Evolution of Communication

In particular, 2 papers from Proc of Artificial Life II
ed. CG Langton C Taylor JD Farmer and S Rasmussen
Addison Wesley 1991

(1) Bruce MacLennan
Synthetic Ethology:
An Approach to the Study of Communication (pp 631-658)
THIS LECTURE

Another for reference

and (2) Greg Werner and Michael Dyer
Evolution of Communication in Artificial Organisms
(pp 659 - 687)

There are many more recent papers on all aspects of communication, in fact one of the more popular Alife subject areas. Not all the work is good!

Other work

Couple of other mentions of recent stuff:

Luc Steels 'Talking Heads'

Ezequiel di Paolo, on 'Social Coordination',
DPhil thesis plus papers via web page
http://www.cogs.susx.ac.uk/users/ezequiel/

What is communication ?

What is communication, what is meaning? Cannot divorce these questions from philosophical issues. Here is a very partial survey:

Naive and discredited **denotational** theory of meaning
'the meaning of a word is the thing that it denotes'

bit like a luggage-label.

Runs into problems, what does 'of' and 'the' denote?

What is it -- ctd

Then along came sensible people like Wittgenstein -- the idea of a 'language game'.

"Howzaaat?" makes sense in the context of a game of cricket.

The meaning of language is grounded in its use in a social context. The same words mean different things in different contexts.

Social context

cf Heidegger -- our use of language is part of our culturally constituted and situated world of needs,concerns and skilful behaviour.

SO... you cannot study language separately from some social world in which it makes sense.

Synthetic Ethology

So, (says MacLennan) we must set up some simulated world, some ethology in which to study language.

Ethology = looking at behaviour of organisms *within* their environment (not a Skinner box)

Burghardt's definition

GM Burghardt (see refs in MacLennan)
Definition of communication (see any problems with it?):

"Communication is the phenomenon of one organism producing a signal that, when responded to by another organism, confers some advantage (or the statistical probability of it) to the signaler or its group"

Grounding in evolutionary advantage

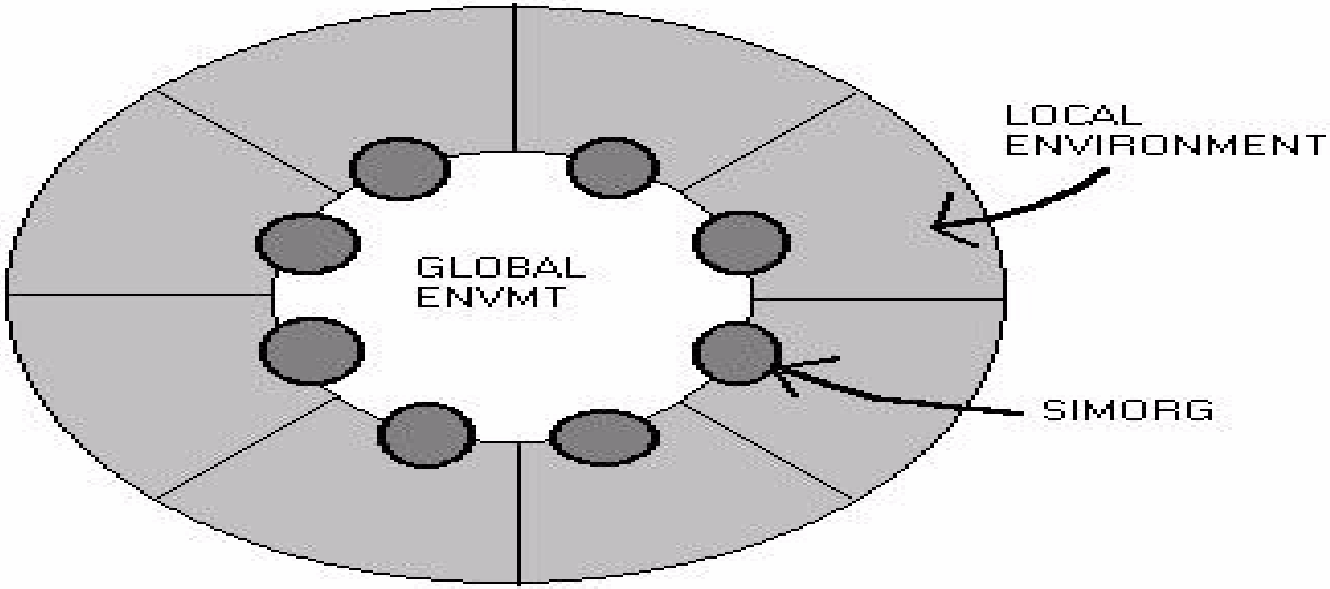
Criticisms

Ezequiel Di Paolo's methodological criticism of Burghardt:

