Circadian Rhythms and Behavior

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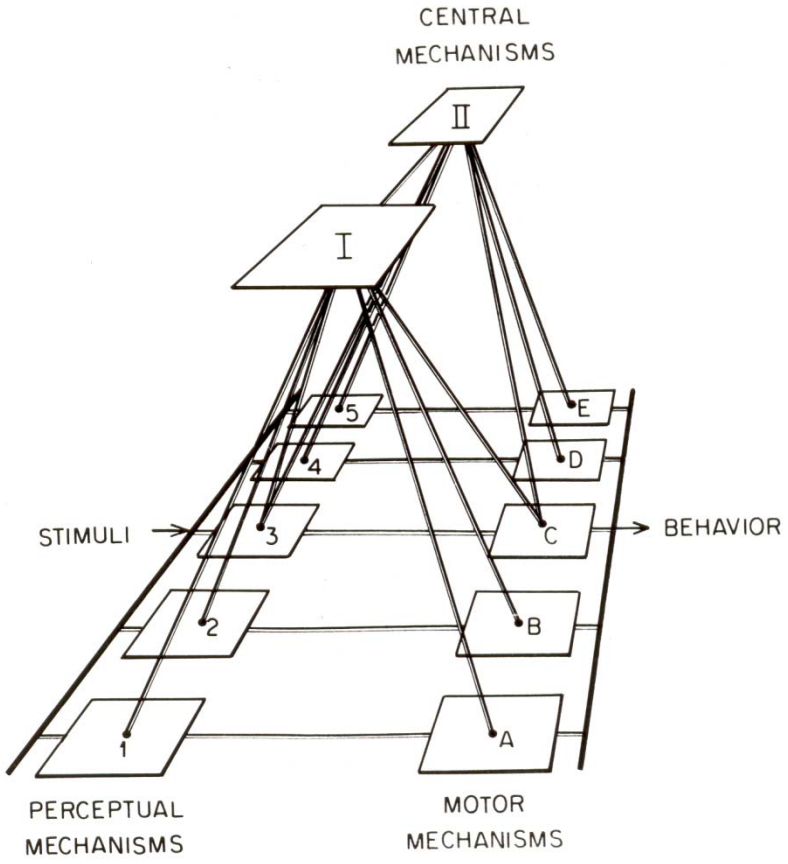
Outline

- Behavior systems and causal factors
- Dustbathing as a model system
- Rhythms as a causal factor
  - Rhythms and feeding
  - Rhythms and dustbathing
  - Rhythms and sleep
- Development of sleep
- Discussion: Implications for humans

