The Reciprocity-Symmetry Generalization: Protopredicates and the Organization of Lexical Meanings

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Abstract This paper systematically analyzes the relations between logical symmetry and lexical reciprocity. A new generalization about these phenomena is uncovered, which is referred to as the *Reciprocity-Symmetry Generalization*. An analysis of this generalization leads to a new formal theory of lexical reciprocity. The theory builds on a new notion of *protopredicates*, which connects binary and unary meanings at the interface between the lexical items and mental concepts. Because of its foundational nature and plausibility for other languages besides English, the Reciprocity-Symmetry Generalization is conjectured to be a language universal. Although this generalization is new with this paper, it appears to have been silently sensed since early transformational works in the 1960s, without any general analysis. By uncovering this generalization and accounting for it, the present work removes considerable confusion surrounding the pertinent semantic questions.

Keywords reciprocity · collectivity · symmetry · plurals · thematic role

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1 Introduction

A binary predicate R is standardly called **symmetric** if for every x and y, the statement $R(x, y)$ is logically equivalent to $R(y, x)$. Examples for symmetric predicates in English include relational adjectives, nouns and verbs, as in the following equivalent sentences.

(1) a. Rectangle A is identical to Rectangle B $\Leftrightarrow$ Rectangle B is identical to Rectangle A.

b. Mary is John's cousin $\Leftrightarrow$ John is Mary's cousin.

c. Sue collaborated with Dan $\Leftrightarrow$ Dan collaborated with Sue.

Such truth-conditional equivalences lead formal semantic accounts to classify the binary predicates *identical to*, *cousin* (*of*), and *collaborate with* as symmetric (Partee 2008).

A fascinating property of symmetric binary predicates is their systematic homonymy with **reciprocal** predicates. For instance, the binary predicates in (1a–c) all have unary alternates that give rise to the following plural sentences.

(2) a. Rectangle A and Rectangle B are identical.
b. Mary and John are cousins.
c. Sue and Dan collaborated.

Almost all symmetric binary predicates like *identical to*, *cousin* (*of*) and *collaborate* (*with*) have unary alternates, as in (2).[1] However, the converse is not true. There is a considerable class of unary predicates that are intuitively reciprocal, but have a binary alternate that is not symmetric. For instance, consider the following sentences.

(3) a. Sue hugged Dan / Sue kissed Dan / Sue collided with Dan.
b. Sue and Dan hugged/kissed/collided.

The binary predicates in (3a) are obviously non-symmetric. For instance, Sue may have hugged or kissed Dan without him ever hugging or kissing her back. Similarly, *collide with* is also a non-symmetric relation: if Sue's car hit the rear of Dan's car while it was parked and he was sleeping on its back seat, you may truthfully assert that Sue's car collided with Dan's car, but not that Dan's car collided with Sue's car. Despite their non-symmetric behavior, the predicates *hug*, *kiss* and *collide* have reciprocal-looking collective usages, as illustrated in (3b). This fact challenges the common intuition that lexical reciprocity is somehow related to logical symmetry. Due to this challenge, and perhaps owing something to the exuberance in which the problem was introduced in Dong 1971, the semantic connections between symmetry and lexical reciprocity have remained somewhat obscure. This paper aims to remove a big part of the empirical obscurity and account for the emerging picture.

[1] English only has a handful of symmetric predicates that do not have such alternates: *near*, *far from* and *resemble* are notable examples (see section 6).

The paper is structured as follows. Section 2 makes some preliminary remarks about symmetry and reciprocity in language, and in truth-conditional semantics. Section 3 introduces a new empirical generalization about reciprocal alternations and their connections with (non-)symmetry. One kind of lexical reciprocity is characterized by "plain" equivalences, as between (1a–c) and (2a–c). By contrast, it is argued that with non-symmetric predicates, the connections between sentences, as in (3a) and the corresponding collective sentences in (3b) are not logical but preferential. These connections are referred to as "pseudo-reciprocity." The distinction between plain reciprocity and pseudo-reciprocity leads to a new empirical generalization, referred to as the *Reciprocity-Symmetry Generalization* (RSG): a reciprocal alternation shows a plain equivalence *if and only if* the binary form is symmetric.

Section 4 discusses some previous accounts and argues that they do not account for the RSG. Addressing this problem, section 5 develops a new theory of reciprocal alternations, inspired by Dowty's (1991) analysis of *protoroles*. In this theory, reciprocity alternations are viewed as the result of a derivational stage that intermediates between mental concepts and predicate meanings in the lexicon. This intermediate level is defined using abstract predicates referred to as *protopredicates*. Denotations of lexical predicates in plain alternations are derived by protopredicates that are associated with *collective concepts* like "Identity," "Cousinhood" or "Collaboration," which specify *sets of entities*. The respective protopredicate connects the two lexical predicates – the unary-collective predicate and the binary predicate – by a rule that explains the symmetry of the latter. By contrast, pseudo-reciprocal alternations are derived by protopredicates that are associated with two concepts: a collective concept and a binary concept. Such pairs of concepts – for example, a collective Hug vs. a binary-directional Hug – are logically independent, although they are regulated through lexical preferences – for example, a collective hug preferably, though not necessarily, involves two binary hugs. The conceptual connections between the two homonymous entries of verbs like *hug* are specified within one protopredicate, but these connections are distinguished from logical derivations in formal semantics.

Section 6 mentions some recent unpublished work providing new evidence for the proposed theory from irreducible collectivity and Hebrew reciprocal comitatives, and from experimental results about pseudo-reciprocal predicates like *hug* and *collide*.

2 On the Linguistic Expression of Symmetry and Reciprocity

The claim that pairs of sentences as in (1a–c) are "equivalences" invites a clarification about the difference between truth-conditional semantics and information structuring in natural language. Clearly, each of the two sentences in such pairs conveys something different about the participants' involvement. Thus, *A collaborated with B* implies that, from the point of view of the speaker, A and B have different capacities or statures. The implication is reversed in the sentence *B collaborated with A*. More vividly, perhaps: *Podolsky collaborated with Einstein* is a natural way of highlighting the work of the physicist Boris Podolsky on the EPR paradox. By contrast, *Einstein collaborated with Podolsky* might not convey the importance of the collaboration for Podolsky's career. Plausibly, such differences are not truth-conditional: it is hard to come up with contexts in which one of the sentences in such pairs is clearly true while the other one is clearly false. The differences between sentence pairs as in (1a–c) is commonly related to Figure-Ground effects and other non-truth-conditional phenomena (Talmy 1975, 2000, Tversky 1977, Dowty 1991, Gleitman et al. 1996). Thus, our claim that binary predicates as in (1a–c) are symmetric, as they are normally considered in formal logic, does not stand in opposition to further pragmatic considerations in cognitive semantics and cognitive psychology.

A similar remark holds with respect to the claim that the reciprocal sentences (2a–c) are equivalent to the respective sentences in (1a–c). For the same reasons discussed above, to say that *Podolsky collaborated with Einstein* is surely different than saying than the two physicists collaborated. And for the same reasons, the claim about the "equivalence" between the reciprocal sentences and their transitive correlates concerns the truth-conditions of these sentences, not their full informational content.

As a further clarification, it should be noted that the label "reciprocal" for sentences (2a–c) should not be understood as implying that they are somehow derived from equivalent reciprocal sentences like the following.

(4) Rectangle A and Rectangle B are identical to *each other*.

