Cooperation: its role in recent theories of human unique cognition
The Vygotskian Intelligence Hypothesis (Moll & Tomasello, 2007)

“... primate cognition in was driven mainly by social competition, but beyond that the unique aspects of human cognition—the cognitive skills needed to create complex technologies cultural institutions and systems of symbols, for example—were driven by, or even constituted by, social cooperation.” (Tomasello et al. 2005).
“Uniquely human [shared intentionality] cognition enables...generalized social norms that make possible the creation of social-institutional facts, such as money, marriage and government, whose reality is grounded totally in the collective practices and beliefs of a social group.”

This has been called collective intentionality (Searle)
Fig. 2 Box plots illustrating the death rate from intergroup aggression for chimpanzees and humans in subsistence societies. 

Boxes enclose the 25th, 50th and 75th percentile of each data set. The 50th percentile (median) is indicated by a thick horizontal line. Whiskers indicate the 10th and 90th percentiles, and dots indicate more extreme outliers. The number of populations for each data set (N) is given below the graph. Two estimates are shown for chimpanzees: one based strictly on observed or inferred cases, and one that also includes suspected cases. Human data are shown for subsistence farmers and hunter-gatherers.

Table 7 Rates of physical attack in adult male chimpanzees and humans

<table>
<thead>
<tr>
<th>Species</th>
<th>Community</th>
<th>When</th>
<th>Attacks per 100,000 h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chimpanzee</td>
<td>Kibale–Kanyawara</td>
<td>1998</td>
<td>2,670</td>
</tr>
<tr>
<td>Chimpanzee</td>
<td>Gombe–Kasekela</td>
<td>1978</td>
<td>1,464</td>
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<td>1976</td>
<td>1,931</td>
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<td>1970</td>
<td>3,030</td>
</tr>
<tr>
<td>Chimpanzee</td>
<td>Median</td>
<td></td>
<td>2,301</td>
</tr>
<tr>
<td>Human</td>
<td>Arnhem</td>
<td>1977–1988</td>
<td>6</td>
</tr>
<tr>
<td>Human</td>
<td>Land–Mangrove</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Chimpanzee data are from Muller (2002). Human data are calculated from Burbank (1992). For definitions and calculations, see Methods. Attacks were cases of aggression involving non-lethal physical contact.
Evidence

- Joint attention: declarative/informative pointing.
- Communicative intentions (Grice).
- Collaborative activities.
Mechanisms for the evolution of cooperation
**terminology**

- A cooperator is someone who pays a cost, $c$, for another individual to receive a benefit, $b$.
- A defector has no cost and does not deal out benefits.
  - Costs = what decreases your ‘fitness’
  - Benefits = what increases your ‘fitness’
  - Fitness = proportion of the individual's genes in all the genes of the next generation
- Based on expected utility theory
  - Expected utility = $\sum p(x_i)u(x_i)$
Should I jump in the river to save someone?

- Benefit: +50
- Save person: 30
- Get injured: -28
- Get injured: -70

Decision point:
- Altruistic: 0.60
- Non-altruistic: 0.40

Cost/benefit ratio: c/b = 0.93

Considerations:
- Do nothing!
5 rules for the evolution of cooperation

- Martin Nowak
  - Evolutionary Biologist - Harvard
- Unifies game theory with evolutionary biology.
  - Science, 2006 314
1. Kin selection/inclusive fitness

- “I will jump into the river to save two brothers or eight cousins” (Haldane)

- Natural selection can favor cooperation if the donor and the recipient of an altruistic act are genetic relatives.

- Hamilton’s rule states that the coefficient of relatedness, $r$, must exceed the cost-to-benefit ratio of the altruistic act:

$$ r > \frac{c}{b} $$

- Relatedness is defined as the probability of sharing a gene. The probability that two brothers share the same gene by descent is $1/2$; the same probability for cousins is $1/8$. 
2. Direct reciprocity

Food sharing among chimpanzees
Prisoners' dilemma

Prisoner A
- Confess: 5 years, 5 years
- Remain silent: 20 years, 0 year

Prisoner B
- Confess: 0 year, 20 years
- Remain silent: 1 year, 1 year

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Payoffs:  $R =$ reward  $P =$ punishment  $T =$ temptation  $S =$ sucker

Game assumes (1) rationality (maximize own payoff, no concern for others) and (2) common knowledge.
If number of ‘turns’ (N) is not known or is random, then cooperation can be an equilibrium strategy.