Behavior System Model



Structure – components

Motivation – activation of components

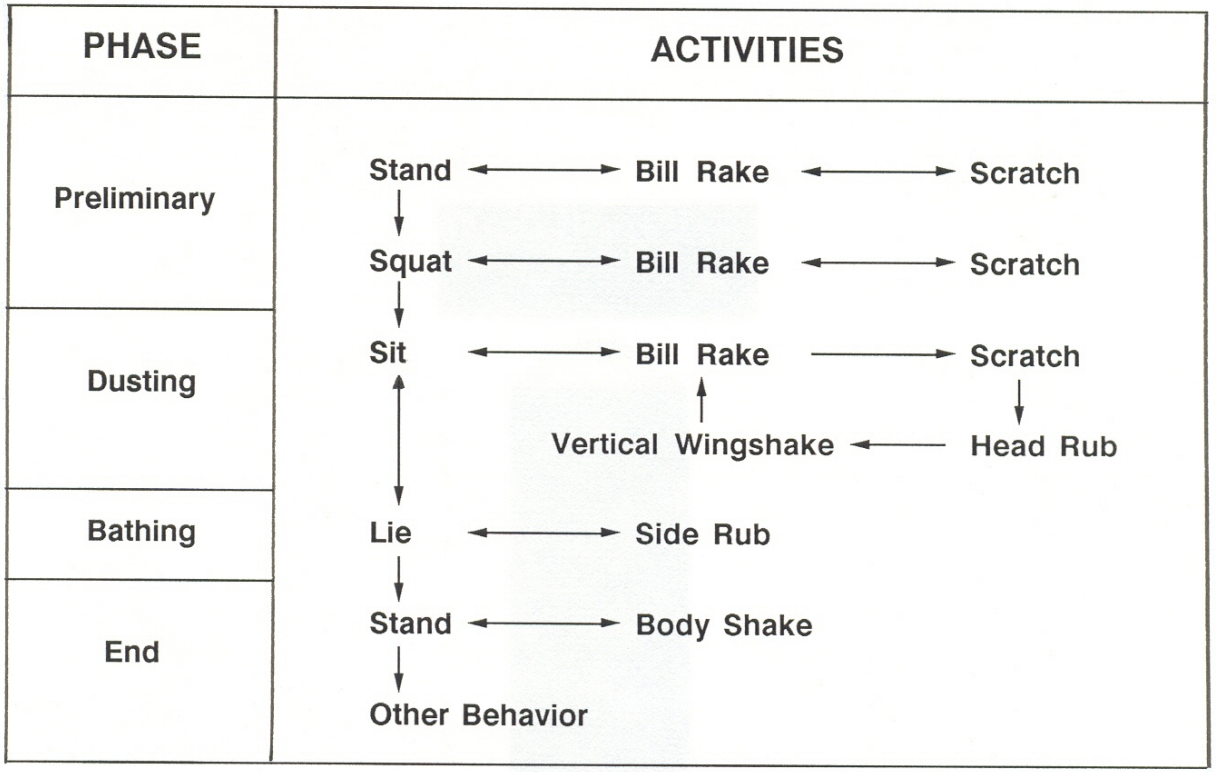
Development – changes in structure

Interaction of components

Causal factors for behavior

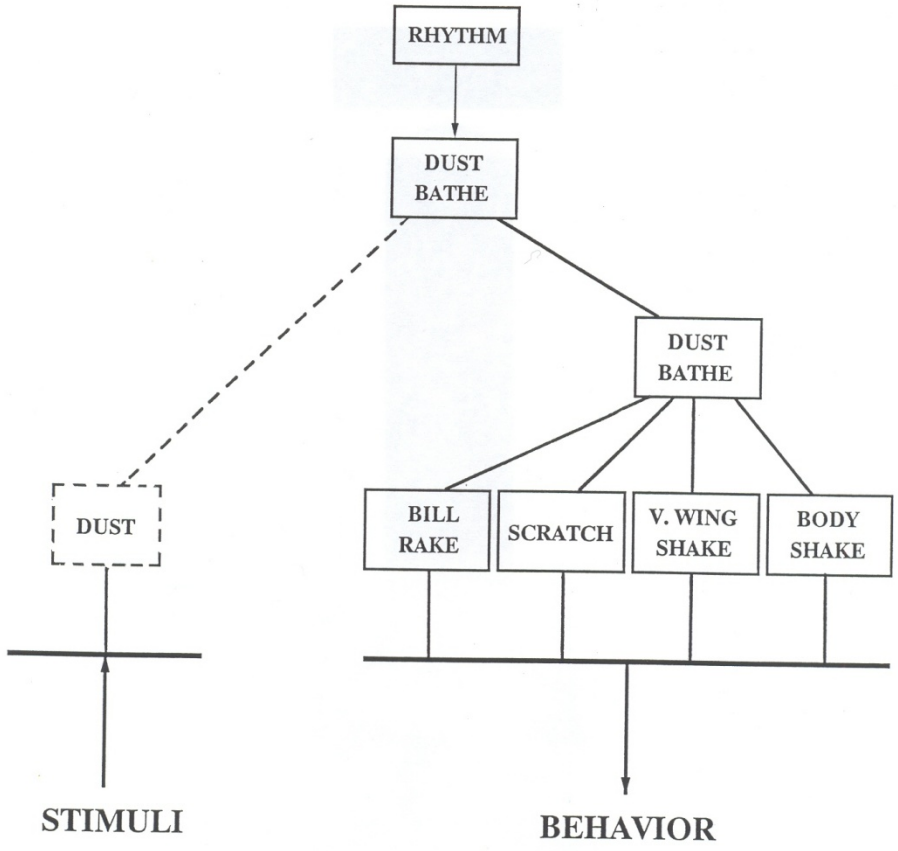
- Factors specific to the behavior
  - Internal (endogenous)
  - External
- General causal factors
  - Circadian clocks
  - Interactions with other behaviors