The relation between the binary use of the adjective *identical* in (1a) and its collective use in (2a) is a non-trivial lexical fact: the same phonological material – the word *identical* – has two syntactic and semantic functions. By contrast, the ability to use the pronominal expression *each other* in (4) as an argument of the relational adjective *identical to* is a simple fact about the way this pronoun works, which tells us little about the word *identical*. Virtually all binary predicates appear in reciprocal sentences like (4), whether or not they have a lexical-reciprocal entry. For instance, sentences like *Sue and Dan forgot each other* are perfectly OK due to the general properties of *each other* as a syntactic argument. However, the binary predicate *forget* has no lexical reciprocal correlate: strings like *Sue and Dan forgot*, to the extent that they are acceptable, involve not reciprocity, but an implicit argument (e.g., "forgot something relevant to the context of utterance"). This is only one of many distinctions between lexical reciprocity as in (2) and quantificational reciprocity as in (4). Some further distinctions are discussed in Carlson 1998, Dimitriadis 2008 and Siloni 2012, among others. Despite these distinctions, some confusions surrounding the term "reciprocity" are still widespread. Indeed, early transformational accounts, notably Gleitman 1965, assumed that a sentence like (2a) has (4) in its derivational history. Apparently, convictions that there must be some derivational relation between such sentences have persisted for over half a century. As a matter of fact, at present there is little evidence to support such views, which are also not represented in most recent work on quantificational reciprocity (Dalrymple et al. 1998, Kerem et al. 2009, Sabato & Winter 2012, Mari 2014, Poortman et al. 2016). The possible relation between lexical reciprocity as in (2) and quantificational reciprocity as in (4) is a complex topic, which is still poorly understood. Studying this problem is supplementary to, and partly dependent on, the main tenets of the present work.

3 The Reciprocity-Symmetry Generalization

To address the challenges for the theory of reciprocal predicates, we introduce a formal semantic criterion that distinguishes two sub-classes of such predicates. Reciprocal alternations with predicates like *identical*, *cousin* and *collaborate* are referred to as *plain reciprocity*. For instance, when characterizing the semantic relation between the predicates (*are*) *identical* and *identical to* as plain reciprocity, we rely on the following equivalence:

(5) A and B are identical
$\Leftrightarrow$ A is identical to B, and B is identical to A

The repetition of two "identical to" statements in (5) may seem unnecessary due to the symmetry of this predicate. However, it is required for generality, as explained below. To generalize the plain reciprocity pattern in (5), suppose that P is a unary-collective predicate and R is a binary predicate, such that both P and R are associated with the same morphological form. Due to the morphological relation between them, we classify P and R as *alternates*. For instance, for the adjective *identical*, P is the plural collective usage as in *A&B are identical*, whereas R is the alternate binary form *identical to*. To characterize the semantic alternation between P and R as plain reciprocity, we require the following:

(6) **Plain reciprocity (plainR):** For all x, y such that $x \neq y$:
$P(\{x,y\}) \Leftrightarrow R(x,y) \wedge R(y,x)$

In words: we say that plainR obtains between P and R if for every pair of entities x and y, the collective predicate P holds of the doubleton $\{x,y\}$ if and only if the binary predicate R holds between x and y in both directions.[2] Thus, due to the definition in (6), the equivalence in (5) characterizes the alternation of the predicate *identical* as plain reciprocity, where P is the unary-collective use of the predicate and R is the binary form *identical to*.

After stating the general condition of plainR alternations, let us now return to the redundancy we feel in (5). This redundancy is due to the symmetry of the binary predicate *identical to*. However, the general definition of plainR alternations in (6) does not assume anything about symmetry of the binary predicate R (see footnote 2). This is deliberately so, for symmetry of a binary predicate R should analytically be distinguished from

[2] Note that this does not mean that R is symmetric: it only means that the predicate R holds "symmetrically" between the x's and y's that satisfy $P(\{x,y\})$. For other x's and y's, the predicate R may hold in one direction only, hence (6) does not require R to be symmetric.

the sort of reciprocity we see in the corresponding collective predicate P. As we shall see below, it is possible to define artificial collective predicates that stand in plain reciprocity to non-symmetric binary predicates. Since we want the notion of plain reciprocity in (6) to be well-defined for all binary predicates, we do not assume anything about R's symmetry.

Notwithstanding, a deep connection between symmetry and reciprocity has been maintained by most previous works on the topic (see section 4 below). Here it is claimed that in fact, such a connection only exists for the reciprocal alternations that we classified as *plain* reciprocity. Although logic alone cannot account for such connections, I propose that the connection between plain reciprocity and symmetry is a valid empirical generalization. The part of this connection that we have so far observed is officially stated below.

(7) **Reciprocity-Symmetry Generalization (RSG, first version):** All binary predicates in natural language that take part in plainR alternations are truth-conditionally symmetric.

This generalization states that logical symmetry is a necessary property of any binary predicate in natural language that stands in a plainR alternation to a collective predicate. A major aim of this paper is to substantiate this generalization and account for it.

More examples for predicates that give rise to plainR alternations are given below.

(8) **Predicates in plainR alternations:**
Verbs: collaborate (with), talk (with), meet (with), marry, debate, match, rhyme (with)
Nouns: cousin (of), twin (of), sibling (of), neighbor (of), partner (of)
Adjectives: identical (to), similar (to), parallel (to), adjacent (to)

As expected by the RSG, the binary guises of all these predicates are logically symmetric. Note that some collective predicates in such alternations also have non-symmetric variants. For instance, unlike *talk with*, the form *talk to* is not symmetric, because Sue may be talking to Dan when he is not talking to her. As will be demonstrated below, the alternation between collective *talk* and *talk to* is *not* plainR. By contrast, the alternation between collective *talk* and *talk with* is plainR: in any sentence *A&B talk*, the reciprocal interpretation is equivalent with *A is talking with B and B is talking with A*.

The reciprocal interpretation is not the only reading of the verb *talk*. Like many other reciprocal predicates – for instance, *collaborate*, *similar*, and *friend*, among others – this verb also has a distributive interpretation. For instance, *Sue and Dan are talking* can be true when each of the two people is talking, but they are not talking with each other. This distributive use of intransitive *talk* should be analyzed as distinct from its reciprocal use. To see that, consider, for instance, the following example:

(9) Dan and Sue haven't been talking for ages.

Sentence (9) can be interpreted as true if Dan and Sue haven't had mutual communication for a long time, even if each of them has constantly been talking to other people. This means that the reciprocal interpretation of (9) can be true when the distributive interpretation is false: a sign of a genuine ambiguity between two readings. This ambiguity is plausibly related to the acceptability of sentences like *Sue is talking*.

By contrast, when reciprocal sentences are unacceptable in the singular – as in **Sue met* – the reciprocal reading is the only reading of the plural intransitive: *Sue and Dan met* can only mean that the two people met with each other. Thus, while intransitive *talk* is ambiguous between a reciprocal and a distributive reading, intransitive *meet* is unambiguously reciprocal. The reason for this contrast between different reciprocal predicates is not our main problem here, but it is useful to keep it in mind (see also Ginzburg 1990).

