

Composing reciprocity: An analysis of scattered reciprocals*

Filipe Hisao Kobayashi
Massachusetts Institute of Technology

Abstract *Scattered reciprocals* (SRs) are Brazilian Portuguese constructions built from two discontinuous phrases which can offer a new window into the issue of the building blocks of reciprocity. By investigating how reciprocity is compositionally built in sentences with SRs, a puzzle emerges: SRs can apparently take split scope around other quantifiers, but only if these quantifiers are pronounced in a position outside of the reciprocal’s scope domain. I argue that these are only apparent cases of split scope and, building on Murray (2008) and Dotlačil (2012), I propose a decompositional account of reciprocals which is formalized in Champollion, Bledin & Li’s (2017) Plural Predicate Logic, a static logic which makes use of sets of assignment functions to model plurals. The resulting analysis allows us to view SRs and reciprocal pronouns like *each other* as being built from the same pieces, with the only difference between them being in how they are syntactically built.

Keywords: reciprocals, *each other*, plurals, cumulativity, Plural Predicate Logic

1 Introduction

A common strategy for expressing reciprocity in natural language is via reciprocal pronouns, i.e., dedicated nominals that tend to have a bipartite morphological structure, like English *each other*, Mandarin Chinese *bi-ci* ‘this-that,’ and Hungarian *egy-más* ‘one-other.’ The morphological complexity of reciprocal pronouns has led researchers, most notably Heim, Lasnik & May (1991), to propose that these reciprocals are also syntactically complex. Because their pieces are always seen together, such analyses of reciprocal pronouns end up having to say that they are only separated covertly.

In the present paper, I analyze reciprocals that are *overtly* syntactically complex. Scattered Reciprocals (SRs), as I call them, are discontinuous reciprocals found

* For valuable discussion and feedback, I am grateful to Athulya Aravind, Elitzur Bar-Asher Siegal, Keny Chatain, Sherry Yong Chen, Luka Crnić, Mary Dalrymple, Patrick D. Elliott, Danny Fox, Kai von Fintel, Enrico Flor, Martin Hackl, Dag Haug, Sabine Iatridou, David Pesetsky, Eric Reuland, Roger Schwarzschild, Yasutada Sudo, Stanislao Zoppi, and the audiences at the Workshop on Cross-linguistic Semantics of Reciprocals and SALT 30. All mistakes are, of course, my own.

in Brazilian Portuguese, among other languages, which are built from two distinct phrases, *um* ‘um’ and *o outro* ‘the other’. As illustrated in (1), each piece of an SR occupies a distinct position in a sentence: *um* has the syntactic distribution of an adverb, whereas *o outro* has the distribution of a nominal.

- (1) Os elefantes estão *um* encarando *o outro*.
the elephants are one staring the other
‘The elephants are staring at each other.’

A hallmark property of SRs is the fact that the dependency established between its pieces does not seem to be subject to any kind of syntactic locality constraints.¹ For example, as shown in (2), the dependency between *um* and *o outro* can be established across relative clauses, which are domains known to be islands for both overt movement and scope taking.²

- (2) Os tatus vão (*um*) comer (*um*) a comida [que *o outro* achar].
the armadillos will one eat one the food that the other find
≈ ‘The armadillos will each eat the food that the others find.’

I take this to show that *um* and *o outro* are *underlyingly* discontinuous: data like (2) rules out analyses in which the discontinuity of SRs is merely superficial (e.g., derived via movement). This property of SRs offers a new window into the question of what exactly are (or at least *can be*) the building blocks of reciprocity. Given that *um* and *o outro* are syntactically independent phrases with their own interpretation, how does each of them contribute to the overall meaning of reciprocity?

In this paper, I investigate the division of labor between *um* and *outro*. In order to do so, I look into the interactions of SRs with another quantificational item *Q*. By finding cases in which *Q* scopes between *um* and *o outro*, we should be able to identify which part of the reciprocal’s meaning is contributed by *um* and which is contributed by *o outro*. The investigation of these sentences leads us to a puzzle: SRs seems to take split scope around *Q* but only if *Q* pronounced outside the scope domain of *um*. Given the paradoxical nature of this state of affairs, I conclude that split scope is only apparent.

Following the analysis of reciprocals proposed in Murray (2008) and further developed in Dotlačil (2012), I move to a more expressive framework in which

1 In this sense, SRs differ from other very similar constructions found in other languages, such as French or Russian reciprocals. These constructions, analyzed in LaTerza (2011, 2014), are also built from *one* and *other*, but their pieces can only be separated by *one* preposition.

2 Belletti (1982) argues that the dependency established between the pieces of Italian SRs are just like the one between a reflexive and its antecedent. However, in Italian, sentences like (2) also seem to be possible (Stanislao Zompì and Enrico Flor, p.c.).

dependencies between plural arguments are stored with the help of sets of assignment functions. The analysis is formalized in PPL*, a slightly modified version of Champollion et al.'s (2017) *Plural Predicate Logic* (PPL), which is a static extension of standard predicate logic in which formulae are evaluated with respect to sets of assignments. The proposal decomposes Murray's (2008) semantics for reciprocals and distributes it between *um* and *o outro*. This is shown to be enough to solve the puzzle posed by the interaction of SRs and other quantificational items. The paper concludes with a discussion of the differences and similarities between SRs and *each other*. I suggest that both reciprocals are built from the same pieces but differ only in how they are syntactically built.

2 On the division of labor between *um* and *o outro*

2.1 The role of *o outro*

The piece *o outro* is composed of a singular definite determiner *o* and the singular adjective *outro* 'other.' I now present evidence that suggests that, in SRs, *o outro* is still interpreted as a singular denoting expression that introduces a non-identity component, just like the description *the other*.