Dustbathing Flow Diagram



After van Liere, 1986

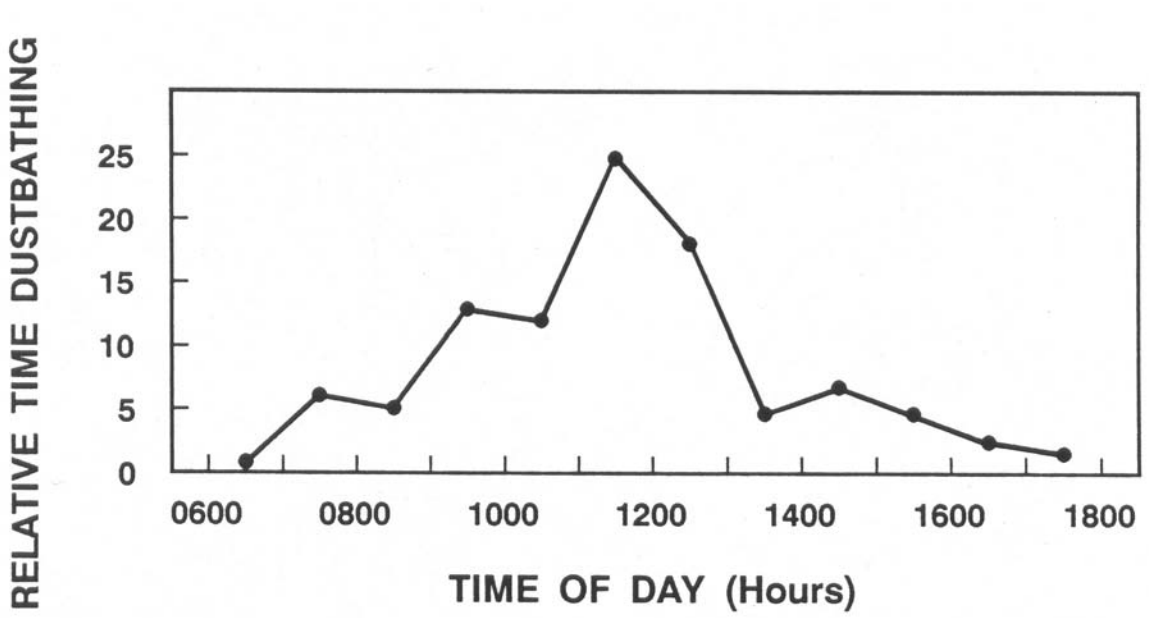
Dustbathing Behavior System



Causal Factors for Dustbathing

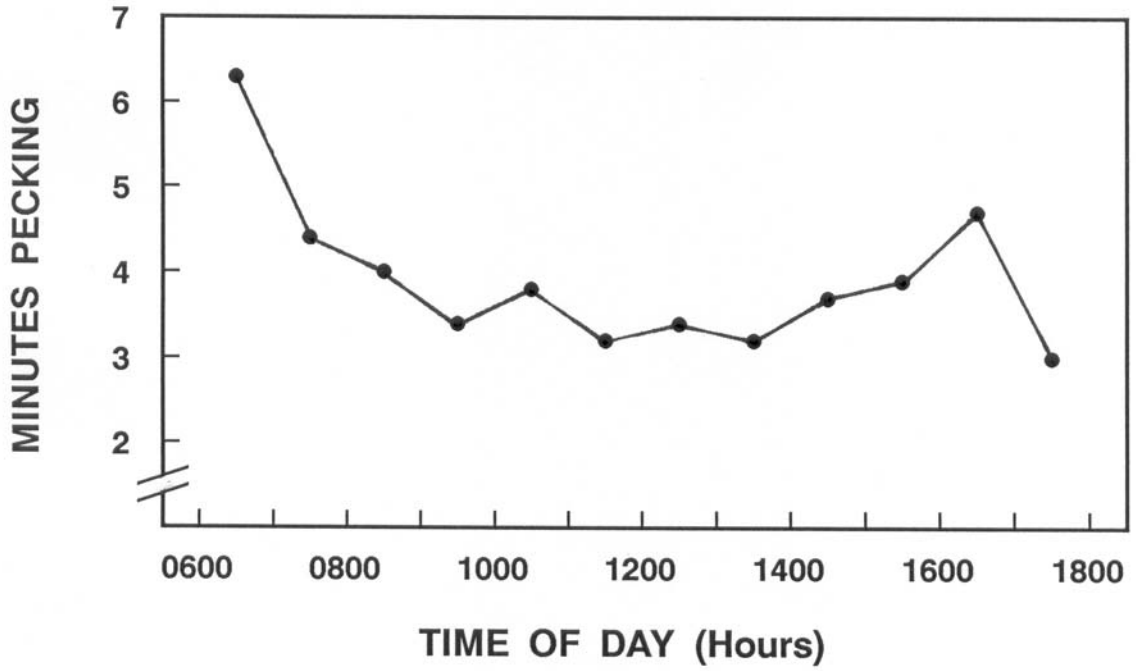
- Specific causal factors
  - Internal: Dust deprivation
  - External: Dust, Light/Heat
- General causal factor
  - Circadian system