"This mixes up a characterisation of the phenomenon of communication with an (admittedly plausible) explanation of how it arose"

Another dodgy area: treatment of *'communication'* as '*transmission of information*' without being rigorous about definition of **information.**

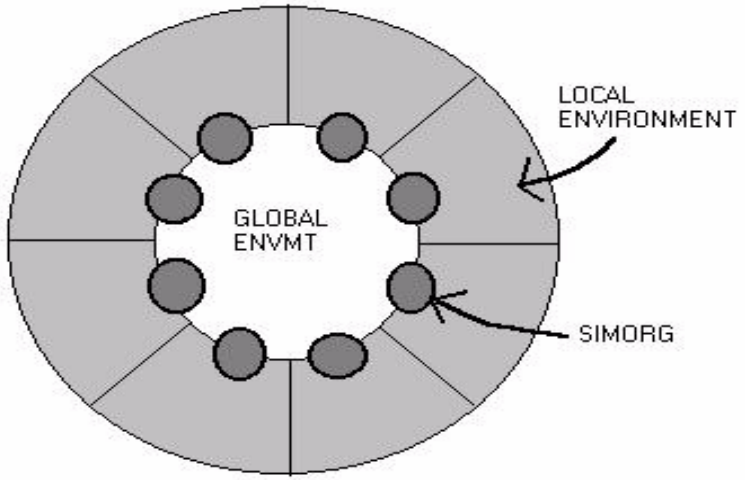
Simorgs



Simulated organisms: why should there be any *need* to communicate (MacLennan asks..) ??

Simorg world

OK, set it up so that each simorg has a *private* world, a **local environment** which only they can 'see',
With one of 8 possible symbols *a b c d e f g h*



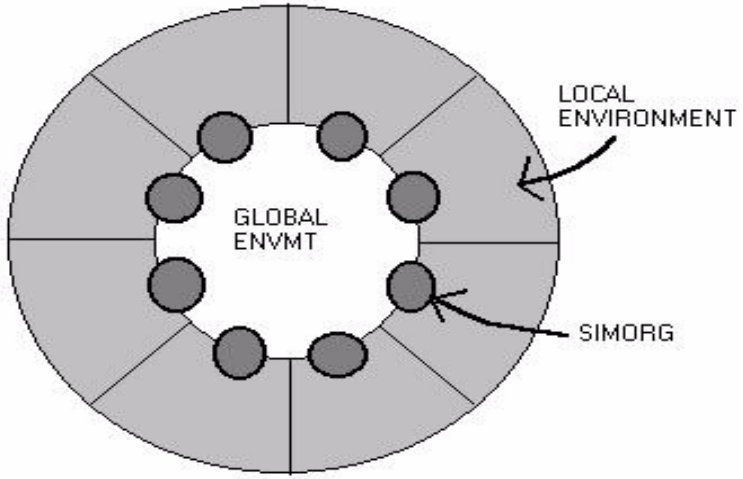
Plus there is a *shared* public world, a **global environment** in which any simorg can make or sense a symbol.
-- one of 8 possible symbols *p q r s t u v w*

Why communicate ?

Simorgs have to:

(a) 'try to communicate their private symbol'
and

(b) 'try to guess the previous guy's'



Each simorg can **write** a symbol *p-to-w* in global env ('emit') and **raise a flag** with symbol *a-to-h* ('act')

Writing a new symbol over-writes the old.

Simorg actions

When it is its turn, a simorg both writes a symbol and raises a flag, eg [*q, d*] -- depending on what its genotype 'tells it to do' (see later for explanation).

What counts as success is when it raises a flag *matching* the **private symbol** of the simorg who had the previous turn (normally turns go round clockwise)

Ie if simorg 5 does [*q, d*], when simorg 4's private symbol happened to be *d*', then this counts as 'successful communication' (via the global symbols) and **both** simorg4 and simorg5 get a point !