To see that the number features of *o outro* are interpreted, consider a scenario where there are three students, Al, Bea and Cece, and that each of them will see the other two of them meeting in the park (i.e., Al will see Bea and Cece meet, etc.). To describe this situation, one could utter the English sentence in (3), with the plural definite *the others* as the subject of *meet*. However, if we try to describe this scenario with SRs, what we get is an ungrammatical sentence, as shown in (4).

- (3) They will each see the others meet in the park.
 (4) * Eles vão *um* ver *o outro* se encontrar n-o parque.
 they will one see the other REFL meet in-the park
 Intended: 'They will each see the others meet in the park.'

The difference between these sentences can be viewed as a result of the fact that the singular morphology in *o outro* is semantically interpreted, as it naturally explains why it cannot be an argument of a collective predicate like *se encontrar* 'meet.'

To show that *o outro* is the locus of the non-identity component present in the meaning of reciprocals, I make use of a fact about the interpretation of reciprocal in elliptical contexts uncovered by Elliott & Murphy (2019). Observe the question-answer pair in (5), where the answer has an elided VP. Its antecedent is the question's VP, which contains *o outro*, yet, surprisingly, the answer in (5) is interpreted as *I will talk to Pedro*.

- (5) a. Q: Você e o Pedro vão *um* [VP cuidar d-o outro]?
 you.SG and the Pedro will one take.care of-the other
 Q: ‘Are you two going to take care of each other?’
 b. A: Eu vou Δ.
 I will
 A: ‘I will.’

As pointed out by Elliott & Murphy (2019), this can be explained if the antecedent VP, rather than containing an entire reciprocal, only contains the reciprocal’s non-identity component. As illustrated in the simplified representations in (6), we can take the VPs in (5) to both denote the set of all x s.t. x takes care of the individual among the addressee and Pedro that is not identical to x .

- (6) Q: You and Pedro will one [VP $\lambda_x t_x$ take care to the other $_x$]
 A: I will [VP $\lambda_x t_x$ talk to the other $_x$]

2.2 The role of *um*

The first remark concerning *um* has to do with the fact that it tracks the scope of *atomic* distributivity in reciprocal sentences. This can be seen in the pair of sentences in (7), which differ only with respect to the position *um* occupies in the sentence. In (7a), where *um* c-commands the *dois presentes* ‘two gifts’, only one interpretation is available: each of them must have bought two gifts for the other (i.e., ‘two gifts’ must be interpreted distributively with respect to the subject). Sentence (7b) has this interpretation as well, but it also has another in which they bought two gifts *in total* (i.e., ‘two gifts’ is interpreted cumulatively with respect to the subject).

- (7) a. Eles dois vão *um* comprar dois presentes pr-o cachorro d-o outro.
 they two will one buy two gifts for-the dog of-the other
 ‘The two of them will buy two gifts for each other’s dog.’
 b. Eles dois vão comprar dois presentes *um* pr-o cachorro d-o outro.
 they two will buy two gifts one for-the dog of-the other
 ‘The two of them will each buy two gifts for the other’s dog.’

The generalization that emerges, then, is that whatever is pronounced under the scope of *um* must be interpreted distributively. This is also true of verbs: although the subject of *levantar* ‘lift’ can be interpreted collectively, sentence (8) is only true if each lifting was done by a single monkey.

- (8) Os macacos tinham *um* levantado o outro.
 the monkey had one lifted the other

‘The monkeys had each lifted the others.’

There are now two possible analyses of *um* we should entertain given the data discussed above, each corresponding to one of the two standard accounts of reciprocals. These can be illustrated by the two different paraphrases of (9) in (10).³

- (9) Os alunos vão *um* se irritar com o *outro*.
 the students will one REFL get.mad with the other
 ‘The students will get mad at each other.’
- (10) a. *Every pair of students* is such that one will get mad at the other.
 b. *Every student* will get mad at *every other student*.

The paraphrase in (10a) involves quantification over pairs, as in, for example, the analysis of reciprocals of Dalrymple et al. (1998). The one in (10b), on the other hand, takes reciprocals to involve two different quantifiers over individuals, as in Heim et al.’s (1991) analysis of *each other*. We can take either *um* to denote a universal quantifier over pairs or take *um* and *o outro* to each denote a universal quantifier over individuals.

Although these two approaches (as presented here) give rise to the same truth-conditions, they make different predictions concerning the possible interpretations of sentences containing SRs and a third quantifier *Q*. If there are indeed two quantifiers in these sentences, then *Q* should be able to scope between them. If, however, there is a single polyadic quantifier, this should not be possible.

Sentence (11), where *o outro* is trapped within a relative clause, is able to distinguish the two proposals. This sentence has a single meaning, namely the one predicted by the view in which *um* is a quantifier over pairs. As spelled out in (11a), it is true only if each pair of students is such that one bought two photos that the other likes. The view that takes each of *um* and *o outro* to be a quantifier *cannot* get this reading, as *o outro* is trapped within a scope island. This approach predicts this sentence to only have the odd reading spelled out in (11b), where each student bought two photos liked by every other student.

