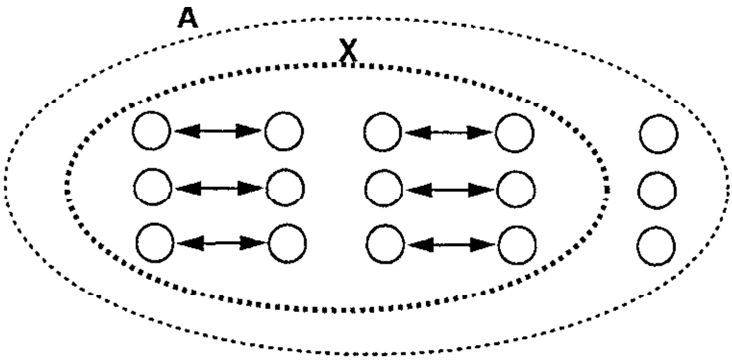
Now consider example (125):

(125) ( = (17)) Many people at the party yesterday are married to each other.

Again, the relation of *being married to* is symmetric, so the six definitions for RECIP collapse to three. Example (125) does not mean that there is a set of many partygoers each two of whom are married (as required by SR or SAR, defined by FUL\I), nor even each two of whom are connected by a chain of marriages (as required by IR or IAR, defined by LIN*I*); our cultural assumptions in a monogamous society do not countenance more than two people being married to each other in the strong or intermediate sense of reciprocity. The only remaining definition is IAO(=OWR, defined by TOT*I*).

In fact, example (125) means that the total number of partygoers whose spouse is at the party is many. This is illustrated in diagram (126): the dotted oval labeled $X$, which includes all couples, must contain many partygoers:

(126)




Notice now that IAO(=OWR) is closed under union of its first argument. Thus IAO holds of the sum of all couples among the partygoers, and this totality is the largest closed set, which the mode BC seeks on a finite domain.

In general, for concepts of reciprocity defined in terms of TOT$\backslash I$, the reciprocal may seem to hold not of a whole set $X$ of domain members meeting the antecedent quantifier's requirements but rather of subsets of $X$ – that is, $X$ appears to comprise all domain members that are reciprocally related to other ones. It may at first sight appear that a different mode of combination is necessary for such cases, such as the putative mode of combination (i) (or, equivalently, (ii)):

(i) $Q(A, \bigcup\{X \subseteq A \mid \text{RECIP}^{\#\dagger}(X, R)\})$
(ii) $Q(A, \{x \mid \exists Y \subseteq A(x \in Y \wedge \text{RECIP}^{\#\dagger}(Y, R))\})$

In van der Does (1993), mode (i) is proposed as one way to combine collectives with quantified subjects; since reciprocals hold of a group, it might be thought that the same range of modes of combination would be necessary for reciprocals. And in fact, Kamp and Reyle (1993) implicitly argued for mode (ii) for reciprocals with quantified antecedents. As Propositions 2 and 3 state, however, the apparent use of a different mode of composition which sums small sets is a by-product of particular $\text{RECIP}^{\#\dagger}$ meanings which are closed under union.

PROPOSITION 2. $\{X \subseteq A \mid \text{TOT}\backslash I(X, R^{\dagger})\}$ is closed under union, for each value of $^{\dagger}$.

PROPOSITION 3. $BC(Q, A, TOT\backslash I, R^{\dagger}) \Leftrightarrow RM(Q, A, TOT\backslash I, R^{\dagger})$ fo all $Q$, $A$, $R$ and values of $^{*\dagger}$, where $RM(Q, A, \text{RECIP}^{*\dagger}, R)$ is defined a mode (i) above.

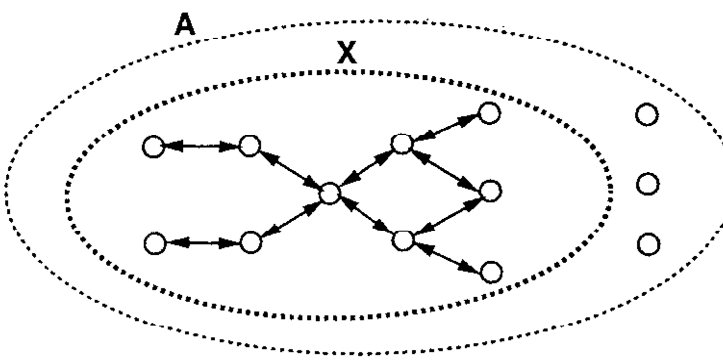
It is, then, unnecessary to propose additional modes of combination, sinc BC suffices for all the cases we have examined.