A very robust strategy for iterative PD: ‘tit for tat’
Direct reciprocity can lead to the evolution of cooperation only if the probability, \( w \), of another encounter between the same two individuals exceeds the cost-to-benefit ratio of the altruistic act:

\[
w > \frac{c}{b}
\]

In the river example only if it was almost certain that you’d encounter the same person who you saved in the river again would altruism for non-relatives evolve!
3. Indirect reciprocity

- Helping someone establishes a good reputation, which will be rewarded by others.

- When deciding how to act, we take into account the possible consequences for our reputation.

- We feel strongly about events that affect us directly, but we also take a keen interest in the affairs of others, as demonstrated by *gossip*. 
Natural selection favors strategies that base the decision to help on the reputation of the recipient.

Theoretical and empirical studies of indirect reciprocity show that people who are more helpful are more likely to receive help.

– (e.g. Nowak & Sigmund, 2005, Nature 437)
Indirect reciprocity can only promote cooperation if the probability, $q$, of knowing someone’s reputation exceeds the cost-to-benefit ratio of the altruistic act:

$$q > \frac{c}{b}$$

In the jumping in the river example, the probability of knowing the person’s reputation must be almost 1.0 for it to have evolved through this mechanism.
“...selection for indirect reciprocity and human language has played a decisive role in the evolution of human intelligence. Indirect reciprocity also leads to the evolution of morality and social norms” (Nowak, 2006)
4. Network reciprocity

- Social networking means that some individuals interact more often than others within a population and they can help each other cooperatively.

- Forming networks (who reciprocate) can favor cooperation if the benefit-to-cost ratio exceeds the average number of neighbors, $k$, per individual.

\[ \frac{b}{c} > k \]

- In the jumping in the river example $b/c$ is a little more than 1. The average number of neighbours per individual in the population must be only 1 for this to have evolved through a network in which the two are members.
5. Group selection

- Selection acts not only on individuals but also on groups. A group of cooperators might be more successful than a group of defectors.

- Individual selection is in opposition to group selection in this case: more competitive individuals within a group are selected against at the inter-group level.

- If \( n \) is the maximum group size and \( m \) is the number of groups, then group selection allows evolution of cooperation, provided that

\[
\frac{b}{c} > 1 + \left( \frac{n}{m} \right)
\]
Mechanisms for the evolution of cooperation

**Kin selection**

$r > c/b$

**Direct reciprocity**

$w > c/b$

**Indirect reciprocity**

$q > c/b$

**Network reciprocity**

$b/c > k$

**Group selection**

$b/c > 1 + (n/m)$

**Fig. 3.** Five mechanisms for the evolution of cooperation. Kin selection operates when the donor and the recipient of an altruistic act are genetic relatives. Direct reciprocity requires repeated encounters between the same two individuals. Indirect reciprocity is based on reputation; a helpful individual is more likely to receive help. Network reciprocity means that clusters of cooperators outcompete defectors. Group selection is the idea that competition is not only between individuals but also between groups.
Measures of evolutionary success

Without cooperation mechanism: \( \alpha < \gamma \) and \( \beta < \delta \)

With mechanisms:
If \( \alpha > \gamma \): Evolutionary Stable Strategy (ESS).
If \( \alpha + \beta > \gamma + \delta \): Risk Dominant (RD).
Table 1. Each mechanism can be described by a simple $2 \times 2$ payoff matrix, which specifies the interaction between cooperators and defectors. From these matrices we can directly derive the necessary conditions for evolution of cooperation. The parameters $c$ and $b$ denote, respectively, the cost for the donor and the benefit for the recipient. For network reciprocity, we use the parameter $H = [(b - c)k - 2c]/[(k + 1)(k - 2)]$. All conditions can be expressed as the benefit-to-cost ratio exceeding a critical value. See (53) for further explanations of the underlying calculations.