- (11) Os três alunos vão *um* comprar [duas fotos que o *outro* gosta].
 the three students will one buy two photos that the other likes
- a. *Attested interpretation*
 $\forall x \forall y (x \neq y \wedge \text{student}(x) \wedge \text{student}(y) \rightarrow$
 $\exists z (\#(z) = 2 \wedge \text{photos}(z) \wedge \text{likes}(y, z) \wedge \text{will-buy}(x, z)))$

³ For convenience, I am assuming that the interpretation of (9) corresponds to *Strong Reciprocity* (i.e., $\forall x, y \in A (x \neq y \rightarrow xRy)$, where *R* is the relation being reciprocated and *A* the set of individuals denoted by the reciprocal’s antecedent). For a discussion of the different interpretations of reciprocal sentences - a topic I do not discuss here - see Langendoen (1978) and Dalrymple, Kanazawa, Kim, Mchombo & Peters (1998).

b. *Unattested interpretation*

$$\forall x(\text{student}(x) \rightarrow \exists z(\#(z) = 2 \wedge \text{photo}(z) \wedge \forall y(\text{student}(y) \wedge y \neq x \rightarrow \text{likes}(y, z)) \wedge \text{bought}(x, z)))$$

I therefore conclude that *um* must involve quantification over pairs.

2.3 Reciprocal split scope?

Consider the following situation. There are three friends and each one of them has a dog. They are throwing a party soon, so each friend will buy, for each dog owned by a friend of theirs, one gift. Thus, each friend will buy a total of two gifts. In such a situation, one can truthfully utter the English sentence in (12), where *two gifts* is interpreted under the scope of *each* but is at the same time interpreted cumulatively with respect to *the others' dogs*.

(12) The three of them will each buy two gifts for the others' dogs.

Given the discussion in the previous subsection, it comes as no surprise that (13) is taken to be false in such a situation, as it would require each student to buy, for every dog, two gifts rather than just one.

(13) Eles três vão *um* comprar dois presentes pr-o cachorro d-o outro.
 they three will one buy two gifts for-the dog of-the other
 ≈ 'Every pair is such that one will buy two gifts for the others' dog.'

What is surprising, however, is that the very similar sentence (14) can truthfully describe this scenario. The crucial difference between the two sentences is the position of *um*: the numeral is in its scope in (13) but not in (14).

(14) Eles três vão comprar dois presentes *um* pr-o cachorro d-o outro.
 they three will buy two gifts one for-the dog of-the other
 'The three of them will buy two gifts for each other's dogs.'

This is a very puzzling state of affairs. Sentence (14) has a reading which corresponds to the meaning sentence (12), in which the numeral is interpreted in between a distributor and the element that introduces the non-identity condition. However, this is only possible if the numeral is not actually pronounced between the two pieces of SRs. When that is the case, such apparent cases of reciprocal split scope are simply impossible. The puzzle, then, is a syntax-semantics mismatch: the interpretation one expects to find when the numeral is interpreted between distributivity and non-identity is only available when the numeral is not pronounced between *um* and *o outro*.

2.4 Interim summary

The discussion above has identified three properties of SRs: (i) *o outro* introduces a non-identity component and has its singular morphology interpreted, (ii) *um* is a quantifier over pairs, (iii) SRs can apparently take split scope around a quantifier only if it the quantifier is not pronounced in the c-command of *um*.

The greatest challenge here is conciliating facts (ii) and (iii). If *um* is a quantifier over pairs, (iii) should be impossible. I propose that the cases which seem to involve reciprocal split scope are indeed only apparent, and *one* indeed involves non-decomposable quantification over pairs. The strategy I employ to solve this issue is to follow the analyses of reciprocity in Murray (2008) and Dotlačil (2012) and move to a more expressive framework in which dependencies established between plural arguments can be stored. This move allows to analyze (14), under its relevant reading, along the lines of the paraphrase in (15). Crucially, in this paraphrase, *two gifts* does not scope in-between the pieces of the reciprocal.

- (15) The three of them bought gifts for each other's dogs, they each bought two gifts in total.

3 Framework

Following the analyses of reciprocals of Murray (2008) and Dotlačil (2012), my analysis of SRs is couched in a framework which uses sets of assignment functions to model plurals. I depart from these authors, however, in that I do not formalize my proposal within a dynamic logic. Here, I adopt PPL*, a slightly modified version of Champollion et al.'s (2017) Plural Predicate Logic (PPL). This section is dedicated to presenting PPL* and a compositional procedure which translates natural language expressions to PPL* formulae.

3.1 PPL*

PPL* is a slightly modified version of Champollion et al.'s (2017) PPL. Like PPL, PPL* is an extension of ordinary predicate logic in which formulae are not evaluated with respect to assignments but rather with respect to *sets* of assignments. In this respect, they are similar to the dynamic plural logics of van den Berg (1996) and Brasoveanu (2008). However, they differ from these systems in that they are static.

There are three significant differences between PPL* and PPL. First, the lexicon of PPL*, but not the one of PPL, contains individual constants. Furthermore, in PPL* assignments are taken to be functions from variables to *singular* individuals, whereas in PPL plural individuals are also in the range of assignments. Finally, while in PPL* predicates are interpreted collectively with respect to sets of assignment, they

are interpreted distributively in PPL. These last two properties bring PPL* closer to van den Berg’s (1996) Dynamic Plural Predicate Logic (DPIL) than to Brasoveanu’s (2008) Plural Compositional Discourse Representational Theory (PCDRT).

PPL* formulae are evaluated with respect to a model $\mathfrak{M} = \langle \mathcal{D}, \mathfrak{I} \rangle$ where \mathcal{D} is a domain of (singular) individuals and \mathfrak{I} is a standard interpretation function where $\mathfrak{I}(P) \subseteq (\mathcal{P}(\mathcal{D}) \setminus \{\emptyset\})^n$ for any n -ary predicate P and $\mathfrak{I}(c) \in \mathcal{P}(\mathcal{D}) \setminus \{\emptyset\}$ for any individual constant c . Although \mathcal{D} only contains singular individuals, observe that predicates take arguments that are sets of individuals and individual constants denote sets of individuals.