Dustbathing during the day



Data from Hogan & van Boxel, 1993

Feeding during the day



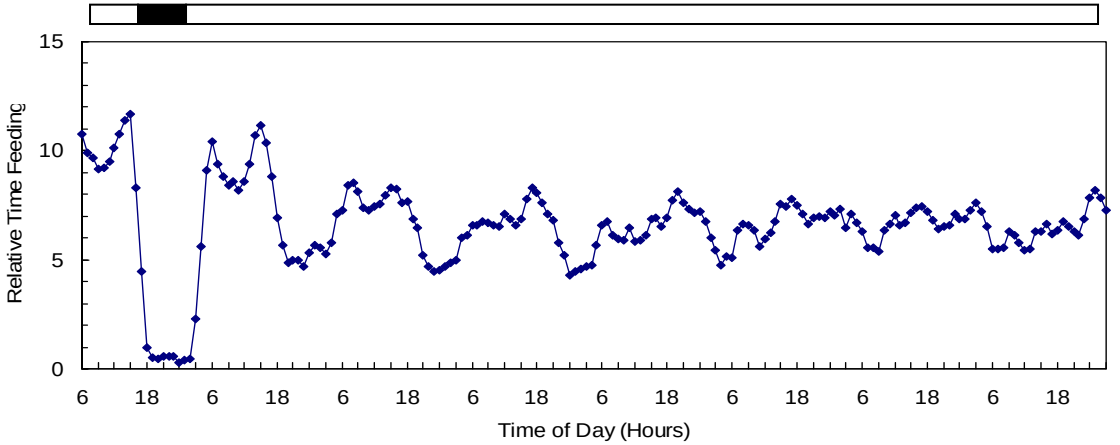
Experiments on circadian control

Expose animals to constant conditions and look for a free-running rhythm

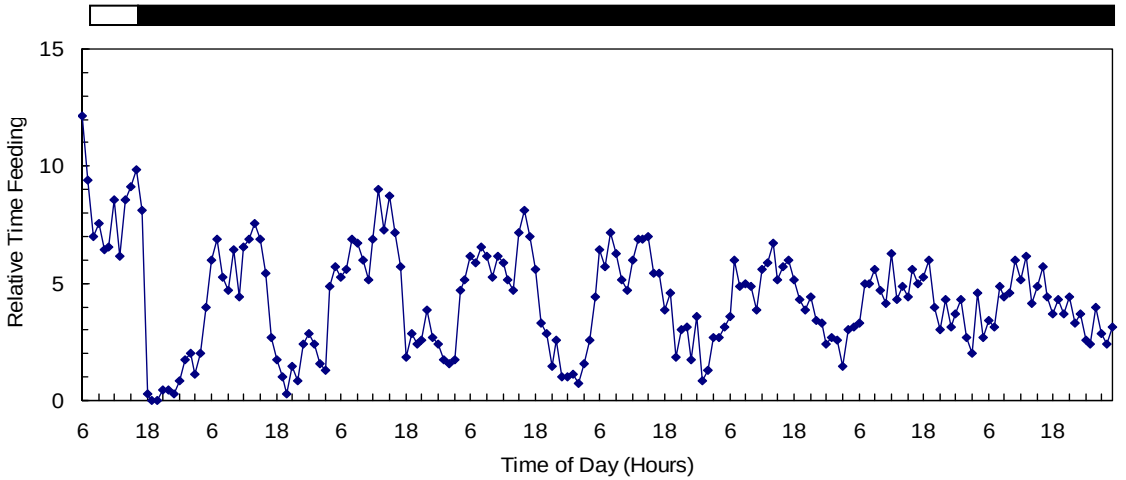
Chicks raised for first 2 weeks of life under 12:12 L:D conditions and then exposed to constant conditions (light/dark/dim light) for 7-8 days. On the final LD day and subsequent days under constant conditions, behavior was recorded and analyzed.