Evaluating their success

How do you test them all, give them scores? --

(A) minor cycle -- all private symbols are set arbitrarily by 'God', turns travel 10 times round the ring, tot up scores

(B) major cycle -- do 5 minor cycles, re-randomising all the private symbols before each major cycle.

Total score from (B) for each simorg is their 'fitness'

Simorg genotype

Each simorg faces 64 possible different situations --
8 symbols *a-to-h* privately, plus
8 symbols *p-to-w* in the public global space.

For each of these 64 possibilities, it has a genetically specified pair of outputs such as [*q, d*] which means '**write** *q* in public space, **raise flag** *d*'

So a genotype is 64 such pairs, eg

[*q d*] [*w f*] [*v c*]... ... 64 pairs long .. .. [*r a*]

The Evolutionary Algorithm

A Genetic Algorithm selects parents according to fitness (actually he used a particular form of steady-state GA) and offspring generated by crossover and mutation, treating pairs [*q d*] as a single gene.

NOTE: the importance of using steady-state GA, where only one simorg dies and is replaced at a time -- it allows for *'cultural transmission*', since the new simorg is born into '*an existing community*'

Adding learning

To complicate matters, in some experiments there was an additional factor he calls 'learning'.

Think of the genotype as DNA, which is inherited as characters.

When a simorg is born, it translates its DNA into a lookup table, or transition table, which is used to determine its actions.

How ‘learning’ works

WHEN learning is enabled, then after each action it is checked to see if it 'raised the wrong flag'.

If so, the entry in the lookup table is changed so that another time it would 'raise the correct flag' (ie matching previous simorg's private symbol)

BUT this change is *only* made to the phenotype, affecting scores and fitness, **NO CHANGE** is made to the genotype (which is what will be passed on to offspring) -- ie it is *not* Lamarckian.

How to interpret results?

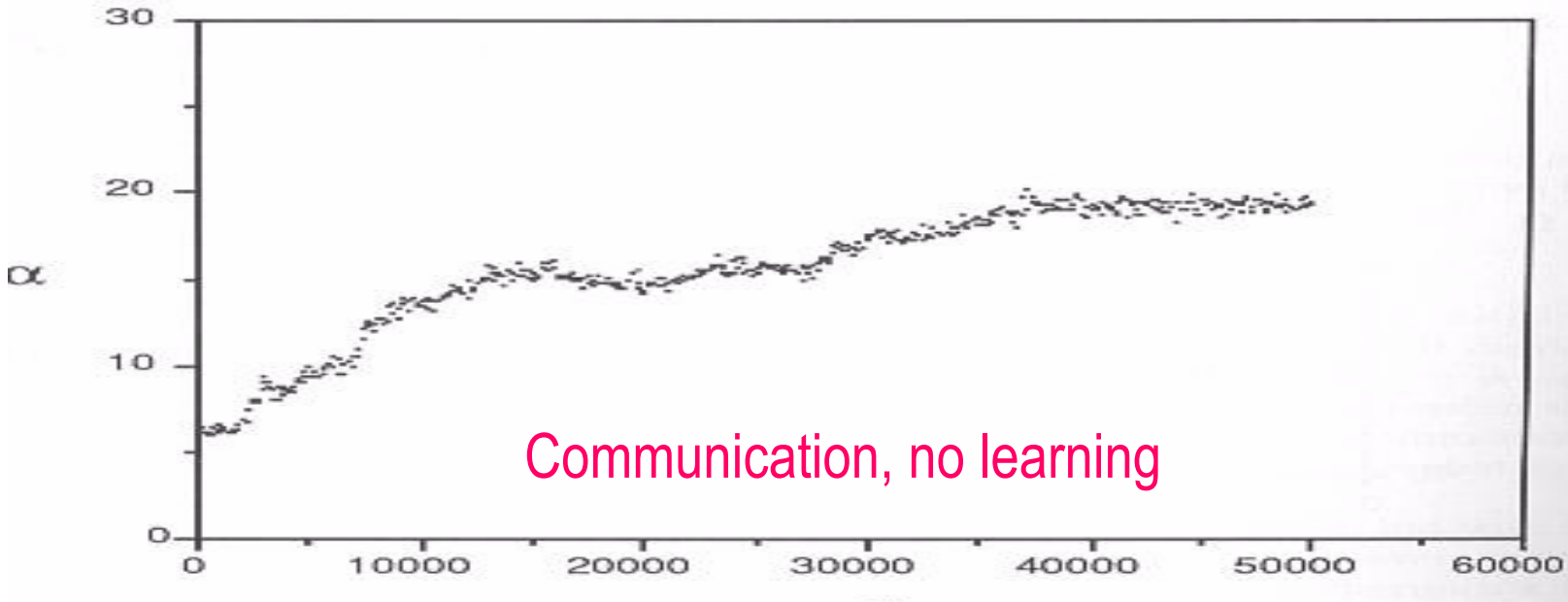
Suppose you run an experiment, with 100 simorgs in a ring, 8 private (*a*-*h*) and 8 public (*p*-*w*) symbols, for 5000 new births.