Formulae are also evaluated relative to non-empty sets of total functions from variables to \mathcal{D} , which I refer to as *plural assignments*. Plural assignment are often represented in tables, as in (16): table G represents the plural assignment $\{g_1, g_2, g_3\}$, where $g_1 = \{\dots \langle x, \text{ann} \rangle, \langle y, \text{cece} \rangle \dots\}$, $g_2 = \{\dots \langle x, \text{bea} \rangle, \langle y, \text{cece} \rangle \dots\}$, and $g_3 = \{\dots \langle x, \text{bea} \rangle, \langle y, \text{dee} \rangle \dots\}$. The differences between G and H (16) illustrates in which ways plural assignments are more expressive simple assignments.

(16) *Plural assignment*

G	...	x	y	...
g_1	...	ann	cece	...
g_2	...	bea	cece	...
g_3	...	bea	dee	...

H	...	x	y	...
h_1	...	ann	cece	...
h_2	...	bea	dee	...
h_3	...	bea	dee	...

Plural assignments store two relevant kinds of information. We can talk about the *global value* of x in G , denoted by $G(x)$ and defined in (17), which is the set containing the values that each g in G assigns to x . Iconically, we can think of $G(x)$ as the collection of all elements in the x column of the G table in (16). Note then, that although \mathcal{D} only contain singularities, we can get to pluralities via plural assignments.

$$(17) \quad G(x) := \{g(i) \mid g \in G\}$$

We can also talk about *dependent values* of x , which are the values of x in a subset of G restricted by another variable. So, rather than picking up the global value of x in G , we can also pick up the value of x relative to the subset of G where each g maps y to $cece$, denoted by $G|_{y=cece}(x)$ as defined in (18).

$$(18) \quad G|_{i=d} := \{g \in G \mid g(i) = d\}$$

In (16), G and H agree in the global value they assign to x : $G(x) = H(x) = \{\text{ann}, \text{bea}\}$. However, they disagree in the y -dependent values of x : for example, $G|_{y=cece}(x) = \{\text{ann}, \text{bea}\}$ and $H|_{y=cece}(x) = \{\text{ann}\}$. The point here is that we

have two plural assignments that agree on the global value of x , but they store different kinds of dependencies between x and y . It is this property of plural assignments that allows PPL* to account for different readings of sentences containing plurals.

I now move on to the semantics of PPL*. Below in (19), I present the interpretation of terms (I omit the relativity to a model in for simplicity). Note that terms always denote non-empty sets of individuals.

(19) *Interpretation of terms*

$$\llbracket \alpha \rrbracket^G = \begin{cases} \mathcal{I}(\alpha) & \text{if } \alpha \text{ is an individual constant} \\ G(\alpha) & \text{if } \alpha \text{ is a variable} \end{cases}$$

The interpretation of atomic formulae is given in (20). All of these are interpreted “collectively” with respect to the plural assignment: the interpretation of these formulae is always relative to the global value of variables.

(20) *Interpretation of atomic formulae*

$$\begin{aligned} \llbracket P(\alpha_1, \dots, \alpha_n) \rrbracket^G = \mathbb{T} & \text{ iff } \langle \llbracket x_1 \rrbracket^G, \dots, \llbracket x_n \rrbracket^G \rangle \in \mathcal{I}(P) \\ \llbracket \alpha = \beta \rrbracket^G = \mathbb{T} & \text{ iff } \llbracket \alpha \rrbracket^G = \llbracket \beta \rrbracket^G \\ \llbracket \#(\alpha) = n \rrbracket^G = \mathbb{T} & \text{ iff } |\llbracket \alpha \rrbracket^G| = n \end{aligned}$$

The interpretation of conjunction is straightforward, as shown below. Since I do not use any other connective in what follows, the reader is referred to [Champollion et al. 2017](#) for further discussion.

(21) *Interpretation of conjunction*

$$\llbracket \varphi \wedge \psi \rrbracket^G = \mathbb{T} \text{ iff } \llbracket \varphi \rrbracket^G = \llbracket \psi \rrbracket^G = \mathbb{T}$$

Existential quantifiers in predicate logic evaluate the formulae in their scope relative to a modified assignment. In a similar way, existential quantifiers in PPL* evaluate the formulae in their scope relative to a modified plural assignment. The issue, then, is how to define such modified plural assignments. As in PPL, PPL* borrows [Brasoveanu’s \(2008\) PCDRT’s](#) definition of plural assignment modification, defined in (22b), which is an extension from the notion of modified assignment in predicate logic, defined in (22a). Existential quantification is then defined as in (23).

(22) *Assignment modification*

- a. $g[x]h :=$ for any variable v , if $v \neq x$, then $g(x) = h(x)$
- b. $G[x]H :=$ for any $g \in G$ there is an $h \in H$ s.t. $g[x]h$,
and for any $h \in H$ there is an $g \in G$ s.t. $g[x]h$

(23) *Existential quantifier*

$$\llbracket \exists x(\varphi) \rrbracket^G = \mathbb{T} \text{ iff there is an } H \text{ s.t. } G[x]H \text{ and } \llbracket \varphi \rrbracket^H = \mathbb{T}$$

An important aspect of existential quantification as defined in (23) is that it introduces both individuals and dependencies non-deterministically. To see that it also introduces new dependencies, observe the plural assignments in (24): both $G[x]H$ and $G[x]H^*$ are true, but H and H^* differ with respect to the kinds of dependencies they store.

(24) *Quantificational contexts*

G	...	x	...	H	...	x	y	...	H^*	...	x	y	...
g_1	...	ann	...	h_1	...	ann	dee	...	h_1	...	ann	dee	...
g_2	...	bea	...	h_2	...	ann	ed	...	h_3	...	bea	ed	...
				h_3	...	bea	ed	...	h_4	...	bea	dee	...