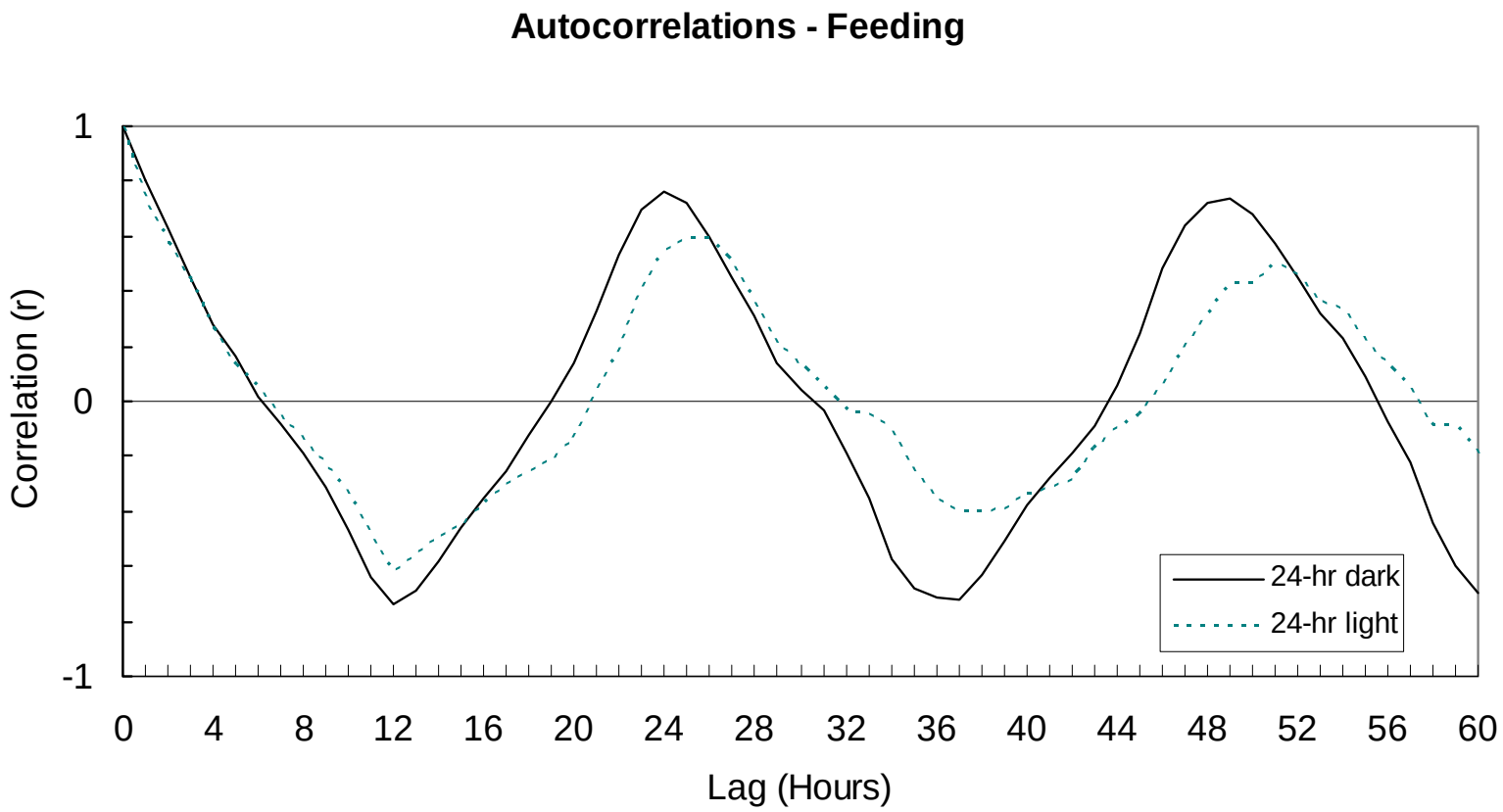
Feeding – Free running

24-hr Light
(3-hr running average)



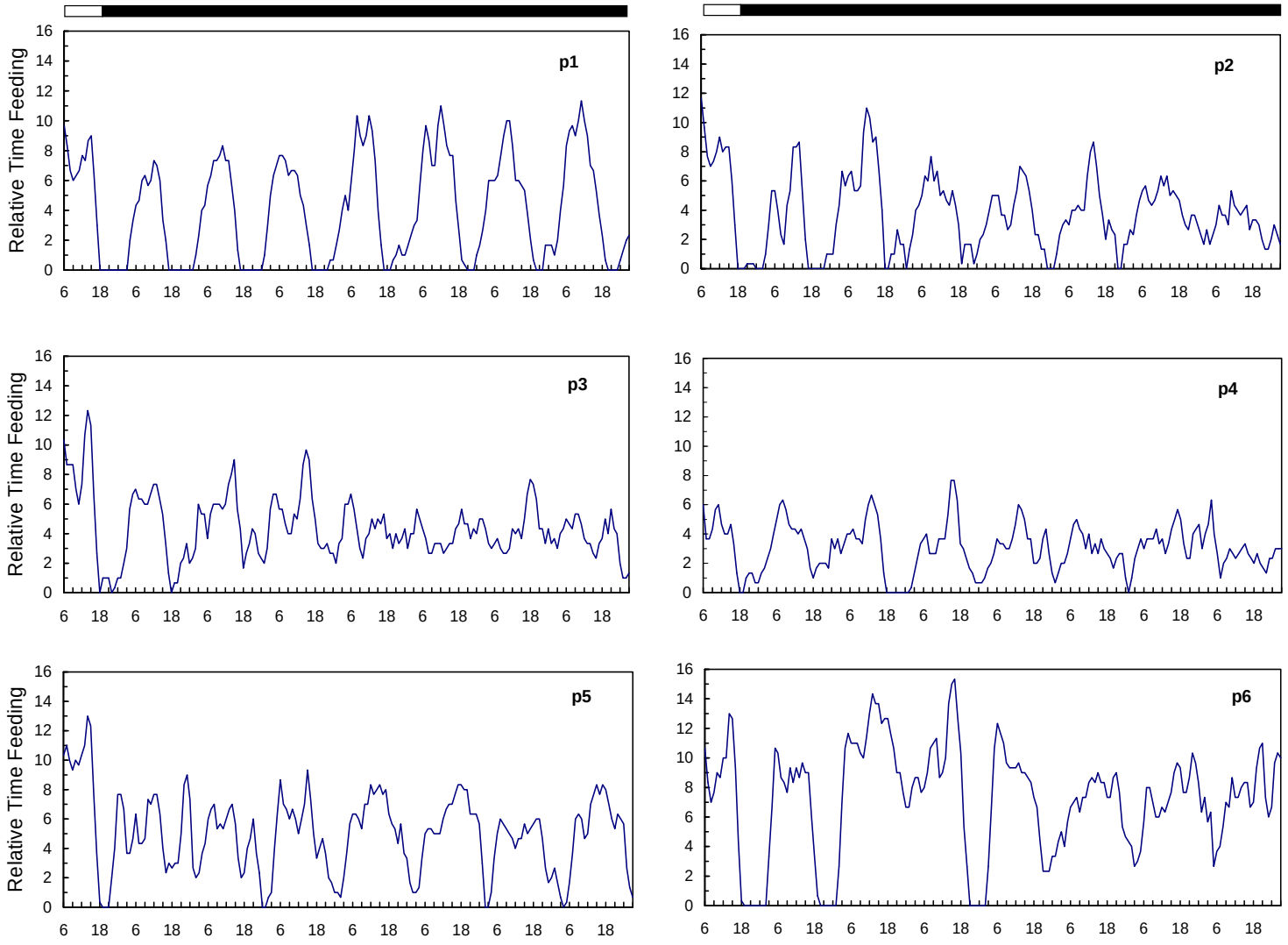
24-hr Dark
(3-hr running average)