You *may* find communication taking place, after selection for increased fitness, with some (initially arbitrary) code being used such as
'if my private symbol is *a*, write a *p* into public space -- if you see a *p*, raise a flag with *a*' -- etc etc.

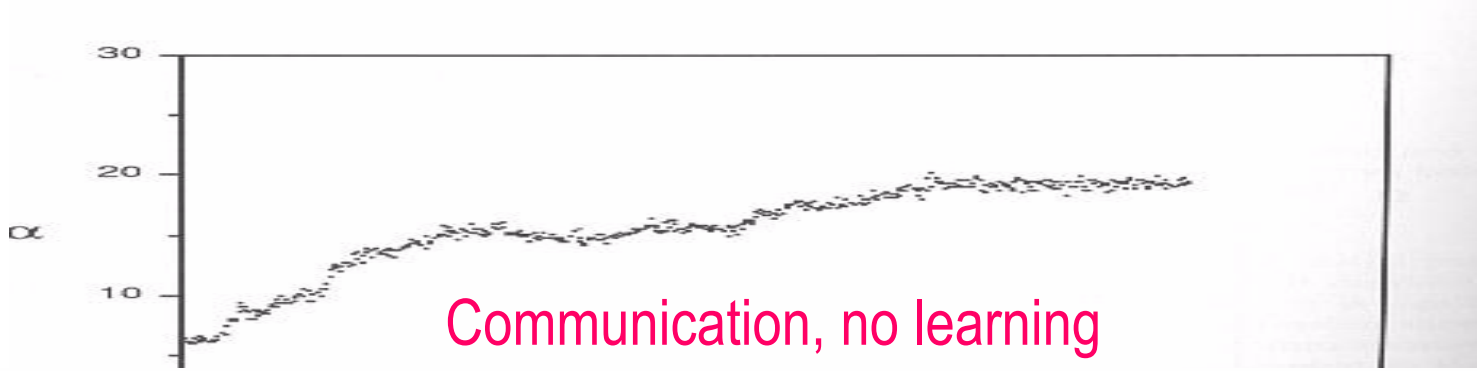
But how can you objectively check whether there really is some communication?

Tests for 'communication'