The final operator we need to define is the distributive operator Δ . Its definition is in (25). Given a plural assignment G , Δ_x evaluates the formula in its scope relative to all subsets of G containing assignments in which x is mapped to the same individual. For example, given the plural assignment H^* in (24), $\llbracket \Delta_x(\varphi) \rrbracket^{H^*}$ will be true if φ is true relative to the subset of H^* which contains the assignments in which x is mapped to Ann ($= \{h_1\}$) and relative to the subset of H^* which contains the assignments in which x is mapped to Bea ($= \{h_3, h_4\}$).

(25) $\llbracket \Delta_x(\varphi) \rrbracket^G = \mathbb{T}$ iff every $d \in G(x)$ is such that $\llbracket \varphi \rrbracket^{G|_{d=x}} = \mathbb{T}$

Finally, we define truth in a model:

(26) $\llbracket \varphi \rrbracket_{\mathfrak{M}} = \mathbb{T}$ iff $\llbracket \varphi \rrbracket_{\mathfrak{M}}^G = \mathbb{T}$ for any plural assignment G

3.2 Fragment and sample sentences

In this subsection, I present a simple fragment in which natural language expressions are translated into PPL formulae. The system has two basic types: e , the type of variables, and t , the type of sentences. Complex types are defined in the standard way. Table 1 presents a set of sample lexical entries with their types and translations. Complex constituents are translated via functional application, defined in (27).

(27) If $\alpha \rightsquigarrow a$ and $\beta \rightsquigarrow b$, then $[\alpha \beta] \rightsquigarrow a(b)$ or $b(a)$, whichever is defined

Futhermore, I assume that noun phrases undergo QR before translation leaving behind a coindexed trace. This is illustrated in (28).

(28) a. Ann smokes.
 b. $\text{Ann}^x [t_x \text{ smokes}] \rightsquigarrow \exists x(x = \text{ann} \wedge \text{smokes}(x))$

<i>Phrase</i>	<i>Type</i>	<i>Translation</i>
t_i	e	i
frogs	$e \rightarrow t$	$\lambda i. \Delta_i(\text{frog}(i))$
saw	$e \rightarrow (e \rightarrow t)$	$\lambda i. \lambda j. \Delta_i \Delta_j(\text{saw}(i, j))$
two	$(e \rightarrow t) \rightarrow (e \rightarrow t)$	$\lambda P. \lambda i. \#(i) = 2 \wedge P(i)$
Ann^i	$t \rightarrow t$	$\lambda p. \exists i(i = \text{ann} \wedge p)$
D_i	$t \rightarrow t$	$\lambda p. \Delta_i(p)$
a^i/E^i	$(e \rightarrow t) \rightarrow (t \rightarrow t)$	$\lambda P. \lambda p. \exists i(P(i) \wedge p)$

Table 1 Example lexical entries

Before moving on to my analysis of SRs, I illustrate how PPL* can account for cumulative readings of sentences containing plurals. Take sentence (29), which under its cumulative interpretation can describe a scenario in which one armadillo saw two elephants and another armadillo saw one elephant. I take numerals to be adjectives and bare numerals to have a covert existential determiner E. The structure in (30a) is translated into the PPL formula in (30b).⁴

(29) Two armadillos saw three elephants.

(30) a. $[E^x \text{ two armadillos}] [E^y \text{ three elephants}] t_x \text{ saw } t_y$

b. $\exists x \exists y (\#(x) = 2 \wedge \Delta_x(\text{armadillo}(x)) \wedge \#(y) = 3 \wedge \Delta_y(\text{elephant}(y)) \wedge \Delta_x \Delta_y(\text{saw}(x, y)))$

The formula (30b) is true if, given any arbitrary H , we can find a modified assignment G just like H except that: (i) $G(x)$ has cardinality two and each member of $G(x)$ is an armadillo, (ii) $G(y)$ has cardinality three and each member of $G(y)$ is an elephant, and (iii) for any d in $G(x)$ it is the case that d saw every member of $G|_{d=x}(y)$. In the state of affairs described above, the assignment in (31) verifies (i)-(iii): there are two armadillos in column x , three elephants in column y , and each row is composed of an x that saw a y . From now on, rather than spelling out the truth conditions of PPL* formulae, I will simply present a plural assignment, like the one in (31), which can verify the formula in the scope of the first couple of existential quantifiers.

⁴ Because it makes verifying the formulae much easier, I constantly rely on the following equivalence from predicate logic which the reader can verify that also holds for PPL*: if φ does not contain a free occurrence of x , $\llbracket \varphi \wedge \exists x(\psi) \rrbracket^G = \llbracket \exists x(\varphi \wedge \psi) \rrbracket^G$ for any G .

(31)

G	...	x	y	...
g_1	...	armadillo ₁	elephant ₁	...
g_2	...	armadillo ₁	elephant ₂	...
g_3	...	armadillo ₂	elephant ₃	...

We now analyze a sentence which involves both distributivity and cumulativity. The sentence in (32) can be uttered in a scenario where each of three frogs ate one fly, and two of them did so in front of an armadillo and the other one did so in front of another armadillo.

(32) Three frogs ate one fly in front of two armadillos.

The relevant reading of (32) contains two nouns being interpreted cumulatively relative to each other (*three frogs* and *two armadillos*), but one of them is interpreted distributively (*one fly*). We can easily account for this by following a proposal by Dotlačil (2012) allowing the null distributive operator D to take scope inside a noun phrase. This is shown in (33a), where a D anaphoric to *three frogs* takes scopes within the phrase *one fly*.