$\tau \approx 24.5$ hr (Dark)
$\tau \approx 25.5$ hr (Light)

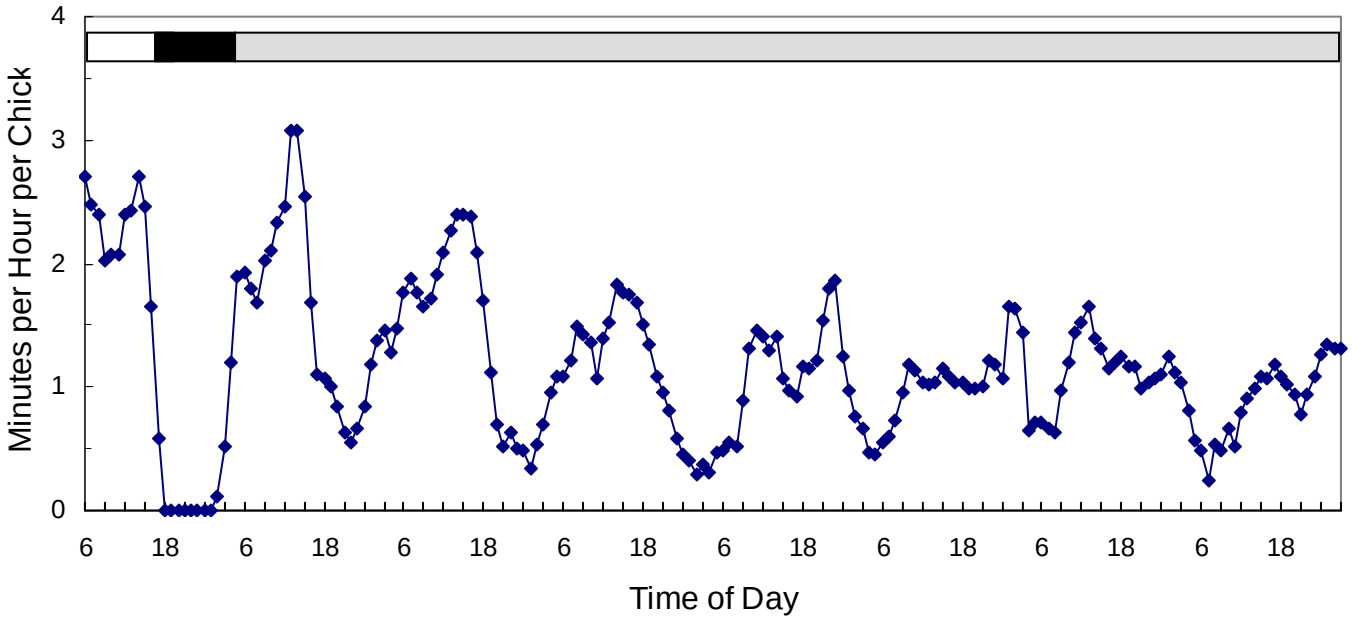
Individual Feeding DD (3-hr running average)