Let us now get back to generalization (7). One important caveat about this generalization concerns the lack of symmetry in gender with binary predicates like *sister* and *brother*, which support plainR alternations. For instance: A and B are sisters if and only if A is B's sister and B is A's sister. This means that the *sister* (*of*) alternation must be classified as plainR. However, the relation *sister of* clearly has non-symmetric usages: if Mary is some boy's sister, he obviously cannot be considered to be "Mary's sister." Schwarz (2006) and Partee (2008) show motivations for analyzing gender as a presupposition of kinship nouns, rather than as a truth-condition.[3]

[3]Schwarz argues that *Kim isn't his sister* implies that Kim is a female as much as *Kim is*

Similar proposals have been made for gender marking on other items (Sudo 2012). This means that the symmetry tests of the RSG should be applied to what Von Fintel (1999) calls "Strawson entailments": entailments that hold between sentences provided that their presuppositions are satisfied. Indeed, Schwarz and Partee analyze *sister* and *brother* as "Strawson-symmetric": symmetric in situations that satisfy their gender presuppositions. This removes the potential challenge to the RSG in (7), which only relies on truth-conditional symmetry. A similar caveat holds for any language that marks gender on predicates.[4]

We now move on to one outstanding challenge for theories of lexical reciprocity: the behavior of verbs like *hug*, *kiss* and *collide* as in (3). To show that such verbs do not support plainR, we should consider the following question: what are the semantic relations between the following two sentences?

(10) Sue and Dan hugged.

(11) Sue hugged Dan and Dan hugged Sue.

To be sure, sentence (11) does not entail (10) (Dong 1971, Carlson 1998): suppose that Sue hugged Dan while he was sleeping; then, after Dan woke up, Sue fell asleep and he hugged her while she was sleeping. In such a scenario (11) is true while (10) is false.

Furthermore, collective sentences like (10) do not uniformly entail "symmetric statements" like (11) either. As Winter et al. (2016) experimentally show, under certain circumstances, Dutch speakers may judge a sentence

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his sister does, and suggests that the gender implication scopes over negation like other presuppositions.

[4]In English, there are not many gender-sensitive binary predicates that show a plainR behavior (though this phenomenon may have also developed with plural terms like *girlfriends*, *boyfriends*, *wives* and *husbands* when applied to gay couples). Gender-sensitive plainR alternations are more common in languages with grammatical gender. For instance, in Hebrew even the predicates *zehe le* (identical-SG.MASC to) and *zeha le* (identical-SG.FEM to) are gender-marked. Nevertheless, the Hebrew concept of identity is as symmetric as it can get in other languages: *Sue zeha le-Dan* holds iff *Dan zehe le-Sue* does. Similarly, both English and Hebrew support equivalences like *Sue is Dan's sister* ⇔ *Dan is Sue's brother*. Reasonably, this happens because the symmetry of the concept "Sibling" is independent of its realization by a gender-neutral noun (which doesn't exist in Hebrew).

like (10) as true while judging (11) to be false. For example, in the situation of figure 1, many speakers judged the Dutch translation of 'the girl and the woman are hugging' as true, while judging 'the woman is hugging the girl' as false. According to the standard semantics of conjunction, this judgement renders (11) false for such speakers, even though they accept (10) as true.

Figure 1

We conclude that it is hardly possible to derive the meaning of (10) from a conjunction like (11) of binary statements. Although there is much to say about the semantic relations between collective usages of verbs like *hug* and their binary usages, these relations are not fully definable using standard two-valued logic. The full semantic connection between the two forms of *hug* is more likely to be described by "soft" cognitive-conceptual principles, rather than by classical logical rules (see section 6).

We refer to all collective-binary alternations that do not satisfy the plainR characterization in (6) as **pseudo-reciprocity** (pseudoR). The relation between the two usages of *hug*, *kiss* and *collide* is an example for this kind of alternation. Another example is the predicate *be in love*. If A is in love with B and B is in love with A, neither of them has to be aware of the other's feelings, or even know that the other one knows her. In such situations, the love relations between the two people are not accompanied by "collective intentionality" (a term due to Searle 1990). Thus, the sentence *A&B are in love* misses a critical ingredient of its collective interpretation, and can hardly be considered true. In such an "independent love" situation, the sentence is only true under its distributive-existential interpretation "A is in love (with someone) and B is in love (with someone)." Similarly, if A is talking to B and B is talking to A, the collective interpretation of sentence *A&B are talking* is unacceptable if A and B are not intentionally engaged in a talk, for example, because they are not listening to each other.[5] Thus, the collective reading of intransitive *talk* and

[5]Roberto Zamparelli (pers. comm.) suggests imagining a situation in which A is talking to B and B is talking to A over the phone, in an attempt to conduct a phone talk. Suppose that the line is bad and neither of them is hearing the other, while neither of them is aware of the problem. In such a situation, the collective reading of the sentence *A&B are talking* is likely to be judged as false.

the binary form *talk to* are in a pseudoR alternation. The *talk* (*with/to*) case illustrates that the same unary-collective predicate – in this case *talk* – may show different plainR/pseudoR alternations with different binary predicates. Some languages support such multiple plainR/pseudoR alternations more regularly than English (see section 6).[6]

Another example for a pseudoR alternation appears with the Hebrew verb *makir* ('knows', 'is familiar with', 'has heard of'). Consider for instance the following sentence.

(12) morrissey *makir et* hod ma'alata, ve-hod ma'alata *makira et* morrissey
'Morrissey *knows*-MASC ACC Her Majesty, and Her Majesty *knows*-FEM ACC Morrissey'

Sentence (12) is most probably true of the two celebrities, at least when *makir* is interpreted in the sense of 'has heard of'.[7] However, this does not yet support the truth of the following sentence.

(13) morrissey ve-hod ma'alata *makirim*
'Morrissey and Her Majesty *know*-PLUR (= are acquainted with each other)'

Sentence (13) entails a personal acquaintance between Morrissey and Her Majesty, whereas (12) does not: if Morrissey and the queen have never met or talked, (13) is false while (12) is still likely be true. Note that unlike what we saw with the English predicates *be in love* and *talk*, sentences like (13) only have a collective interpretation and no distributive interpretation. This is because the verb *makir* does not tolerate singular subjects with null objects (e.g., **morrissey makir* 'Morrissey knows'). Therefore, the plural intransitive use of the verb *makir* in (13) is unambiguously collective, and only has the sense 'be in an acquaintance relation.'

To sum up, pseudoR alternations are distinguished from plainR alternations in that they do not show the equivalence in (6). Furthermore,

[6]In English, a similar but subtler contrast is found between transitive *meet* and *meet with*. Witness the contrast in *A met (with) B at the station* (Dixon 2005:361–362).

[7]Morrissey himself used this sense of *know* in a song from 1986: "So I broke into the Palace/With a sponge and a rusty spanner/She said: 'Eh, I know you, and you cannot sing'/I said: 'that's nothing – you should hear me play piano'" (The Smiths, *The Queen is Dead*).

for most of the predicates showing pseudo-reciprocity, it is questionable if there is any complete logical description of the semantic relations between the two forms. This lack of regularity hardly deserves the title "reciprocal." The label *pseudo-Reciprocity* is intended to underline this point.

The list below summarizes some of the predicates that show the pseudoR alternation.

(14) **Predicates in pseudoR alternations:** talk (to), (fall/be) in love (with), hug, touch, embrace, pet, fuck, fondle, box, *makir* (Hebrew 'know')

All the binary usages of these pseudoR predicates are non-symmetric. This justifies the following strengthening of the generalization in (7).

(15) **Reciprocity-Symmetry Generalization (RSG, final version):** A reciprocal alternation between a unary-collective predicate P and a binary predicate R is plainR if and only if R is truth-conditionally symmetric.