<table>
<thead>
<tr>
<th>Kin selection</th>
<th>Payoff matrix</th>
<th>Cooperation is...</th>
<th>ESS</th>
<th>RD</th>
<th>AD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$C$</td>
<td>$D$</td>
<td>$b &gt; \frac{1}{c}r$</td>
<td>$b &gt; \frac{1}{c}r$</td>
<td>$b &gt; \frac{1}{c}r$</td>
</tr>
<tr>
<td>Kin selection</td>
<td>$D$</td>
<td>$b - rc$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Direct reciprocity</td>
<td>$C$</td>
<td>$(b-c)/(1-w)$</td>
<td>$-c$</td>
<td>$b &gt; \frac{1}{c}w$</td>
<td>$b &gt; \frac{2-w}{w}$</td>
</tr>
<tr>
<td>Direct reciprocity</td>
<td>$D$</td>
<td>$b$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Indirect reciprocity</td>
<td>$C$</td>
<td>$b-c$</td>
<td>$-c(1-q)$</td>
<td>$b &gt; \frac{1}{c}q$</td>
<td>$b &gt; \frac{2-q}{q}$</td>
</tr>
<tr>
<td>Indirect reciprocity</td>
<td>$D$</td>
<td>$b(1-q)$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Network reciprocity</td>
<td>$C$</td>
<td>$b-c$</td>
<td>$H-c$</td>
<td>$b &gt; \frac{k}{c}$</td>
<td>$b &gt; \frac{k}{c}$</td>
</tr>
<tr>
<td>Network reciprocity</td>
<td>$D$</td>
<td>$b-H$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Group selection</td>
<td>$C$</td>
<td>$(b-c)(m+n)$</td>
<td>$b &gt; \frac{1+n}{m}$</td>
<td>$b &gt; \frac{1+n}{m}$</td>
<td>$b &gt; \frac{1+n}{m}$</td>
</tr>
<tr>
<td>Group selection</td>
<td>$D$</td>
<td>$bn$</td>
<td>0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

$r$...genetic relatedness

$w$...probability of next round

$q$...social acquaintanceship

$k$...number of neighbors

$n$...group size

$m$...number of groups
Indirect reciprocity

Payoff matrix

<table>
<thead>
<tr>
<th></th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>$b-c$</td>
<td>$-c$</td>
</tr>
<tr>
<td>D</td>
<td>$b$</td>
<td>0</td>
</tr>
</tbody>
</table>
3 theories of human communication

1. Signal selection theory: against a context of competing interests.


1. Signal selection theory

- In standard theories of evolutionary biology, reliable signalling requires cooperation but cooperation is vulnerable to cheaters when there are competing interests.

- How do reliable signals get established in any animal population in the presence of cheaters who may bluff with the signal?
Suppose a signaler can be either starving or just hungry, and she can signal that fact to another individual which has food.

Suppose that she would like more food regardless of her state, but that the individual with food only wants to give her the food if she is starving.

While both players have identical interests when the signaler is starving, they have opposing interests when she is only hungry.

When the signaler is hungry she has an incentive to lie about her need in order to obtain the food.

And if the signaler regularly lies, then the receiver should ignore the signal and do whatever he thinks best.

– From John Maynard Smith
Costly signalling

- The evolutionary biologist Zahavi gives us an answer to the problem of how to tell apart bluffers from honest signalers when interests do not perfectly overlap – the HANDICAP Principle.

- Signals may be perceived as reliable/honest when they are costly enough to produce (are associated with handicaps), such that they effectively screen out bluffers who cannot bear such costs / handicaps.

- If sending one signal is costly, it might only be worth the cost for the starving person/animal to signal.
The analysis of when costs are necessary to sustain honesty has been a significant area of research in both biology and economics.
2. Gricean communication

- This kind of open, cooperative and direct communication is based on the follow scheme.
  - ‘I intend that you recognize my intention that you know, feel, do, x’

- Joint goal to attain an understanding of the intended message.

- Essentially cooperative.
Important concepts for Gricean communication

- In common knowledge, not only does A know $x$ and B know $x$, but A knows that B knows $x$, and B knows that A knows $x$, and A knows that B knows that A knows $x$, and vice versa.