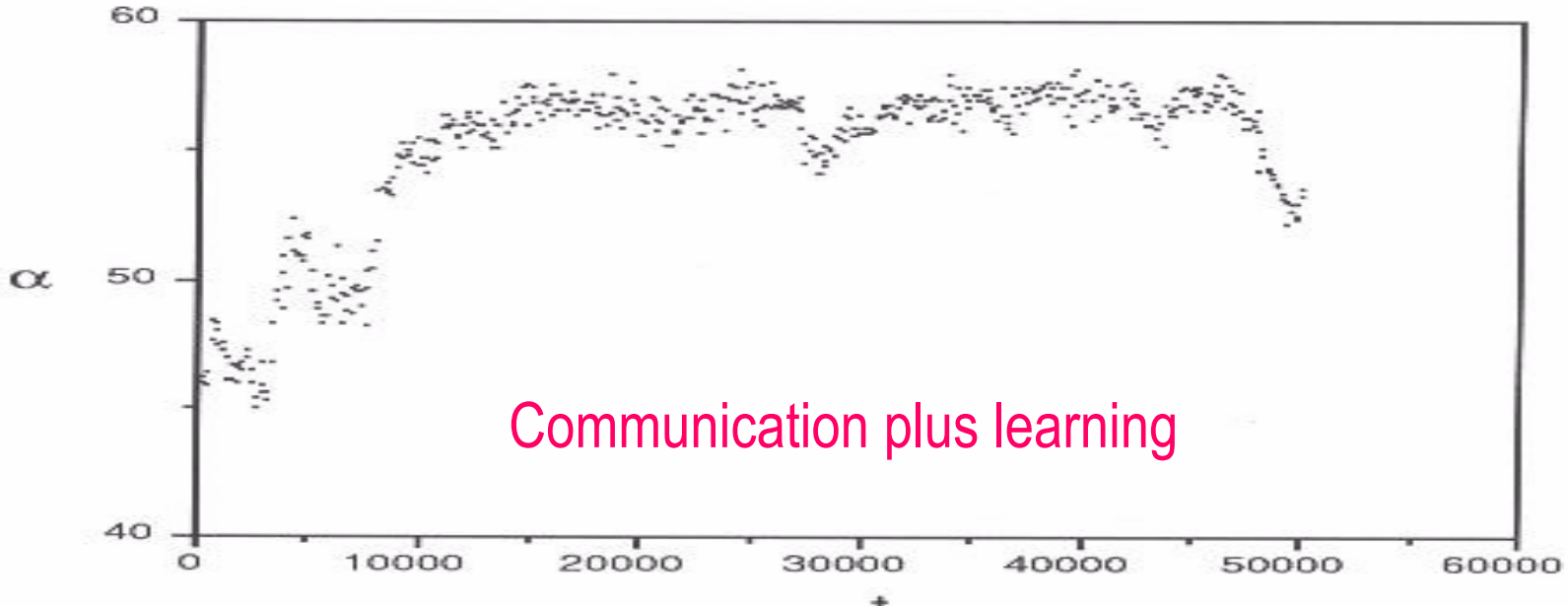
(1) Compare results doing as above with results when the global envt symbol is vandalised at every opportunity -- ie replaced with a random symbol. Fitnesses should differ when there is/is not such vandalism.



Comparison with learning



Communication, no learning



Communication plus learning

Dialects test

(2) Second way to test for communication: keep a record of every symbol/situation pair, such as

'see a global p, raise flag a' -- how often seen?
'see a global p, raise flag b' -- ditto
... ...
see a global w, raise flag h' -- ditto

If no communication, one should not expect any particular pattern to emerge, whereas with communication you should expect such statistics to have some discernible structure.

Evidence of dialects

TABLE 3 Denotation Matrix, Communication Permitted and Learning Disabled

	situation							
symbol	0	1	2	3	4	5	6	7
0	695	5749	0	1157	0	2054	101	0
1	4242	11	1702	0	0	0	1	0
2	855	0	0	0	0	603	862	20
3	0	0	0	0	1003	430	0	1091
4	0	0	0	0	0	0	2756	464
5	0	0	40	0	548	0	817	0
6	1089	90	1	281	346	268	0	62
7	0	201	0	288	0	0	2	0

$$V = 2.272352$$
$$H = 3.915812$$
$$\eta = 0.3052707$$

Comments

- Rarely a one-to-one denotation in the matrix
- Not always symmetric
- Probabilistic -- symbol 4 'means' situation 6 84% of time, means situation 7 16% of time.

Interesting comment: this method of GA saw communication arising, ---- **but** the original experiments were deterministic in the sense that: “least fit always died, the two fittest simorgs always bred to produce the replacement offspring” -- in these original experiments communication never arose !

Some different views

See Ezequiel di Paolo
"An investigation into the evolution of communication“
Adaptive Behavior, vol 6 no 2, pp 285-324 (1998)
via his web page
http://www.cogs.susx.ac.uk/users/ezequiel/

Suggests the idea of information as a commodity has contaminated many peoples' views, including MacLennan.

MacLennan explicitly sets up the scenario such that some information is not available to everyone.

Communication without such information

BUT there are often phenomena that we think of as communication when all relevant info is available to all concerned

-- eg within a wolf pack forming a coordinated pattern for hunting prey.

Signals as actions rather than packages of information.

Communication as Social coordinated activity.

Autopoiesis

Maturana and Varela 1988
The Tree of Knowledge: the biological roots of human understanding. Shambala Press, Boston

If 2 or more organisms have their activities coupled
(in a dynamical systems sense -- each perturbs the activity of the other)
then their activities become coordinated.

This establishes a consensual domain.

Communication as interaction in a consensual domain

Communication can be defined as the behavioural coordination that we can observe as a result of the interactions that occur in a consensual domain.

This is complex stuff, worth pursuing. Di Paolo's work offers a good way in.