This strengthened version of the RSG adds to (7) the requirement that if the reciprocity alternation between P and R is not plainR – that is, it is qualified as pseudo-reciprocity – then R is not symmetric. Thus, plainR alternations characterize precisely those symmetric binary relations that have a reciprocal alternate.[8]

The RSG is linguistically revealing because it is not logically necessary. A way to show it is by inventing artificial predicate meanings that would violate this principle. For instance, suppose that the transitive verb *hug* had a morphological alternate *Xhug* with the unary-collective meaning defined in (16) below.

(16) Let *Xhug* have the meaning 'hug each other, but not necessarily at the same time.'

[8]The RSG in its formulation in (15) is neutral with respect to symmetric binary predicates like *resemble*, *near* and *far from*, which have no reciprocal alternates in English. Section 6 refers to a more speculative generalization than the RSG: that *all* binary predicates stem from collective concepts, even when those concepts are not realized as collective predicates in the language under consideration. For instance, Greek and Hebrew do have some reciprocal correlates corresponding to these symmetric binary concepts.

This collective predicate would be in a plainR alternation to the non-symmetric transitive verb *hug*. This is because of the equivalence *A&B Xhugged* $\Leftrightarrow$ *A hugged B and B hugged A*. Having such a plainR alternation with a non-symmetric predicate like *hug* would violate the first part of the RSG (the "only if" direction of (15)). Conversely, we can also define a hypothetical symmetric binary predicate in a pseudoR alternation to a unary-collective predicate. For instance, consider a hypothetical transitive construction *Xtalk to*, which would stand in a morphological alternation to the collective intransitive verb *talk*. Suppose that such a *talk* construction had the meaning of the binary predicate defined in (17).

(17) Let x *Xtalk to* y mean 'x talks to y and y talks to x (without necessarily listening to each other).'

The sentence *A Xtalked to B and B Xtalked to A* would not entail the collective reading of *A&B talked*. Such a case of pseudoR alternation with a symmetric binary predicate like *Xtalk* would also go against the RSG (the "if" direction of (15)).

These two artificial cases illustrate that both directions of the RSG are not logically necessary. Thus, relying on our assumption that the RSG generally holds, we should look for a linguistic theory of the correlation that it describes. This is the topic of the next sections.

4 Previous Accounts and the RSG

Early transformational accounts proposed two different strategies for treating reciprocal alternations. Gleitman (1965) proposed a deletion rule, where eliminating *each other* in binary constructions leads to the unary-collective entry. Lakoff & Peters (1969) proposed a conjunct movement rule that maps *and* conjuncts to PP adjuncts. Semantically, we can describe Gleitman's rule as an operator **U** that maps any binary relation R to the following unary-collective predicate:

(18) $\mathbf{U}(R) = \lambda A.\forall x,y \in A.x \neq y \rightarrow R(x,y)$

Lakoff & Peters' proposal can be mimicked by an operator **B** that maps any unary-collective predicate P to the following binary predicate:

(19) $\mathbf{B}(P) = \lambda x.\lambda y.P(\{x,y\})$

Both operators analyze plainR alternations like (5) correctly. However, in both works it was incorrectly assumed that all binary predicates in reciprocal alternations are symmetric. This prediction is in agreement with the RSG in all that concerns plainR alternations. Furthermore, while Gleitman's account has to stipulate logical symmetry, Lakoff & Peters's rule successfully predicts symmetry as a corollary: trivially, $\mathbf{B}(P)$ is symmetric for every collective predicate P. Somewhat unfortunately, in subsequent linguistic work, the logical term "symmetric predicate" has often been confused with the much vaguer linguistic notion of "standing in a reciprocal alternation" (see Partee 2008 for remarks on some of the terminological issues). This confusion obscured the observation, originally made in Dong 1971, that neither Gleitman (1965) nor Lakoff & Peters (1969) treat the alternations that we here classify as pseudoR. For instance, the **U** operator would wrongly analyze *A&B hugged* as meaning 'A&B hugged each other', ignoring the simultaneity requirement of intransitive *hug*.[9] Conversely, the **B** operator would analyze *A hugged B* as meaning 'A&B hugged', ignoring the non-symmetry of the former. Gleitman and Lakoff & Peters did not consider such cases of pseudoR, and as a result, their theories are empirically incomplete. In a later work, Ginzburg (1990) treated plainR alternations using rules similar to **U** and **B**, proposing linguistic criteria for determining which of them should be used in each case: (in)felicity with reflexive arguments (*A is similar to/*met herself*) and null complements (*A is similar/*met*). Ginzburg did not discuss predicates like *hug* and *kiss*, and his criteria are orthogonal to the plainR/pseudoR distinction. Like the transformational works from the 1960s, Ginzburg's proposal does not account for pseudoR alternations or the plainR/pseudoR distinction.

Later in the 1990s, non-symmetric predicates like *hug* and *kiss* have regained considerable linguistic attention. Gleitman et al.'s (1996) experimental study involved two experiments asking participants to (i) grade various predicates for symmetry, and (ii) indicate how close in meaning reciprocal sentences like *A&B met/kissed* are to the same sentences with an overt *each other*. Gleitman et al. report no correlation between the

[9]With Hebrew *makir* ('know') the counterexample to Gleitman's account would not rely on tense: *A&B makirim* ('A&B are acquainted with each other') would be interpreted by the **U** as equivalent to 'A knows B and B knows A.' As examples (12)–(13) demonstrate, such an analysis would be inadequate.

results, but note (p. 354) that "it becomes progressively harder to find distinguishing events and states [between the unary predicate and the binary predicate with an overt reciprocal – Y.W.] as we ascend the symmetry ladder." This intuition also underlies the RSG. Gleitman et al. do not develop the point further than that. Rather, they conclude that "symmetry" is a lexical-semantic property of certain predicates, distinct from standard logical symmetry. Gleitman et al. illustrate this claim by pairs of binary predicates like *kiss/love* and *collide with/hit*, which are all logically non-symmetric, but where only the first predicate in each pair takes part in reciprocal alternations. Gleitman et al. propose (pp. 355–356) that because verbs like *kiss* and *collide* show the alternation, their binary guises are perceived as "more symmetric" than predicates like *love* and *hit*. While this may be correct, it does not explain why the non-symmetric predicates like *hug* and *kiss* do not support plain reciprocity like the logically symmetric predicates like *marry* or *match*, and only show pseudo-reciprocal relations with their unary-collective alternates (see section 3, the discussion following examples (10) and (11)).

More recent works have concentrated on the connection between thematic roles, reciprocity and events (Carlson 1998, Dimitriadis 2008, Siloni 2012). These works all find interesting distinctions between binary predicates and collective predicates in pseudoR alternations. Notably, as Carlson observes, sentences like *A&B hugged each other five times* are interpreted differently than *A&B hugged five times*. Carlson concludes that the unary-collective predicate must be treated as basic, rather than as derived from the binary predicate. As we show below, this insight, which also underlies Lakoff & Peters' older work, is useful as a basis for analyzing the origins for the RSG, but without further assumptions it does not explain it. Dimitriadis (2008) and Siloni (2012) propose different rules for interpreting reciprocal predicates. These rules are meant as general accounts of the alternation. Therefore, they also do not account for the RSG or the plainR/pseudoR distinction.

In another semantic study of reciprocity, Mari (2014) analyzes sentences like *The boys followed each other into the room*. The non-symmetric predicate *follow into* is furthermore *a*symmetric.[10] Mari's work argues for

[10]Asymmetric binary predicates like the transitive verb *follow* require non-symmetry

systematic generalizations about asymmetry with overt reciprocals like *each other*, but it does not address lexical reciprocity. Asymmetric predicates like *follow* usually reject reciprocal alternations in the lexicon. See, for example, the unavailability of reciprocity in *The boys followed into the room*.[11] Like Mari's work, other recent works on *each other* (e.g., Dalrymple et al. 1998, Kerem et al. 2009, Sabato & Winter 2012, Poortman et al. 2016) also do not address the relations between such quantifiers and lexically reciprocal predicates.