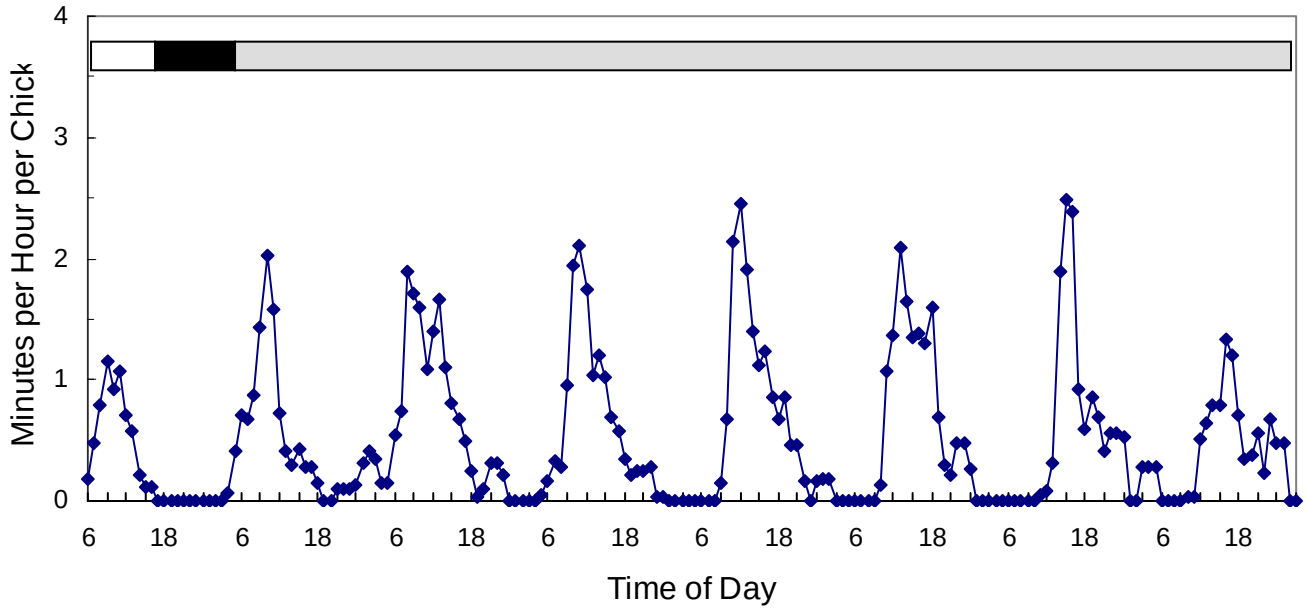
Dim Light Experiment: Feeding and Dustbathing

Feeding registered automatically, but dustbathing observed on video tapes. Dim light was a standard 25-W light bulb that provided about 1.5 lux in the cages.

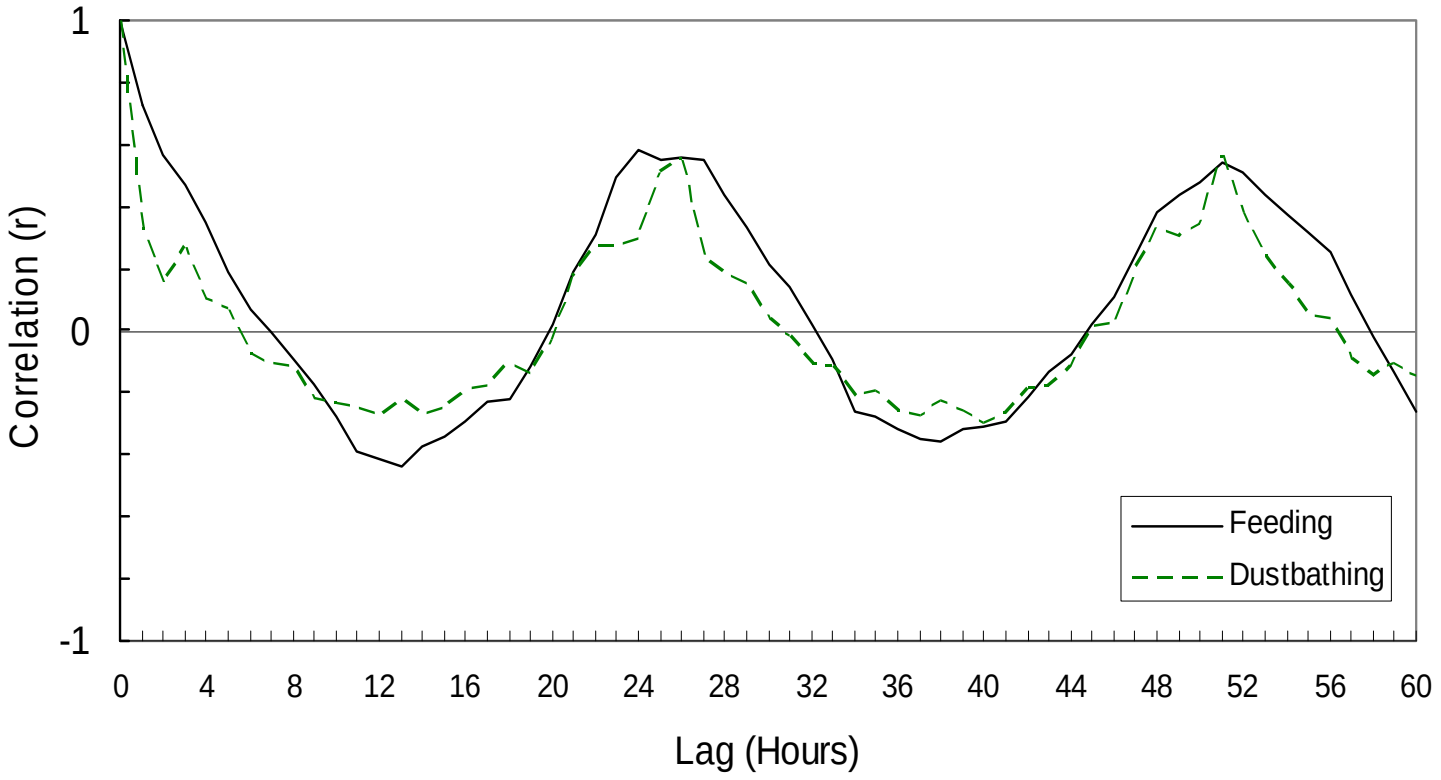
Dim Light Feeding (3-hr running average)



