1 Some approaches to the meaning of reciprocals

A variety of interpretations:

1. a. Mary, John and Sue know/like/admire each other.
   b. Mary, John and Sue are similar to each other.
   c. The expressions $2 \times 2$, $3 + 1$ and $5 - 1$ are equal to each other.

   \[ \triangle \quad \text{Strong Reciprocity (SR)} \]

2. Mary, John and Sue are sitting alongside each other.

   \[ \quad \quad \]

3. Mary, John, Sue and Bill are staring at each other.

   \[ \quad \quad \quad \]

4. a. The four planks are stacked atop each other.
   b. The four circles are contained in each other.

   \[ \quad \quad \quad \]

5. Mary, John, Sue and Bill gave measles to each other.

   \[ \quad \quad \quad \quad \]

**Early approach** (Langendoen 1978):
Try to find a logically weak reading for reciprocals that would cover all interpretations.

**Challenge:** Why should a weak reading be strengthened so often?
Later approach (Roberts 1987, Dalrymple et al. 1998):
The interpretation of reciprocal expressions is sensitive to the interpretation of other elements in the sentence/discourse: there is no one logical meaning of reciprocals.

Challenges for later approach:
1. What are the “external” factors governing the interpretation of reciprocals? Do they involve linguistic or extra-linguistic information?
2. How can we determine the core meaning(s) of reciprocals?
3. How precisely do the core meaning(s) and “external” factors determine the interpretation of reciprocals?

Dalrymple et al’s answer:
1. External factors include (unspecified) contextual non-linguistic information.
2. There is a limited number of logical operators, which together determine possible reciprocal meanings.
3. The Strongest Meaning Hypothesis (SMH) chooses the strongest reciprocal meaning that is consistent with the external factors.

Challenges for Dalrymple et al’s answer:
1. How to delimit the contextual factors? Can we preserve compositionality?
2. What are the origins of reciprocal ambiguity? What is the justification for the SMH?

1. Compositionality: All external factors (linguistic or non-linguistic), which are relevant for the interpretation of the reciprocal, are encoded in the interpretation of the reciprocated predicate.
2. No ambiguity: There is only one meaning of reciprocals, sensitive to the interpretation of the reciprocated predicate.
3. Generality: The SMH is a meta-theoretical principle that determines how logical meanings depend on external factors.

Example (Dalrymple et al):
(6) The children followed each other into the church.
(7) The children followed each other into the tree house.
(8) The children followed each other around the Maypole.

Compositionality:

(9) \( \text{RECI}(\text{follow}_{\text{PP}})) (\text{the} \text{children}) \)

(a) \textit{Dalrymple et al}: The meaning \text{RECI} is determined only given all the contextual information.

(b) \textit{Alternative}: The meaning \text{RECI} is only sensitive to the meaning follow_{PP}.

i. \textit{Groups} (Schwarzschild 1996, Winter 2000): Partitions of definites into groups (6) is affected by general contextual factors.

ii. \textit{Sabato and Winter} (2005a): Partitions are not derived by the meaning \text{RECI}.

iii. \textit{Sabato and Winter} (2005b): \text{RECI} is derived directly by the meaning of follow_{PP} (which may on its own right be sensitive to contextual factors).

No ambiguity:

1. \textit{Dalrymple et al}: The meaning \text{RECI} is not unique.

2. \textit{Sabato and Winter} (2005b): \text{RECI} is a function that takes the interpretation of the predicate as argument.

Challenges for alternative line:

1. What is the interpretation of predicates?

2. What is the general status of the SMH? (Winter 1996, 2001b)

2 Logical meanings vs. non-logical meanings

Traditional “logical”/“non-logical” distinction:

“Logical” words like every, some, and, or, inside, outside, before, after – meaning is completely specified:

\[
\text{every } N \text{ VP} \quad \Rightarrow \quad N \subseteq \text{VP} \\
\text{S}_1 \text{ and } \text{S}_2 \quad \Rightarrow \quad S_1 \land S_2 \\
\text{NP}_1 \text{ is outside } \text{NP}_2 \quad \Rightarrow \quad \text{location}(\text{NP}_1) \cap \text{location}(\text{NP}_2) = \emptyset
\]