(33) a. $[E^x \text{ three frogs}] [E^y D_x [\text{one fly}]] [E^z \text{ two armadillos}] t_x \text{ ate } t_y \text{ in front of } t_z$
 b. $\exists x \exists y \exists z (\#(x) = 3 \wedge \Delta_x(\text{frog}(x)) \wedge \Delta_x(\#(y) = 1 \wedge \text{fly}(y)) \wedge \#(z) = 2 \wedge \Delta_z(\text{armadillo}(z)) \wedge \Delta_x \Delta_y \Delta_z(\text{ate_in_front_of}(x, y, z)))$

Assignment G in (2) verifies (33b): there are three frogs in column x , for every frog in x there is one fly in y , there are two armadillos in column z , and each row of G is composed of an x that ate a y in front of z .

(34)

G	...	x	y	z	...
g_1	...	frog ₁	fly ₁	armadillo ₁	...
g_2	...	frog ₂	fly ₂	armadillo ₁	...
g_3	...	frog ₃	fly ₃	armadillo ₂	...

4 An analysis of Scattered Reciprocals

My analysis of SRs builds on the proposal of Murray (2008), further developed in Dotlačil (2012), concerning the meaning of reciprocals. The key idea is that there are two components to a reciprocal: they take an antecedent and introduce a new entity which is (i) globally identical to the reciprocals antecedent but (ii) locally distinct from it. The paraphrase in (35) illustrates this.⁵

⁵ Sternefeld (1998) and Beck (2001) also have analyses (of some) reciprocal sentences along these lines.

- (35) These girls trust each other.
 a. *Global identity*: the girls saw the girls
 b. *Local non-identity*: each seeing occurred between non-identical girls

In what follows, I distribute these two components of reciprocity along the two pieces of SRs. I first show how we can account for the meaning of basic SR sentences, then I move to the discussion of sentences in which SRs interacts with a numeral.

4.1 Basic sentences

The discussion in §2 showed that *um* must involve some kind of quantification over pairs whereas *o outro* must be the locus of the non-identity component associated with the meaning of reciprocity. With this in mind, I propose the translations for *um* and *o outro* presented in (36).⁶

- (36) a. $um_j^i \rightsquigarrow \lambda p. \exists i(i = j \wedge \Delta_i \Delta_j(p))$
 b. $o\text{-}outro_{i,j} \rightsquigarrow \lambda p. i \neq j \wedge p$

For the analysis to get off the ground, we need to assume that *o outro* always occurs inside the scope domain of *um*. This requirement seems correlated with the fact that *um* must always c-command *o outro*: although *um* may usually appear either in a VP-internal or VP-external position, as in (37) the VP-internal position leads to ungrammaticality. This is because *um* cannot c-command *o outro* from such a low position.

- (37) Eles vão (*um*) [[comer (**um*) a comida] com o o garfo d-*o outro*].
 they will one eat one the food with the fork of-the other
 \approx ‘They will each eat the food with the others’ fork.’

In (38), we see an English gloss of a basic SR sentence. The structure in (39a) is translated to the formula in (39b).

- (38) Alex and Bea *um* talked to *the other*.
 (39) a. [Alex and Bea]^x *um*_x^y *o-outro*_{x,y} [_{t_x} saw _{t_y}]
 b. $\exists x \exists y (x = \text{alex} \cup \text{bea} \wedge x = y \wedge \Delta_x \Delta_y (x \neq y \wedge \Delta_x \Delta_y (\text{saw}(x, y))))$

⁶ Dotlačil (2012) argued that, under certain conditions, English *each other* is interpreted as I propose *o outro* to be interpreted.

The assignment in (2) can verify the (39b): column x can be summed up to a set containing Alex and Bea, columns x and y have the same members, and in each row there is an x non-identical to y such that x talked to y .⁷

(40)

G	...	x	y	...
g_1	...	alex	bea	...
g_2	...	bea	alex	...

4.2 Sentences with other quantifiers

In §2, we saw that in sentences like (41), where a numeral pronounced in the c-command domain of um , this numeral is interpreted under the scope of quantification over pairs. The present analysis easily accounts for that. Sentence (41) is mapped to the structure in (42a)⁸, which is then translated to (42b).

(41) Al, Bea and Cece um bought two gifts for *the other*.

(42) a. $[Alex, Bea, Cece]^x um_x^y [[E^z \text{ two gifts}] o \text{ outro}_{x,y} [t_x \text{ bought } t_z \text{ for } y]]$

b. $\exists x \exists y (x = alex \cup bea \cup cece \wedge x = y \wedge \Delta_x \Delta_y (\exists z (\#(z) = 2 \wedge \Delta_z (\text{gift}(x)) \wedge x \neq y \wedge \Delta_x \Delta_z \Delta_y (\text{buy_for}(x, z, y))))))$

The formula in (42b) can be verified by the schema in table 2: first, G satisfies the first two conjuncts in (42b) because both columns x and y sum up to a set containing Alex, Bea and Cece; then we break the G into six sub-assignments, each corresponding to a different x - y -pair; these are then modified into H_1, \dots, H_6 where, the column z of each of those sums up to two gifts and, in each of their rows, x bought a z for y .

Now we only need to account for the apparent split scope cases. Remember that, as opposed to sentences like (41), those like (43) can describe a scenario where each of Al, Bea and Cece bought two gifts in total. To get the desired interpretation, (43) needs to be mapped to the structure in (44a), where a D anaphoric to the subject takes scope inside the noun phrase *two gifts*. This structure is then mapped to (44b).

(43) Al, Bea and Cece gave two gifts um for *the other*.

(44) a. $[Alex, Bea, Cece]^x [E^z D_x \text{ two gifts}] um_x^y o \text{ outro}_{x,y} [t_x \text{ gave } t_z \text{ for } y]$

⁷ Like Murray (2008) and Dotlačil (2012), when the antecedent of the reciprocal is composed of more than two singularities, the truth conditions we get is one that corresponds to so-called *Weak Reciprocity* (e.g., $\forall x \in A \exists y \in A (x \neq y \wedge xRy) \wedge \forall y \in A \exists x \in A (x \neq y \wedge xRy)$).