5 Protopredicates and the RSG

This section develops a formal account of reciprocal alternations, which derives the RSG as a corollary. We start from the common intuition that natural language predicates classify eventualities, and that arguments of predicates represent participants in those eventualities according to different thematic roles (traditionally referred to as "agent," "patient," etc.). No special assumptions are made about the semantic properties of these roles, or the way they are hard-coded into predicate meanings. In consistency with the agnostic approach in Dowty 1991, we may think of thematic roles according to what Dowty calls *protoroles*: sets of "entailments of a group of predicates with respect to one of the arguments or each." Following this approach, a formal level of predicate meaning representation is defined, using what I will refer to as *protopredicates*: abstract predicates that make thematic distinctions between entities insomuch as they are relevant for describing logical entailments. Non-symmetric binary predicates like *attack* must logically distinguish their arguments. Accordingly, the protopredicates corresponding to such predicate are binary like their surface forms. By contrast, symmetric binary predicates like *cousin*

under all situations. Thus, a situation in which A follows B into the room must be a situation in which B is not following A into the room. Non-symmetric verbs like *hug* are not asymmetric: it is, of course, possible (and even likely) for A to hug B at the same time when B hugs A.

[11] One asymmetric predicate that does appear in English as a collective entry is *stacked*, as in *The two chairs are stacked*. Hebrew has another asymmetric predicate that can act collectively: *okev* ('consecutive'), as in *3 ve-4 hem misparim okvim* (3 and 4 are numbers consecutive-PLUR, 'one of the numbers 3 and 4 follows the other'). This rare kind of example has not been studied in previous work, and remains a challenge for further research.

of do not make any logical distinctions between their arguments. Therefore, the protopredicates deriving symmetric predicates are assumed to be unary-collective, and derive both binary-symmetric forms like *cousin of* and unary-collective forms like *cousins*. This immediately accounts for plainR alternations. The protopredicates for pseudoR alternations as with the verb *hug* are defined as denoting unions of binary relations and unary-collective relations. This correctly avoids any logical connection between forms such as the two entries for English *hug*. After defining the details of this semantic architecture, it is shown that it expects the RSG as a formal corollary.

Natural language predicates – verbs, nouns and adjectives – can all be seen as names of *concepts*, which speakers use for categorizing situations in their environment. The notion of "thematic role" is based on typical properties of participants in the situations categorized by a predicate concept. For instance, one of the participants in a situation that we may call an *attack* is typically active, hostile, forceful, violent, etc. The other participant is viewed as more passive. A participant of the first kind is traditionally called an "agent," whereas a participant of second kind is called a "patient." To avoid prejudice, we here do without these classical notions. What is important for our purposes is that any situation that we might classify as an *attack* invites us to distinguish between two different "roles" of the participants. Addressing the precise nature of such distinctions would involve big questions like the specification of the events that fall under concepts like "Attack." This enterprise is far beyond the focus of this paper. Fortunately, to develop a theory of reciprocal alternations, we only need to acknowledge the mere existence of role distinctions. Thus, we assume that in any situation that is categorized as falling under the concept "Attack," there are two designated objects, which are distinguished by their "role" in that situation. For generality, we here use the abstract labels "$\mathbf{r}_1$" and "$\mathbf{r}_2$" for these two roles. Further specifics about the conceptual-semantic content of these labels are irrelevant for our purposes here.

In general, each situation that is categorized by a given concept must have one or more participants in some or other "role" that is specified by that concept. In principle, there may be overlaps between the sets of participants of different roles. For instance: with a binary predicate like *attack*, a person may attack herself, in which case two different roles are assigned to the same entity.[12]

For further illustration, (20) below informally describes some different attack situations, with participants A, B, C and D, and their assumed roles.

(20) Attack 1: A has role $\mathbf{r}_1$ ("agent"); B has role $\mathbf{r}_2$ ("patient").
Attack 2: D has role $\mathbf{r}_1$; C has role $\mathbf{r}_2$.
Attack 3: E has both roles $\mathbf{r}_1$ and $\mathbf{r}_2$.

These situations support the following sentences, respectively.

(21) a. A attacked B.
b. D attacked C.
c. E attacked herself.

To describe situations as in (20), we define what we here call a *protopredicate*.[13] A protopredicate is a relation that relates participants in situations not according to their argument position, but according to their semantic roles. In the case of the protopredicate for the verb *attack*, each syntactic argument specifies a different role, hence the protopredicate is fully aligned with the linguistic form. Accordingly, the protopredicate that corresponds to the situations in (20) is simply the following binary relation:

(22) $\{\langle \mathrm{A}, \mathrm{B}\rangle, \langle \mathrm{D}, \mathrm{C}\rangle, \langle \mathrm{E}, \mathrm{E}\rangle\}$

This is the traditional analysis using binary relations for transitive verbs like *attack*. More generally: all protopredicates for non-symmetric binary forms are assigned the type b ("binary"). We use the notation $\mathbf{P}^b$ to indicate that a protopredicate $\mathbf{P}$ is of type b. Thus, the meaning of the verb

[12]A more complicated case of overlap between roles appears when Sue and Dan form a group that attacks itself. To simplify the analysis of reciprocity, we here ignore such situations that involve group arguments. The question of the right representation of such situations using collective protopredicates is related to the general semantic question of how to classify groups and plurals in the lexicon, which goes beyond the scope of this paper. See Dowty 1987, Winter 2002 for a distinction between two types of collectivity. The present paper addresses the only type of collectivity that is invoked by reciprocal predicates in their unary-collective guise – the type that Winter refers to as "set predicates."

[13]The term implies the intuitive connection with Dowty's protoroles, but the current treatment does not presuppose Dowty's conceptions, and can also be implemented under other approaches to thematic roles. I thank Chris Piñón for pointing this out to me.

attack is described by a binary protopredicate $\mathbf{attack}^b$.[14] The binary relation in (22) is one possible denotation of the protopredicate $\mathbf{attack}^b$. Other non-symmetric transitive verbs (*admire, see*) and non-symmetric relational nouns and adjectives (*father of*, *boss of*, *fond of*) receive a similar treatment using binary protopredicates.

Here it should be noted that *b*-type protopredicates like **attack** do definitely *allow* situations that do not distinguish participants in terms of their roles. For instance, in one of the situations described in (22) above, E attacked herself. In this situation, E has both roles $\mathbf{r}_1$ and $\mathbf{r}_2$. In models where all attack events are such self-attacks, the two roles are not extensionally distinguished. However, as illustrated by the other situations in (22), there is no restriction that *forces b*-type protopredicates to show "role symmetry" in all models. For this reason, transitive verbs like *attack* are correctly treated as non-symmetric: in some models (though not necessarily in all models) they denote non-symmetric binary relations.

Something quite different must be said about relational expressions like *marry*, *collaborate*, *friend* (*of*) or *identical* (*to*). The situations that such expressions categorize are "inherently symmetric": the participants in them cannot be logically distinguished in terms of their roles. Thus, although sentences like *Sue collaborated with Dan* or *Sue married Dan* give the impression that Sue was somehow more active or prominent, we make no logical distinction between her role and Dan's role in the situation. Accordingly, in such cases we let each participant receive one and the same role. Because all participants are treated as equal, it is not important to decide if this role is "agent-like," "patient-like," etc. For neutrality, we denote such roles "$\mathbf{r}_{1\text{-}2}$," and intuitively refer to it as "collective".[15]

For example, let us consider the following marriage situations:

(23) Marriage 1: Each of A and B has the role $\mathbf{r}_{1\text{-}2}$.