In contrast to example (125), the statement

(127) Many people at the party yesterday have been married to eac other.

is naturally understood as having stronger truth conditions than (125), a Ray Jackendoff pointed out to us (p.c.). Strong Reciprocity cannot hol in this instance: three or more people cannot all have been marrie pairwise, as Strong Reciprocity would assert, except in violation of th common assumption that spouses are of opposite sexes. Now, howeve divorce is prevalent enough that a set of many serially monogamou partygoers could potentially satisfy Intermediate Reciprocity with respe to the relation *having been married to*:

(128)




Thus the Strongest Meaning Hypothesis predicts that (127) will b interpreted as IR: that is, as meaning that a set of many partygoers exis in which each member is linked to every other one by a chain of past o present marriages.[17] This correct prediction demonstrates how successful the SMH accounts for variation in truth conditions triggered by chang as small as from present tense to present perfect.

For reciprocals with monotone increasing quantified antecedents, th

[17] Note that (127) is not interpreted as claiming that in the set of many partygoers, eve two of opposite sex have been married; the truth conditions are not those of Strong Recipro ity restricted to opposite-sex pairs.

mode BC of combination works well together with the Strongest Meaning Hypothesis, accounting straightforwardly for the interpretation of *each other* as an appropriately selected $\textsc{recip}^{\#\dagger}$. We now turn to an examination of reciprocal sentences with non-monotone and monotone decreasing antecedents; we will see that the SMH gives the correct predictions in these cases as well.

### 7.4. *Non-monotone Quantifiers*

Consider example (129), involving a non-monotone reciprocal antecedent:

(129) **The shop lined up four or five copies of a magazine against each other along a shelf**, so the title appears to be a fast seller – a common US practice.

When the reciprocal's quantified antecedent is non-monotone, in general none of the six propositions that BC produces by combining the antecedent quantifier with the six different interpretations of $\textsc{recip}^{\#\dagger}$ is stronger than any other.

PROPOSITION 4. For all non-monotone quantifiers $Q$ and all $\textsc{recip}^{\#_1\dagger_1}$ and $\textsc{recip}^{\#_2\dagger_2}$ such that $\textsc{recip}^{\#_1\dagger_1} \not\Leftrightarrow \textsc{recip}^{\#_2\dagger_2}$, there are a set $A$ and a relation $R$ such that $\mathrm{BC}(Q, A, \textsc{recip}^{\#_1\dagger_1}, R)$ is true and $\mathrm{BC}(Q, A, \textsc{recip}^{\#_2\dagger_2}, R)$ is not.

In fact, utterances such as (129) are natural only in contexts of a special sort. For instance, (129) is felicitous in a context where it is understood that only a single connected group of copies of the magazine are next to each other. More generally, Kamp and Reyle (1993, pages 466–468) point out that reciprocal sentences with non-monotone antecedents often seem not to have well-defined truth conditions unless it is clear that only one 'cluster' of domain members satisfies the reciprocal.

In such contexts, the strength ordering of $\textsc{recip}^{\#\dagger}$ is preserved under BC even for non-monotone quantifiers. Thus the SMH predicts that in such a context, (129) will mean that a set of 4 or 5 copies of a magazine satisfies IR for the relation *being lined up against*, because the stronger definition SR is inconsistent. Unless the context supplies this additional information, there will usually not be a strongest interpretation of the combination of reciprocal with its scope and antecedent. These observations support the conclusion that the SMH should assert that a reciprocal sentence can be uttered felicitously only in a context where there is a unique strongest interpretation consistent with the contextually given assumptions.

Under these assumptions, the Strongest Meaning Hypothesis has the virtue of correctly predicting how the interpretation of reciprocal statements varies with nonlinguistic information, as in the following minimal pair.

(130) Exactly thirty people know each other.

(131) Exactly thirty people are waltzing with each other.