“Non-logical” words – only logical restrictions (Meaning Postulates):

\[
\text{x killed y } \Rightarrow \text{ y died } \quad \Rightarrow \quad \text{RG(kill') } \subseteq \text{die'} \\
\text{x procreated y } \Rightarrow \neg (\text{y procreated x}) \quad \Rightarrow \quad \text{procreate'} \text{ is asymmetric} \\
\text{x is flying } \Rightarrow \neg (\text{x is swimming}) \quad \Rightarrow \quad \text{fly'} \cap \text{swim'} = \emptyset
\]
Defeasible lexical relations: “Non-logical” words also show weak implicational relations among them, especially ones triggered by prototypical behavior:

\[
\begin{align*}
\text{x is a bird} & \prec \text{x can fly} \\
\text{x is a fruit} & \prec \text{x is sweet} \\
\text{x is a vehicle} & \prec \text{x has wheels}
\end{align*}
\]

Typicality relations are defeasible – they are experimentally supported, but they can be cancelled (cf. penguins, olives, sleds).

Summary – two types of meanings:

- **Logical** – meaning is fully specified.
- **Non-logical** – in/defeasible restrictions on meaning.

Reciprocal expressions like *each other, one another, mutually* live in the twilight zone between “logical” and “non-logical” meanings:

- In each given sentence, it seems like they have a logical meaning.
- But this meaning is strongly affected by non-logical factors.

### 3 Meaning of predicates – indefeasible restrictions

*Based on Sabato and Winter (2005a-b).*

**Dalrymple et al.:** Ambiguity + choice principle (SMH).

The functional view:

1. **NO AMBIGUITY** of reciprocals.

2. **MAXIMALITY:** The (single) meaning of reciprocals is a function of the semantic restrictions on the relational expression they combine with. This is the function that *maximizes* the relations given these restrictions.

Thus, when \( R \) is a relation and \( A \) is a group:

- Dalrymple et al.’s analysis: \( \{RECIP_1(A, R), RECIP_2(A, R), \ldots \} + \text{SMH} \)
- Functional analysis: \( RECIP_\Theta(A, R) \), where \( \Theta \) are the semantic restrictions.
3.1 Formalization

**Definition 1:** Let $\Theta \subseteq \wp(E^2)$ be a set of binary relations over $E$ ($\Theta$ is a semantic restriction for binary relations over $E$). Let $R$ be a binary relation in $\Theta$ and let $A$ be a subset of $E$.

$$RECIP_\Theta(A, R) \overset{\text{def}}{=} \forall R' \in \Theta[(R \setminus I)|_A \subseteq (R' \setminus I)|_A \to (R \setminus I)|_A = (R' \setminus I)|_A].$$

$I$ def the identity relation $\{\langle x, x \rangle : x \in E\}$.

$S|_B \overset{\text{def}}{=} S \cap (B^2)$, where $S$ is a binary relation and $B$ is a set.

In words: $R$ restricted to $A$, ignoring the identities in it, is a maximal relation in $\Theta$.

**Definition 2:** Let $\Theta \subseteq \wp(E^2)$ be a set of binary relations over $E$. Let $O$ be a reciprocity operator – a relation between binary relations and sets. We say that $\Theta$ specifies $O$ iff for every set $A \subseteq E$ s.t. $|A| \geq 2$, for every relation $R \in \Theta$:

$$RECIP_\Theta(A, R) \iff O(A, R).$$

In words: $RECIP_\Theta$ is $O$ on the relevant domain.

3.2 Results of these definitions

<table>
<thead>
<tr>
<th>Relation</th>
<th>$\Theta$ restriction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>sym</td>
</tr>
<tr>
<td>1. know, see</td>
<td>−</td>
</tr>
<tr>
<td>2. be equal to</td>
<td>+</td>
</tr>
<tr>
<td>3. sit alongside</td>
<td>+</td>
</tr>
<tr>
<td>4. stare at, kick</td>
<td>−</td>
</tr>
<tr>
<td>5. give measles to</td>
<td>−</td>
</tr>
<tr>
<td>6. stack atop</td>
<td>−</td>
</tr>
<tr>
<td>7. be contained in</td>
<td>−</td>
</tr>
<tr>
<td>8. ?</td>
<td>−</td>
</tr>
<tr>
<td>9. ?</td>
<td></td>
</tr>
<tr>
<td>10. ?</td>
<td>−</td>
</tr>
</tbody>
</table>

Legend:

**Properties of binary relations:** sym=symmetric, asym=asymmetric, trans=transitive, acyc=acyclic, W-acyc= weakly acyclic - there are no simple cycles longer than 2 edges, fun=(possibly partial) function, fun$^{-1}$= the inverse relation is a (possibly partial) function.