[14] The same protopredicate would also be useful for nouns like *attack* (*of*) and *attacker*. The analysis should be adjusted to deal with event arguments, a point that is ignored here for the sake of simplicity. However, events fit into the current framework without special problems.

[15] Working within a specific theory of syntax and the lexicon, Siloni (2012) uses an operation of "bundling" for *deriving* an agent-patient role for reciprocal predicates, but I am not sure that there are semantic motivations for such a rule, or if its meaning could be defined in any general way.

Marriage 2: Each of C and D has the role $\mathbf{r}_{1\text{-}2}$.

This summarizes marriages between A and B and between C and D, which are described by the following sentences.

(24) a. A&B married (alternatively: *A married B*, or *B married A*).
b. C&D married (alternatively: *C married D*, or *C married D*).

The protopredicate corresponding to these two marriages is the following:

(25) $\{\{A, B\}, \{C, D\}\}$

More generally, in each situation describing a monogamic marriage, we assume that the bride and groom form one set of participants, whose members are not distinguished by their roles. Such protopredicates, which only assign the collective role $\mathbf{r}_{1\text{-}2}$, are called "collective" and are assigned the type c. In general, a protopredicate $\mathbf{P}$ of type c is denoted $\mathbf{P}^c$. For both intransitive and transitive guises of the verb *marry*, we employ one and the same collective protopredicate, denoted $\mathbf{marry}^c$. The collectivity of the protopredicate $\mathbf{marry}^c$ is viewed as the origin for the inherent symmetry of the transitive verb *marry*: since the protopredicate does not distinguish different roles, we expect all participants to be equally licensed in different argument positions.

As we shall see below, the postulation of collective protopredicates allows us to immediately derive plainR alternations, similarly to Lakoff & Peters' proposal. How about pseudoR alternations? To account for these alternations, we need to also characterize protopredicates for verbs like *hug*. Such protopredicates are treated as unions of b-type and c-type protopredicates. To see what that means, let us reconsider the two guises of the verb *hug*. In its collective guise, it is very much like *marry*: it has two participants with no difference in their roles. Thus, the sentence *Sue and Dan hugged* does not grammatically convey any difference between the activities of the two people. By contrast, in the sentence *Sue hugged Dan*, the non-symmetric transitive verb makes a role distinction: Sue was active and Dan was (possibly) passive. To describe situations with these two different senses of *hug*, we employ a "mixed" collective-binary type for protopredicates. Protopredicates of this type describe situations like the following.

(26) Hug 1: A has role $\mathbf{r}_1$ and B has role $\mathbf{r}_2$.
Hug 2: B has role $\mathbf{r}_1$ and A has role $\mathbf{r}_2$.
Hug 3: Each of C and D has three roles: $\mathbf{r}_1$, $\mathbf{r}_2$ and $\mathbf{r}_{1\text{-}2}$.
Hug 4: Each of E and F has role $\mathbf{r}_{1\text{-}2}$, and in addition, E has role $\mathbf{r}_1$, and F has role $\mathbf{r}_2$.

We may think of $\mathbf{r}_1$ as "agent," of $\mathbf{r}_2$ as "patient," and of $\mathbf{r}_{1\text{-}2}$ as "collective." Under this interpretation, hugs 1 and 2 in (26) are situations where one participant is active and the other is passive. Hug 3 is a prototypical "collective reciprocal hug": the two participants are collectively engaged ($\mathbf{r}_{1\text{-}2}$), and they are both actively engaged and passively engaged (roles $\mathbf{r}_1$ and $\mathbf{r}_2$). By contrast, Hug 4 is an atypical "collective non-reciprocal hug": both participants have the collective role $\mathbf{r}_{1\text{-}2}$, but only one of them is actively hugging the other one (see figure 1). The situations described in (26) support the following sentences, respectively:

(27) a. A hugged B.
b. B hugged A.
c. C&D hugged; C hugged D; D hugged C.
d. E&F hugged; E hugged F.

The protopredicate corresponding to the situations in (26) is made of the following items, possibly mixing sets and ordered pairs:

- Hug 1 corresponds to the ordered pair $\langle A, B\rangle$.
- Hug 2 corresponds to the ordered pair $\langle B, A\rangle$.
- Hug 3 corresponds to the set $\{C, D\}$ and the pairs $\langle C, D\rangle$ and $\langle D, C\rangle$.
- Hug 4 corresponds to the set $\{E, F\}$ and the ordered pair $\langle E, F\rangle$.

In sum, we get the following denotation for the protopredicate:

(28) $\{\langle A, B\rangle, \langle B, A\rangle, \{C, D\}, \langle C, D\rangle, \langle D, C\rangle, \{E, F\}, \langle E, F\rangle\}$

The example in (28) mimics "collective hugs" using sets such as $\{C, D\}$ and $\{E, F\}$, and "binary hugs" using ordered pairs such as $\langle A, B\rangle$ and $\langle C, D\rangle$. To distinguish such "mixed" protopredicates from *b* and *c* protopredicates, we use the type *bc*. Thus, the protopredicate for the verb *hug*, in both its transitive and intransitive guises, is denoted $\mathbf{hug}^{bc}$.[16]

[16]Note that unlike binary and collective protopredicates, a "mixed" binary/collective

Let us now see how the three types of protopredicates – b, c and bc – are interpreted, and derive denotations of lexical predicates. The general definition (29) below formally specifies protopredicate denotations. In this definition, the notation $\wp^2(E)$ stands for the set $\{A \subseteq E : |A| = 2\}$ of all doubleton subsets of E, that is, all the subsets of E that are made of precisely two members. For convenience, this definition ignores sets of more than two members, although extending it for such cases of collectivity is straightforward.

(29) Let **P** be protopredicate of type b, c or bc. Let E be a non-empty set of entities. A **denotation** of **P** over E contains at least one of two parts: a Binary part and Collective part, denoted $[\![\mathbf{P}]\!]^B$ and $[\![\mathbf{P}]\!]^C$, respectively. These parts are defined below for protopredicates of the three types b, c and bc.

$\mathbf{P}^b$:	$[\![\mathbf{P}^b]\!]^B \subseteq E^2$	$[\![\mathbf{P}^b]\!]^C$ is undefined
$\mathbf{P}^c$:	$[\![\mathbf{P}^c]\!]^B$ is undefined	$[\![\mathbf{P}^c]\!]^C \subseteq \wp^2(E)$
$\mathbf{P}^{bc}$:	$[\![\mathbf{P}^{bc}]\!]^B \subseteq E^2$	$[\![\mathbf{P}^{bc}]\!]^C \subseteq \wp^2(E)$

This definition generalizes what is illustrated in (22), (25) and (28) above. For the predicate $\mathbf{attack}^b$, the denotation (22) only contains pairs, and no collections. For the predicate $\mathbf{marry}^c$, the denotation (25) only contains collections, and no pairs. For the predicate $\mathbf{hug}^{bc}$, the denotation (28) contains both collections and pairs.

