Social Insects
communication & task allocation

by Fred Drumlevitch

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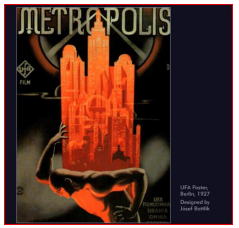


Sociality : benefits view

--- predation risk reduction
--- possible mating advantages
--- environmental buffering
-- structures
-- thermoregulation
-- food procurement

Sociality : characteristics view

--- division of labor
--- specialization on tasks

--- communication

adaptive value of colony efficiency
+
dynamic, variable environment

➔ need *worker behavioral flexibility*
(within constraints imposed by development & phylogeny)

worker behavioral flexibility achievable via
--- dynamically adjustable *rate* of task performance
--- *recruitment* from inactives pool
--- dynamic *task allocation*

tasks : *independent* need perception vs. *communication*-mediated

independent need perception possible, but theoretical and empirical basis for primacy of *communication*-mediated task control.

Worker Connectivity : "communicative interactions that link a colony's workers in a social network and affect task performance"
O'Donnell (2007, 2006)

Social network models

Graph representation

usually :
nodes = workers,
edges = communication links

BUT : Fewell (2003) alternative focus:
nodes = tasks,
edges = individuals transmitting information

Fewell (2003) network representation

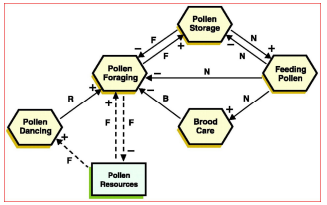


Fig. 1. The network pathways modulating pollen foraging in a honeybee colony (developed with T. Taylor). Nodes are the tasks linked to pollen foraging; vectors are the individuals transmitting information: F, forager; N, nurse; B, brood; R, recruit.

Adaptive advantages of connectivity

1) better time-space information dissemination
   ("farther, faster, or to more individuals")
2) push workers into undesirable tasks
   (when direct fitness effects exist),
   overcome task inertia
   (fixation, or burnout)
3) allows control by key / hub individuals with superior knowledge

"Worker connectivity" = f (key variables), pt.1

1) graph degree = edges per node

--- edges are realized communicative interactions
--- not all encounters produce communicative interactions
--- interaction probability can be function of general activity level and movement rate
    (Cao et al., 2007, referenced in O'Donnell and Bulova, 2007)
--- nature of tasks may constrain interaction opportunities
--- failed interaction may convey information
--- colony modularization can affect graph degree

"Worker connectivity" = f (key variables), pt.2

2) component (interacting group) size

3) sender distribution (= variation in graph degree)
   ➔ key / hub individuals with greater influence

4) strength of interaction effects on receivers
   --- via strength of sender signal
   --- or via receiver response
   --- for >1 interaction threshold, what is summation function, persistence function ?

"Worker connectivity" = f (key variables), pt.3

5) receiver memory loss, and signal decay

6) social inhibition effects
   --- *developmental:* maturation to foragers in honeybees
   --- *theoretical model:* ant foraging model suggests increased efficiency from combination of positive and negative chemical recruitment signals
   (Strickland, 1999, referenced in O'Donnell and Bulova, 2007).

7) response specificity
   general vs. specific activation of receivers
   (Dornhaus and Chittka, 2001, 2004, ref in O'Donnell & Bulova, 2007)

"Worker connectivity" = f (key variables), pt.4

8) other species and task differences

--- variation in mechanism produces variation in time course (detection and persistence)

--- even within a single mechanism, (i.e. pheromones) considerable variation in detection and persistence (with pheromones, via volatility differences)

--- urgent tasks may favor hierarchical communication

Anderson, Franks, McShea (2001) paper

Like Fewell, focus on tasks first

Anderson & Franks (2001) definition of tasks (& subtasks):

"a task is 'an item of work that potentially makes a positive contribution, however small, to inclusive fitness (i.e. direct and indirect fitness)'. Sometimes a subset of the behaviours required to complete a task may appear as a discrete unit in themselves, a subtask."

Tasks first, examine task *structure*

digression

Anderson et al. (2001) proxy measure of task complexity:

"… the degree of cooperation and coordination required for successful task completion, based upon the deconstruction of a task into its component tasks and subtasks."