**Reciprocal meanings:** SR = strong reciprocity, IR = intermediate reciprocity, SAR = strong alternative reciprocity, OWR = one-way weak reciprocity, IAR = intermediate alternative reciprocity, WR = weak reciprocity, IAO = inclusive alternative ordering, LIN = linearity. All these operators are defined in Dalrymple et al. (1998), except for linearity, defined in (11) below.

$(+)$ = property is entailed by other properties
3.3 Empirical consequences

Consequence 1 – a new “linear” reading:

(10) Squares 1, 2, 3 and 4 are contained in each other.

This sentence shows a linear reading, as expected by the definitions:

(11) \( \text{LIN}(A, R) \) def \( A = \{x_1, \ldots, x_n, \ldots\} \land R(x_1, x_2) \land \ldots \land R(x_{n-1}, x_n) \land \ldots \)

Consequence 2 – weakening effects of partitioning: Compare the examples below, following Dalrymple et al.:

(12) The planks are stacked on top of each other.

(13) Planks 1, 2, 3 and 4 are stacked on top of each other.

Consider a situation with four planks: 1 on top of 2, 3 on top of 4. In this situation (13) is much less acceptable than (12).

Dalrymple et al. account for (12) using their weakest reading of reciprocals – IAO. But for (13), IAO would have been too weak.

Our proposal, following Winter (2000): (only) simple plural definites show a partitioning effect, following Schwarzschild (1996), due to the (discourse) anaphoric properties of definites. But other plurals, especially proper name conjunctions, do not allow such anaphoric dependencies. Hence, both (12) and (13) show the LIN reading of the reciprocal, but in (12), unlike (13), this reading applies to two members of a partition, hence the pseudo-IAO effect.

Note that the same reasoning was applied by Dalrymple et al. in their rejection of “partitioned SR” in the men are hitting each other.

Consequence 3 – OWR is directly derived: Dalrymple et al.’s motivating example for OWR is:

(14) The pirates are staring at each other.

(15) \( \text{OWR}(A, R) \) def \( |A| \geq 2 \land \forall x \in A \exists y \in A [x \neq y \land R(x, y)] \)

Dalrymple et al. do not in fact expect OWR in (14), since a stronger reading, IR, is possible here:

(16) \( \text{IR}(A, R) \iff \forall x, y [x \neq y \rightarrow \exists z_1, \ldots, z_n [z_1 = x \land R(z_1, z_2) \land \ldots \land R(z_{n-1}, z_n) \land z_n = y]] \)

However, also OWR requires “maximal situations” with functional relations like stare at, so the present proposal expects it to be the reading of the reciprocal with such relations.

Consequence 4 – IR with small circles and large circles: IR is attested in cases like Dalrymple et al.’s:
(17) Five Boston pitchers sat alongside each other.

Under the present account, this means that *sat alongside* must be weakly acyclic (no simple cycles with more than 2 edges). With large enough sets, acyclicity may be relaxed, but we hypothesize that such a relaxation does not change the prototypical lexical semantic restriction (see below).

**Consequence 5 – unattested readings:**

- IAO – requires predicates with “clicks” of no more than two edges.
- \(SAR(A, R) \leftrightarrow \forall x, y [x \neq y \rightarrow [R(x, y) \lor R(y, x)]]\): anticipated by Dalrymple et al., expected to be attested in cases of purely asymmetric relations (ones that are not acyclic, for example), but no such predicates were found.
- \(WR(A, R) \leftrightarrow \forall x \exists y, z [x \neq y \land x \neq z \land R(x, y) \land R(z, x)]\).
  WR, due to Langendoen (1978), is unexpected as a meaning of *each other* by Dalrymple et al.’s assumptions, as well as by the present ones.