Consider these statements as describing the same situation: several small clubs are jointly holding a party. There are thirty people in the room, comprising the total membership of the several clubs. Everyone knows every other member of the same club but no one knows any member of other clubs. Everyone is waltzing. In this situation, (130) is judged false, and (131) true.

How does the SMH predict this result? Nothing about the relation of *knowing* contradicts interpreting the reciprocal as SR in (130). BC therefore seeks the largest set of people in which everyone knows everyone else. This is the largest club, which cannot have exactly thirty members since the several clubs have thirty members altogether. Hence statement (130) is false in the given situation.

On the other hand, the fact that a person can waltz with only one other person at a time precludes the existence of a set of thirty people each two of whom are waltzing with each other. Since *waltzing* is a symmetric relation, the strongest consistent meaning interprets the reciprocal as IAO(=OWR), which is weaker than both SR(=SAR) and IR(=IAR). Since IAO is closed under union (being definable with TOT$\setminus I$), the largest set, which BC seeks, is the collection of all waltzing couples; this set consists of exactly thirty people in this situation. Hence statement (131) is true. This sort of variation in the literal meaning of reciprocal statements is correctly accounted for by the SMH.

### 7.5. *Monotone Decreasing Quantifiers*

The Strongest Meaning Hypothesis makes an interesting prediction regarding statements with monotone decreasing quantifiers.

(132) Its members are so class conscious that **few have spoken to each other**, lest they accidentally commit a social faux pas.

Note that (132) claims that few members have spoken to another one; it is clearly not a statement about the size of the largest group of members such that each pair of them have spoken. If many members spoke to another one, but almost none spoke to anyone in return, statement (132) would be false. So the reciprocal in (132) must mean IAO. The SMH explains this empirical fact in terms of the following property of Bounded Composition.

PROPOSITION 5. For monotone decreasing, permutation invariant $Q$:
if $\textsc{recip}^{\#_1 \dagger_1} \Rightarrow \textsc{recip}^{\#_2 \dagger_2}$,
then $\mathrm{BC}(Q, A, \textsc{recip}^{\#_2 \dagger_2}, R) \Rightarrow \mathrm{BC}(Q, A, \textsc{recip}^{\#_1 \dagger_1}, R)$,
provided $\textsc{recip}^{\#_2 \dagger_2}$ is closed under union (i.e., is definable using $\mathrm{TOT} \backslash I$).

The strength of reciprocal statements with monotone decreasing quantifiers is exactly the reverse of the various interpretations $\textsc{recip}^{\# \dagger}$ of the reciprocal itself. Thus IAO yields the strongest interpretation of the whole statement, and SR the weakest, when the reciprocal's meaning combines with the meanings of its antecedent and scope. As this combined meaning is not contradicted by any assumptions in the context, the reciprocal in (132) is correctly predicted to mean IAO.

This phenomenon of IAO giving the preferred interpretation with monotone decreasing antecedents is very robust; the SMH accounts just as successfully for many other examples, such as the following.

(133) She said she found other competitors on the women's circuit shallow, with closed minds, elaborating: **No one even chats to each other**.

(134) You know one or two Georges. You've met the occasional Cynthia. But **none of them** have ever lived together, or **even know each other**. You think it's unlikely they could have met up and got married behind your back.

Thus the SMH, which was developed initially to account for the meaning of reciprocal statements with group-denoting antecedents, extends naturally to account equally well for quantified antecedents, in connection with which it makes some unexpected correct predictions.

## 8. Conclusion

We have shown that reciprocal statements exhibit a great variety of meanings. However, reciprocals are not ambiguous, nor are they amenable to a treatment in terms of pragmatic weakening or strengthening of a fixed strong or weak meaning. Rather, their meaning is taken from a small inventory of meanings. Further, we can predict which meaning the reciprocal will have in a given context: it will take on the strongest meaning that is consistent with known facts about the antecedent, the scope, and the context.

The Strongest Meaning Hypothesis is successful in predicting not only the meaning of sentences with nonquantified, group-denoting antecedents, but also the meaning of reciprocal sentences with quantified antecedents. Indeed, it appears that the SMH may be a linguistic instance of a more general perceptual principle that explains the lack of ambiguity of visual percepts in many situations, as discussed by Feldman (1995).

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