From denotations of protopredicates, we derive typed denotations of actual predicates in the lexicon. Specifically: from the denotation of the protopredicate **attack**, we derive a denotation for the transitive verb *attack*; from the denotation of **marry**, we derive denotations for the transi-

protopredicate may have a couple of items per situation, as it is the case for the collective Hugs 3 and 4 in (26), which contribute both sets (e.g., {C, D}) and ordered pairs (e.g., ⟨C, D⟩) to the protopredicate denotation in (28). This multiple use of situations is not represented in the collection in (28). However, when we add events to the semantic system, we must make sure to index items like {C, D}, ⟨C, D⟩ and ⟨D, C⟩ in (28) using the same event – the one entity that corresponds to Hug 3 in (26). By contrast, the pairs ⟨A, B⟩ and ⟨B, A⟩ in Hugs 1 and 2 should be indexed by different events. It is important to keep to this method when dealing with sentences that count events. For instance, the sentence *A&B hugged* only reports one hug, not two or three, even though it is always asserted when *A hugged B* and/or *B hugged A* hold.

tive and intransitive guises of the verb *marry*; from the denotation of **hug**, we derive denotations for the transitive and intransitive guises of the verb *hug*. In most cases this is quite straightforward, as illustrated below.

1. *Collective predicates*: The intransitive verb *marry* denotes the "collective" (C) part of the denotation of the protopredicate **marry**, which is the whole denotation. The intransitive verb *hug* denotes the C part of the denotation of the protopredicate **hug**, which may often be only one part of this predicate's denotation. For instance, from (28) we only select the sets $\{\mathrm{C}, \mathrm{D}\}$ and $\{\mathrm{E}, \mathrm{F}\}$ for the intransitive guise of *hug*.
2. *Binary non-symmetric predicates*: The transitive verb *attack* denotes the "binary" (B) part of the denotation of the protopredicate **attack**, that is, the whole denotation. The transitive verb *hug* denotes the B part of the denotation of the protopredicate **hug**. Thus, from (28) we select the pairs $\langle \mathrm{A}, \mathrm{B}\rangle$, $\langle \mathrm{B}, \mathrm{A}\rangle$, $\langle \mathrm{C}, \mathrm{D}\rangle$, $\langle \mathrm{D}, \mathrm{C}\rangle$ and $\langle \mathrm{E}, \mathrm{F}\rangle$ for the transitive guise of *hug*.

The b protopredicate **attack** derives no intransitive collective entry, since its C part is undefined. By contrast, for the c protopredicate **marry** we do have a method for deriving a transitive entry from the C part. This illustrates a third strategy for *binary-symmetric predicates*. It is similar to the transformational rule proposed by Lakoff & Peters (cf. (19)):

3. The transitive verb *marry* denotes the set of pairs:
   $\{\langle x, y\rangle : \{x, y\} \in [\![\mathbf{marry}^c]\!]^C\}$.

In words, these are the pairs whose elements constitute doubletons in the denotation of the protopredicate **marry**. In (25), those pairs are $\langle \mathrm{A}, \mathrm{B}\rangle$, $\langle \mathrm{B}, \mathrm{A}\rangle$, $\langle \mathrm{C}, \mathrm{D}\rangle$ and $\langle \mathrm{D}, \mathrm{C}\rangle$. Note that such a denotation is by definition symmetric, as explained in section 4 in relation to Lakoff & Peters's proposal.

The last strategy above, which was illustrated for the c-type protopredicate **marry**, is also useful for bc protopredicates like **hug**. In many languages, pseudo-reciprocals like *hug* are associated with an entry "hug with," where "A hugs with B" logically means the same as *A&B hug*. For English, we observed a similar strategy with the verb *talk with*: in contrast to the non-symmetric item *talk to*, which stands in a pseudoR alternation to collective *talk*, the symmetric binary predicate *talk with* stands in a plainR alternation to this collective predicate. Greek and Hebrew are languages that have a more productive "comitative" strategy for deriving verbs in such plainR alternations to collective predicates (see section 6). Formally, such binary "hug with" or *talk with* predicates are derived from *bc* protopredicates in the same way that transitive *marry* is derived above from the *c* protopredicate **marry**. For instance, if **hug** is a *bc* protopredicate with the set {A, B} and the pairs ⟨A, B⟩ and ⟨C, D⟩, then a binary verbal form "hug with" will contain the pairs ⟨A, B⟩ and ⟨B, A⟩: the two ordered pairs for whose members a "collective hug" is encoded by a set in the protopredicate. By contrast, the denotation of the transitive verb *hug* will contain ⟨A, B⟩ and ⟨C, D⟩: the two ordered pairs that encode "directional hugs" in the protopredicate. This accounts for the observation by Winter et al. (2016) that a situation as in figure 1 is a collective hug, despite the lack of one directional hug. In this sense, binary relations like "hug with" and *talk with* behave similarly to the intransitive-collective usages of *hug* and *talk*, rather than to the binary usages of *hug* and *talk to*.

To summarize, three different strategies are used for deriving denotations of predicates from denotations of protopredicates:

- A unary-collective strategy (UC): with *c* and *bc* protopredicates.
- A binary non-symmetric strategy (BNS): with *b* and *bc* protopredicates.
- A binary symmetric strategy (BS): with *c* and *bc* protopredicates.

Specifically, when applied to the protopredicates in (22), (25) and (28), these strategies derive denotations of transitive (*tr*) and intransitive (*iv*) verbs, as described below ("xy" abbreviates "$\langle X, Y\rangle$"):

attack^b: From the protopredicate denotation $\{ab, dc, ee\}$ in (22) we derive:
UC: –
BNS: $[\![\ attack_{tv}]\!] = [\![\mathbf{attack}^b]\!]^B = \{ab, dc, ee\}$
BS: –

marry^c: From $\{\{a, b\}, \{c, d\}\}$ in (25) we derive:
UC: $[\![marry_{iv}]\!] = [\![\mathbf{marry}^c]\!]^C = \{\{a, b\}, \{c, d\}\}$
BNS: –
BS: $[\![marry_{tv}]\!] = \{xy : \{x, y\} \in [\![\mathbf{marry}^c]\!]^C\} = \{ab, ba, cd, dc\}$

hug^{bc}: From $\{ab, ba, \{c,d\}, cd, dc, \{e,f\}, ef\}$ in (28) we derive:

UC: $[\![hug_{iv}]\!] = [\![\mathbf{hug}^{bc}]\!]^C = \{\{c,d\},\{e,f\}\}$

BNS: $[\![hug_{tv}]\!] = [\![\mathbf{hug}^{bc}]\!]^B = \{ab, ba, cd, dc, ef\}$

BS: $[\![hug\_with]\!] = \{xy : \{x,y\} \in [\![\mathbf{hug}^{bc}]\!]^C\} = \{cd, dc, ef, fe\}$

Generalizing this example, we get the following definition for the three general derivational strategies.