So:

task complexity

(links to) task structure, and task allocation

(links to) task-required communication

Anderson et al. Task Taxonomy

Four types of structure:

1) individual tasks
2) group tasks
3) team tasks
4) partitioned tasks

Anderson et al. Task Taxonomy

1) individual tasks
   --- completable by single individual, without assistance
2) group tasks
   --- require multiple workers, concurrent action
   --- BUT *no* division of labor (each worker action same)
3) team tasks
   --- 2 or more different subtasks, done concurrently
   --- multiple workers AND division of labor
4) partitioned tasks
   --- 2 or more different subtasks, done sequentially
   --- multiple workers AND division of labor

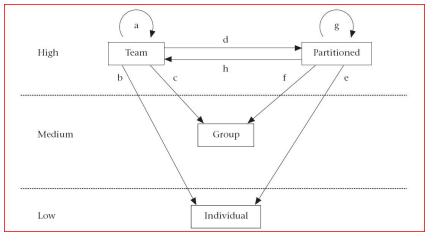
Task Structure Variation

example for 1 behavior type (defense)

Behaviour (and task type)	Species
Individual task	
Squirting foam over victim	*Pachycondyla tridenta*
Abdominal bursting	*Globitermes sulfureus; Camponotus* sp.
Nest blocking by an individual	*Chartergus chartarius*
Group task	
Visual warning and defensive alignment	*Dendromyrmex chartifex; Apoica pallens*
Balling (i.e. 'cook' predator in a ball of bees)	*Apis cerana japonica*
Nest blocking by 2 or more individuals	*Colobopsis truncatus*
Synchronized mobbing	*Polistes annularis*
Team task	
Decapitation	*Pheidole pallidula; P. punctulata*

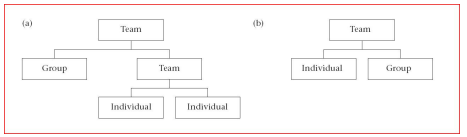
(from Anderson et al. (2001), table 1, truncated)

Anderson et al. Task Complexity and Relationships



from Anderson et al. (2001), figure 1

Task Structure Hierarchy examples



(a) Oceophylla nest construction

(b) Pheidole decapitation, or prey retrieval in Eciton when there are several followers.

(from Anderson et al. (2001) fig. 2, partial)

Anderson Task Model considerations

Complexity value:

individual task/subtask	= 1 point
group task/subtask	= 2 points
team task/subtask	= 3 points
partitioned task/subtask	= 3 points

Nesting permitted, including partitioned subtasks within team tasks

Sum point values for a task and all its subtasks

Intended as relative, *not* absolute, *not* ratio, ranking of task complexity

Task Complexity : examples

Table 2. Summary of the task complexity of some of the tasks discussed in the text

Task	(Sub)task type				Complexity score
	I (1)	G (2)	T (3)	P (3)	
Lanius fuliginosus nest construction	2	1	0	3	13
Oecophylla longinoda nest construction	2	1	2	0	10
Messor barbarus forage retrieval (when there are 5 transfers)	6	0	0	1	9
Atta sexdens forage retrieval (3-stage)	3	0	0	1	6
Decapitation of intruders in *Pheidole pallidula*	1	1	1	0	6
Eciton burchelli forage retrieval (when there is a group of followers)	1	1	1	0	6
Average *E. burchelli* prey retrieval team	1.88	0.12	1	0	5.12
Eciton burchelli forage retrieval (when there is a single follower)	2	0	1	0	5
Guarded slave-making raids	2	0	1	0	5
Hodotermes mossambicus foraging	2	0	0	1	5
Apis dorsata curtain	0	1	0	0	2
Cataglyphis foraging	1	0	0	0	1

I, G, T, and P represent the four (sub)task types, i.e. individual, group, team and partitioned, respectively. Numbers in parentheses signify the score associated with each (sub)task type.

(from Anderson et al. (2001), table 2)

division of labor metrics

Anderson et al. model for task complexity relatively simple

more elaborate division of labor metrics exist

Gorelick and Bertram (2007)
survey more elaborate division of labor metrics

Gorelick and Bertram (2007)

They conclude:

1) Single-output statistic desirable, to permit comparison across different population sizes, different numbers of tasks, etc.

2) Input to function should be a matrix representation, proportion of time that individual *j* spends on task *k* (for minimum loss of info)

3) "… normalized matrix-input generalizations of Shannon's and Simpson's index … should be the indices of choice when one wants to simultaneously examine division of labor amongst all individuals in a population."

Link to ecological diversity measures! But now use for task analysis!

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