**Consequence 6 – no internal partitioning:**

(18) The singers are looking into each other’s eyes.

(19) #John, Paul, George and Ringo are looking into each other’s eyes.

The contrast suggests that there is a limit to weakening by the SMH: (18) is OK, plausibly due to the partitioning effect with definites. (19) is bad, probably because reciprocals require “connectivity” (contra Dalrymple et al.’s IAO), as a weakest possible reading.

4  Meaning of predicates – defeasible restrictions

*Based on work in progress with Nir Kerem and Naama Friedmann.*

Are the restrictions in subsection 3.2 logical? Probably not: similar restrictions are defeasible.

**Example 1 – functionality:**

(20) The girls are *kicking* each other.
  (??)Mary is simultaneously kicking both Sue and Jane.

(21) The girls are *staring at* each other.
  Mary is simultaneously staring at both Sue and Jane.
  
  ↓ ←

(22) The girls are tickling/hitting/painting/touching/catching/pointing at/washing each other.
Unacceptability vs. atypicality – *kick* vs. *tickle*:

![Diagram of unacceptability vs. atypicality]

Example 2 – asymmetry:

(23) The girls *gave measles* to each other.
   (?)*Mary gave measles to Sue and Sue gave measles to Mary.*

(24) The girls *told the story* to each other.
   Mary told the story to Sue and Sue told the story to Mary.

**Hypothesis:** *Typicality restrictions, which are notoriously defeasible, have the same linguistic status as “core”, indefeasible restrictions on the meaning of predicates. Both kinds of restrictions affect the interpretation of reciprocal expressions.*

**Support** (Keil and Batterman 1984): Children aged 5 to 10 prefer the prototypical description of concepts like *robber* or *grandmother* to their core description.

Prototypes of nouns:

![Prototypes of nouns]

Figure 1: (non-)prototypical bird

Prototypes of predicates:

![Prototypes of predicates]

Figure 2: (non-)prototypical tickling
Two types of queries:

Type A: Upon showing a picture of a robin/penguin to the subject: *Is this a bird?*

Type B: *Is a robin/penguin a bird?*

In both types, categorization is quicker with “prototypical” items. Type A involves verification against a pictorial model; Type B involves textual entailment.

Experiments run – prototypical binary relations

1. *Forced Choice*: Given two pictures like Figure 2a and Figure 2b, the subjects are asked to answer quickly:

   “Which situation describes better a tickling?”

2. *Sentence Completion*: Given two incomplete sentences like:

   The boy _______ the old man.
   The boy _______ the old men.

   Add the following verbs in the slots, one verb for each sentence: *hit, remembered.*

Results so far (52 subjects):

*Forced Choice:*

1. Transitive verbs (in Hebrew – lexical TVs) that prefer a singular object: *stab, shake, hit, point at, wipe, comb, tickle, shoot at, touch, put make up on, clean, scratch, paint.*

2. Transitive verbs that prefer a plural object: *make a speech to, take a picture of, draw.*

*Sentence Completion*: Singular-Plural object pairs – *catch-know, tickle-make laugh, scratch-forget, push-hate, stub-take away, stub-meet, hug-remember, hug-make thrilled, lean on-control,*

Experiments for next stage – reciprocal understanding

![Figure 3: pointing at each other](image)
1. **Match picture**: Show pictures like Figures 3a/3b and 4a/4b, and ask whether the following match the picture:

   - The girls are pointing at each other.
   - The boys are making a speech to each other.

   We expect a faster reaction to figures like Figure 1a as compared to Figure 3a (vis à vis 1b/3b).

2. **Textual Entailment**: Questions like the following:

   - John is pointing at Bill; Bill is pointing at George; George is pointing at John. Are John, Bill and George pointing at each other?

   - John is making a speech to Bill; Bill is making a speech to George; George is making a speech to John. Are John, Bill and George making a speech/speeches to each other?

   - John knows Bill; Bill knows George; George knows John. Do John, Bill and George know each other?

   We expect different reactions/response times to the three cases.

**Overall expectation**: Correlation between verbs that prefer singular objects and verbs that allow weaker interpretations for reciprocals.

**References**