(30) Let **P** be a protopredicate of type b, c or bc, with a denotation $[\![\mathbf{P}]\!]$. From **P** we derive a collective predicate denotation $P^{uc}_{\mathbf{P}}$ and two binary predicate denotations $R^{bns}_{\mathbf{P}}$ and $R^{bs}_{\mathbf{P}}$. This is defined as follows:

$P^{uc}_{\mathbf{P}} = [\![\mathbf{P}]\!]^C$ = the collective part of **P**, if defined

$R^{bns}_{\mathbf{P}} = [\![\mathbf{P}]\!]^B$ = the binary part of **P**, if defined

$R^{bs}_{\mathbf{P}} = \{\langle x,y\rangle : \{x,y\} \in [\![\mathbf{P}]\!]^C\}$ = the symmetric binary predicate based on the collective part of **P**, if defined

An important feature of this system is that it does not presuppose any logical connection between the "B-part" and the "C-part" of protopredicates of type bc. For instance, nothing in the system so far forces the protopredicate denotation in (28) to include any of the pairs $\langle \mathrm{E}, \mathrm{F}\rangle$ and $\langle \mathrm{F}, \mathrm{E}\rangle$ when it includes the doubleton $\{\mathrm{E}, \mathrm{F}\}$. This means that nothing rules out situations in which *E&F hugged* is modelled as true whereas *E hugged F* or *F hugged E* is modelled as false. This is an intentional architectural decision, which is supported by the observations of Winter et al. (2016), showing the lack of logical relations between collective *hug* and binary *hug*. Any restrictions on protopredicates on top of the ones that result from their type are assumed to follow from specific features of the concepts they describe. Indeed, for two people to be considered "hugging," it might look plausible to assume that each of them is hugging the other one, as virtually all works on the topic have assumed (Dimitriadis 2008, Siloni 2012). However, as Winter et al. (2016) show, it would be too strong to require that each of the two people in a "collective hug" is hugging the other. The maximum we can require with respect to a sentence like *E&F hugged* is that one of the participants hugged the other, whereas the other collaborated in some way or another. Thus, if **hug**^{bc} includes the doubleton

{E, F}, we should require that it also includes the pair ⟨E, F⟩ or the pair ⟨F, E⟩, but not necessarily both pairs. Similar remark holds for the protopredicate **collide**^{bc}: the sentence *E&F collided* may be truthfully asserted when only one among E and F *collided with* the other. Thus, we do not require both pairs ⟨E, F⟩ and ⟨F, E⟩ to be included in the protopredicate **collide**^{bc} in models where the doubleton {E, F} is.

By contrast, with a protopredicate like **fall in love**, when *E&F fell in love* is truthfully asserted under its collective reading, it is quite plausible to require that each of the participants fell in love with the other. Such differences between the pseudo-reciprocal predicates *hug* or *collide* vs. *fall in love* are not encoded in the types of their protopredicates, which are bc in all three cases. In the proposed system, any semantic connections between the collective entry and the binary entry of such verbs must emanate from properties of the underlying concepts, and not from any grammatical mechanism like the type of protopredicates we assign to them.

We have now formally specifies types of protopredicates and the restrictions that these types put on predicate denotations in natural language, using three methods for deriving these denotations (see (30)). With this formal system, we can establish that the Reciprocity-Symmetry Generalization in (15) follows as a corollary. To do that, we restate the RSG as the following property of the system we have defined.

(31) **Reciprocity-Symmetry Generalization (RSG, formal):** Let **P** be a protopredicate of type c or bc, with P the corresponding unary-collective predicate and R a corresponding symmetric predicate, s.t. $P = \mathbf{P}^{uc}$, and $R = R^{bns}_{\mathbf{P}}$ or $R = R^{bs}_{\mathbf{P}}$. The following conditions are equivalent:
  (i) In every model, $[\![R]\!]$ is a symmetric relation.
  (ii) In every model, $\{x, y\} \in [\![P]\!]$ iff $\langle x, y\rangle \in [\![R]\!]$ and $\langle y, x\rangle \in [\![R]\!]$.

Proof: For simplicity, we abbreviate $R^{bns} = R^{bns}_{\mathbf{P}}$ and $R^{bs} = R^{bs}_{\mathbf{P}}$. There are two cases to consider:

1. **P** is of type c. In this case $R = R^{bs}$ by definition, since R^{bns} is undefined. And any R^{bs} satisfies (i) and (ii) by definition.
2. **P** is of type bc. If $R = R^{bs}$, then again, (i) and (ii) are both satisfied in every model. Otherwise $R = R^{bns}$. In this case neither (i) nor (ii)

holds, e.g., as in the following two counter-models. First, a model where $[\![\mathbf{P}^{bc}]\!] = \{\langle c, d\rangle\}$ makes $[\![R^{bns}]\!]$ non-symmetric, hence in such a model (i) is false. Second, a model where $[\![\mathbf{P}^{bc}]\!] = \{\langle c, d\rangle, \langle d, c\rangle\}$ derives $[\![R^{bns}]\!] = \{\langle c, d\rangle, \langle d, c\rangle\}$ and $[\![P^{uc}]\!] = \emptyset$, hence in such a model (ii) in false.

We conclude that (i) and (ii) are equivalent. Thus, the RSG is supported by the system of protopredicates that we have defined. Specifically, in this system, denotations of artificial predicates like *Xhug* and *Xtalk* in (16) and (17) above cannot be derived:

1. Suppose for contradiction that a unary-collective predicate *Xhug* had the meaning "hug each other, but not necessarily at the same time." The transitive verb *hug* in English is not symmetric. Thus, for the hypothetical collective predicate *Xhug* and the transitive verb *hug* to be derived from the same protopredicate **P**, that protopredicate would have to be of type bc (rather than c). Accordingly, in any model, we would have $[\![Xhug]\!] = [\![\mathbf{P}^{bc}]\!]^C$. The type bc for **P** would allow models in which $\mathbf{P}^{bc} = \{\langle \mathrm{A}, \mathrm{B}\rangle, \{\mathrm{A}, \mathrm{B}\}\}$. Any such model would support the sentence *A hugged B* and *A&B Xhugged* but not the sentence *B hugged A*, in contradiction to the definition of *Xhug*.
2. Suppose for contradiction that a binary predicate *Xtalk* had the meaning "$\lambda x.\lambda y.$ x talks to y and y talks to x, without necessarily listening." Consider a situation S (e.g., as in footnote 5) where both *A talks to B* and *B talks to A* are judged true, but the sentence *A&B talked* is judged false. In such a situation, the sentence *A Xtalked B* would have to be judged true by the hypothetical definition of *Xtalk*. This means that the collective intransitive verb *talk* and the hypothetical transitive verb *Xtalk* would not show a plainR alternation, which rules out the possibility that both predicates are derived from the collective part $[\![\mathbf{P}]\!]^C$ of the same protopredicate. The other possibility is that **P** is of type bc and $[\![Xtalk]\!] = [\![\mathbf{P}^{bc}]\!]^B$. But such a possibility would allow models in which $[\![Xtalk]\!]$ is a non-symmetric binary relation, in contradiction to the hypothetical definition of *Xtalk*.

A sophisticated question here would be to ask why some bc protopredicates should not still be restricted by additional meaning postulates, which might create plainR or symmetry effects that do not follow from the type system. The current approach, and the proof above, rely on the assumption that such meaning postulates are not available. Since languages are assumed to own a type system that encodes the conceptual property of "collectivity" by the label c, they are assumed not to encode plainR or symmetry by predicate-specific meaning postulates.

6 Some Outstanding Issues

See Winter 2016 for some further general issues:

1. Sets with more than two members, and Irreducible Collectivity.
2. Plain reciprocity and comitative prepositions.
3. Predicates, protopredicates, concepts, and polysemy.
4. The RSG as a language universal.

For a recent experimental work on pseudo-reciprocals that supports the current proposal, see Winter et al. 2016.

7 Conclusion

The complex relations between symmetry and lexical reciprocity have been analyzed in detail, and given rise to a novel foundational observation, the Reciprocity-Symmetry Generalization. The semantic analysis of the RSG motivates protopredicates as a lexical engine that formally explains reciprocal alternations, at the interface between mental concepts and lexically interpreted forms.

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