- The need for a *joint attention frame*.
  - This is a shared context for common knowledge of a meaning. Within this context that is being shared, meanings may be clear.
    - E.g. shopping context: how to interpret pointing.
  - Allows for implied meanings that are also clear.
3. Indirect communication (covert intentions)

- “Would you like to come up and see my etchings?” [a sexual come-on]
- “Oh, the washing up hasn’t been done”. [a request]
- Nice store you got there. Would be a real shame if something happened to it. [a threat]
- Officer, is there some way we could take care of the ticket here? [a bribe]
<table>
<thead>
<tr>
<th></th>
<th>Dishonest officer</th>
<th>Honest officer</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Don’t bribe</strong></td>
<td>Traffic ticket</td>
<td>Traffic ticket</td>
</tr>
<tr>
<td><strong>Bribe</strong></td>
<td>Go free</td>
<td>Arrest for bribery</td>
</tr>
<tr>
<td></td>
<td>Go free</td>
<td>Traffic ticket</td>
</tr>
</tbody>
</table>

covert bribe

cooperating

competing
Relationship negotiation

- Politeness Theory proposes that language often serves two purposes:
  - 1. to convey some meaningful content (e.g. a request for x, an order to do y)
  - 2. to negotiate and maintain a relationship.

- What kind of relationships are involved?
  - E.g. dominance, communality, reciprocity
<table>
<thead>
<tr>
<th></th>
<th>Dishonest maitre d’</th>
<th>Honest maitre d’</th>
</tr>
</thead>
<tbody>
<tr>
<td>Don’t bribe</td>
<td>Long wait (dominance/dominance)</td>
<td>Long wait (dominance/dominance)</td>
</tr>
<tr>
<td>Bribe</td>
<td>Instant seating (reciprocity/reciprocity)</td>
<td>Awkwardness (reciprocity/dominance)</td>
</tr>
<tr>
<td>Implicate bribe</td>
<td>Instant seating (reciprocity/reciprocity)</td>
<td>Long wait (dominance/dominance)</td>
</tr>
</tbody>
</table>
Current thinking
(collab. Markus Schaal)

- Unified theory for handicapping, Gricean communication, and indirect speech.
- The above are interrelated with signal detection theory and game theory.
- Revised theory for indirect speech.
  - Defectors and cooperators’ use of indirect speech very different.
  - Reject Pinker’s cooperative vs competitive interpretations.
- The theory treats the application of cooperatively designed principles/rules (normative standards) and the use of language (communication) as the same.
- Both depend on the same cooperative mechanisms, and when one breaks down the other breaks down.
Signal Detection Theory

- Analyzing decision making when there is uncertainty.
Figure 3: Effect of shifting the criterion
\( d' = \frac{\text{separation}}{\text{spread}} \)

\( d' = \text{discriminability index: estimate of strength of signal} \)

ROC curves

\( d' = \text{separation / spread} \)
Reinterpretation of signal detection theory

Dishonest Rule Application ‘Competitive Communication’

Misidentifying a cooperative rule use for a competitive rule use.

Honest Rule Application / ‘Cooperative’ communication

Misidentifying a competitive rule use or a cooperative rule use (e.g. Pinker’s bribe)
FIGURE 26-7
The sigmoid function and its derivative. Equations 26-1 and 26-2 generate these curves.
The diagram illustrates the probability of interpretation (of an 'impartial' listener) on a scale from 0 to 100, with competitive and cooperative signals labeled. Competitive signals are equivalent to a 'defect' move in game theory, while cooperative signals are equivalent to a 'cooperate' move. The max determinate competitive and max determinate cooperative are indicated at the respective ends of the scale, with max indeterminate (context dependent) in the middle.
$d'$ = discriminability index: estimate of strength of signal
Here a measure of the COST of the communication

$d'$ = separation / spread
TYPES OF COST

GRICEAN (context dependent)

High noise, lots of overlap

Low noise, not much overlap

Precise ‘legalese’ (non context dependent)
Gricean communication

\[ d' = 1 \text{ (lots of overlap)} \]

Indirect speech: competitive

\[ d' = 1 \text{ (lots of overlap)} \]
Reputations dive!

Communication breakdown

d' = 1 (lots of overlap)

handicapping (like altruistic punishment)

d' = 3 (not much overlap)
Dynamics?

Gricean communication

$d^* = 1$ (lots of overlap)

Indirect speech

$d^* = 1$ (lots of overlap)

Communication breakdown

$d^* = 1$ (lots of overlap)

Signal Selection / handicapping

$d = 3$ (not much overlap)
Equilibria / dominant strategies for rule use
(in collaboration with Dr Kevin Hasker)