⁸ For reasons of space, I am being very vague about the mapping between the surface form of sentences and the representation that is fed to the translation procedure.

G	...	x	y	...
g_1	...	alex	bea	...
g_2	...	alex	cece	...
g_3	...	bea	alex	...
g_4	...	bea	bea	...
g_5	...	cece	alex	...
g_6	...	cece	bea	...

H_1	...	x	y	z	...
h_1	...	alex	bea	gift ₁	...
h_2	...	alex	bea	gift ₂	...

 \Rightarrow

H_2	...	x	y	z	...
h_3	...	alex	cece	gift ₃	...
h_4	...	alex	cece	gift ₄	...

 \Rightarrow

H_3	...	x	y	z	...
h_5	...	bea	alex	gift ₅	...
h_6	...	bea	alex	gift ₆	...

 \Rightarrow

H_4	...	x	y	z	...
h_7	...	bea	cece	gift ₇	...
h_8	...	bea	cece	gift ₈	...

 \Rightarrow

H_5	...	x	y	z	...
h_9	...	cece	alex	gift ₉	...
h_{10}	...	cece	alex	gift ₁₀	...

 \Rightarrow

H_5	...	x	y	z	...
h_{11}	...	cece	bea	gift ₁₁	...
h_{12}	...	cece	bea	gift ₁₂	...

Table 2 Assignments for (41)

$$\text{b. } \exists x \exists z \exists y (x = \text{alex} \cup \text{bea} \cup \text{cece} \wedge \Delta_x(\#(z) = 2 \wedge \Delta_z(\text{gift}(x))) \wedge x = y \wedge \Delta_x \Delta_y (x \neq y \wedge \Delta_x \Delta_z \Delta_y (\text{buy_for}(x, z, y))))$$

The formula in (44b) can be verified by the assignment in (45): the x column can be summed up into a set containing Alex, Bea, and Cece; for any individual $d \in G(x)$, the subset of G containing all rows where x is mapped to d , there are in total two gifts in z ; the column y can also be summed up into a set containing Alex, Bea, and Cece; and each row of G contains an x that bought a z for a y .

(45)

G	...	x	y	z	...
g_1	...	alex	bea	gift ₁	...
g_2	...	alex	cece	gift ₂	...
g_3	...	bea	alex	gift ₃	...
g_4	...	bea	bea	gift ₄	...
g_5	...	cece	alex	gift ₅	...
g_6	...	cece	bea	gift ₆	...

We see, then, that we are able to get the desired reading without requiring the

numeral and SR to be scopally interact. As already mentioned in the introduction, PPL* allows us to analyze (43) as conveying the same meaning as (46).

- (46) Alex, Bea and Cece bought gifts for each other, and each of them bought two gifts in total.

5 Scattered reciprocals vs *each other*

The analysis of SRs presented above was based on the existing analysis of *each other* of Murray (2008) and Dotlačil (2012). It is only natural, then, that we can then put the pieces of SRs together and arrive at a meaning for *each other*. In this section, I explore the idea that the two reciprocals are built from (almost) the same pieces.

Following Heim et al. (1991), I take *each other* to be indeed syntactically complex, but, like Schein (2001) and LaTerza (2014), I assume that *each* is interpreted in situ, taking scope only above *other*. The decomposition I propose for *each other* is shown in (47).

- (47) a. $\text{each}_j^i \rightsquigarrow \lambda p. \lambda q. \exists i(i = j \wedge \Delta_i \Delta_j(p) \wedge q)$
 b. $\text{other}_{i,j} \rightsquigarrow \lambda p. i \neq j \wedge p$

A basic sentence like (48) would be mapped to the structure in (49a), which would then be translated into (49b).

- (48) Alex and Bea talked to each other.
 (49) a. $[\text{Alex and Bea}]^x [\text{each}_x^y \text{other}_{x,y}] t_x \text{ talked to } t_y$
 b. $\exists x \exists y (x = \text{alex} \cup \text{bea} \wedge x = y \wedge \Delta_x \Delta_y (x \neq y) \wedge \Delta_x \Delta_y (\text{talked_to}(x, y)))$

This particular sentence has the same truth conditions as the basic SR sentence analyzed above. They can also be verified by the assignment in (50): both *x* and *y* columns can be summed up to a set containing Alex and Bea; in every row, *x* is different from *y*; and in every row, *x* talked to *y*.

(50)

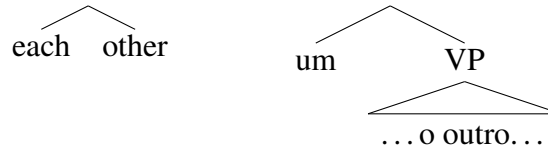
<i>G</i>	...	<i>x</i>	<i>y</i>	...
<i>g</i> ₁	...	alex	bea	...
<i>g</i> ₂	...	bea	alex	...

This analysis of *each other* is basically the one in Murray (2008) and Dotlačil (2012), but with a single difference: it involves distributivity over pairs. This does not seem to affect the interpretation of *each other*, but it allows us to have a unified analysis of both SRs and *each other*.

We can now look at SRs and reciprocal pronouns from a new angle: they are built from the same pieces, but differ in how they are syntactically built. Whereas

each takes scope only over *other*, *um* may take scope over an entire VP containing *o outro* as illustrated in the schema in (51).

(51)



The interaction of *each other* with other numerals is somewhat similar to what we have discussed above. Sentence (52) also has an apparent split scope reading where Alice, Bea and Cece each bought two gifts and then gave them to each other. The analysis of this sentence is very similar to the one give to the SR sentence above: *each other* does not take scope over *two gifts*, and a distributive operator takes scope within the the numeral.

(52) Alice, Bea and Cece bought [two gifts (each)] for each other.

- (53) a. [Alice, Bea and Cece]^x [E^z D_x two gifts] each_x^y other_{x,y} [t_x bought t_z for t_y]
 b. $\exists x \exists z \exists y (x = \text{alex} \cup \text{bea} \cup \text{cece} \wedge \Delta_x (\#(z) = 2 \wedge \Delta_z (\text{gift}(x))) \wedge x = y \wedge \Delta_x \Delta_y (x \neq y) \wedge \Delta_x \Delta_z \Delta_y (\text{buy_for}(x, z, y)))$

The two reciprocals do not always yield the same readings however. I conclude this discussion by pointing out one of these differences. We have seen above that, in SRs, the verb is always interpreted under the scope of distributivity. This is not necessarily the case for *each other*, as *each* only scopes over *other*. So, differently from (8), the sentence in (54) can describe a situation in which every two people lifted the third one. We can get the desired reading if (54) is assigned the structure in (55a) which is then translated to (55b).

(54) Al, Bea and Cece lifted each other.

- (55) a. [Al, Bea and Cece]^x [each_x^y other_{y,x}] [D_y [t_x lift t_y]]
 b. $\exists x \exists y (x = \{\text{al}, \text{bea}, \text{cece}\} \wedge x = y \wedge \Delta_x \Delta_y (x \neq y) \wedge \Delta_y (\text{lift}(x, y)))$

(56)

G	...	x	y	...
g1	...	al	cece	...
g2	...	bea	cece	...
g3	...	al	bea	...
g4	...	cece	bea	...
g5	...	bea	al	...
g6	...	cece	al	...

The assignment in (56) verifies (55b): columns x and y can be summed up to the set containing Al, Bea and Cece; each row contains non-identical values for x and y ; for every $d \in G(y)$, the subset of G containing all assignments that map y to d is such that the sum of individuals in x lifted y .

6 Conclusion

This paper has analyzed complex syntactic constructions called scattered reciprocals. Investigation of the interaction of reciprocals and other quantificational items revealed the need to move to a more expressive framework in which dependencies between plural arguments can be stored. I then proposed a decompositional analysis of SRs based on the proposals of Murray (2008) and Dotlačil (2012) framed within PPL*. After showing how the proposal accounts for the key properties of SRs, I argued that a unified analysis of SRs and reciprocal pronouns like *each other* is possible. I suggested that both are built from the same building blocks but differ syntactically, which allowed me to account for similarities and differences between the two constructions.

References

- Beck, Sigrid. 2001. Reciprocals are Definites. *Natural Language Semantics* 9(1). 69–138. <https://doi.org/10.1023/A:1012203407127>.
- Belletti, Adriana. 1982. On the anaphoric status of the reciprocal construction in Italian. *The Linguistic Review* 2(2). 101 – 138. <https://www.degruyter.com/view/journals/tlir/2/2/article-p101.xml>.
- van den Berg, Martin H. 1996. *Some aspects of the internal structure of discourse: The dynamics of nominal anaphora*: University of Amsterdam PhD dissertation.
- Brasoveanu, Adrian. 2008. Donkey pluralities: plural information states versus non-atomic individuals. *Linguistics and Philosophy* 31(2). 129–209. <https://doi.org/10.1007/s10988-008-9035-0>.
- Champollion, Lucas, Justin Bledin & Haoze Li. 2017. Rigid and flexible quantification in plural predicate logic. In Dan Burgdorf, Jacob Collard, Sireemas Maspong & Brynhildur Stefánsdóttir (eds.), *Semantics and Linguistics Theory (SALT)* 27, 418–437. <https://doi.org/10.3765/salt.v27i0.4190>.
- Dalrymple, Mary, Makoto Kanazawa, Yookyung Kim, Sam Mchombo & Stanley Peters. 1998. Reciprocal expressions and the concept of reciprocity. *Linguistics and Philosophy* 21(2). 159–210.
- Dotlačil, Jakub. 2012. Reciprocals distribute over information states. *Journal of Semantics* 30(4). 423–477. <https://doi.org/10.1093/jos/ffs016>.
- Elliott, Patrick D. & Andrew Murphy. 2019. The *other* reading of reciprocals in

- elliptical contexts. Unpublished manuscript. <https://patrl.keybase.pub/snippets/resniprocal.pdf>.
- Heim, Irene, Howard Lasnik & Robert May. 1991. Reciprocity and plurality. *Linguistic Inquiry* 22(1). 63–101.
- Langendoen, D. Terence. 1978. The logic of reciprocity. *Linguistic Inquiry* 9(2). 177–197.
- LaTerza, Chris. 2011. Thematic roles and the interpretation of one–another reciprocals. *Sinn und Bedeutung* 15 397–417.
- LaTerza, Christopher. 2014. *Distributivity and plural anaphora*: University of Maryland PhD dissertation.
- Murray, Sarah E. 2008. Reflexivity and reciprocity with(out) underspecification. In Alte Grønn (ed.), *Sinn und Bedeutung (SuB) 12*, 455–469. ILOS.
- Schein, Barry. 2001. Adverbial, descriptive reciprocals. In *Semantics and Linguistic Theory (SALT) 11*, 404–430.
- Sternefeld, Wolfgang. 1998. Reciprocity and cumulative predication. *Natural Language Semantics* 6(3). 303–337.

Filipe Hisao Kobayashi
32 Vassar Street
Massachusetts Institute of Technology
Cambridge, USA, 02139
filipek@mit.edu