Dim Light Dustbathing (3-hr running average)

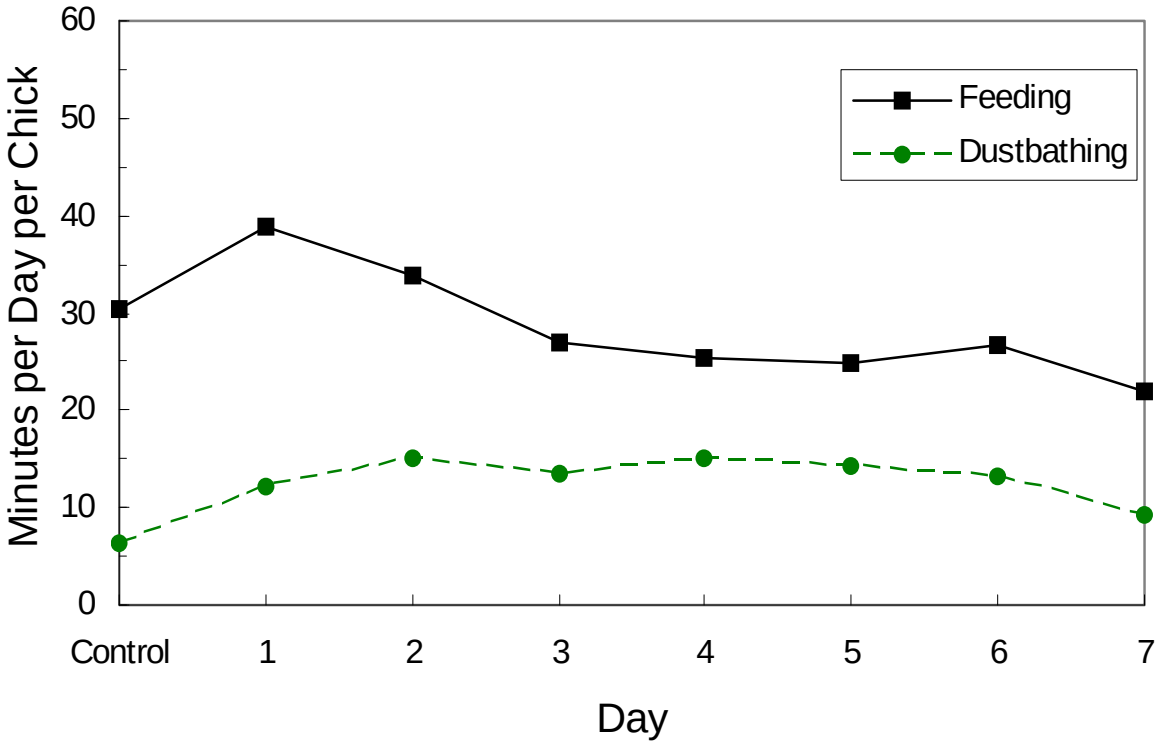


Autocorrelations - Dim Light



$\tau \approx 25.5$ hr

Total Daily Activity (Dim Light)

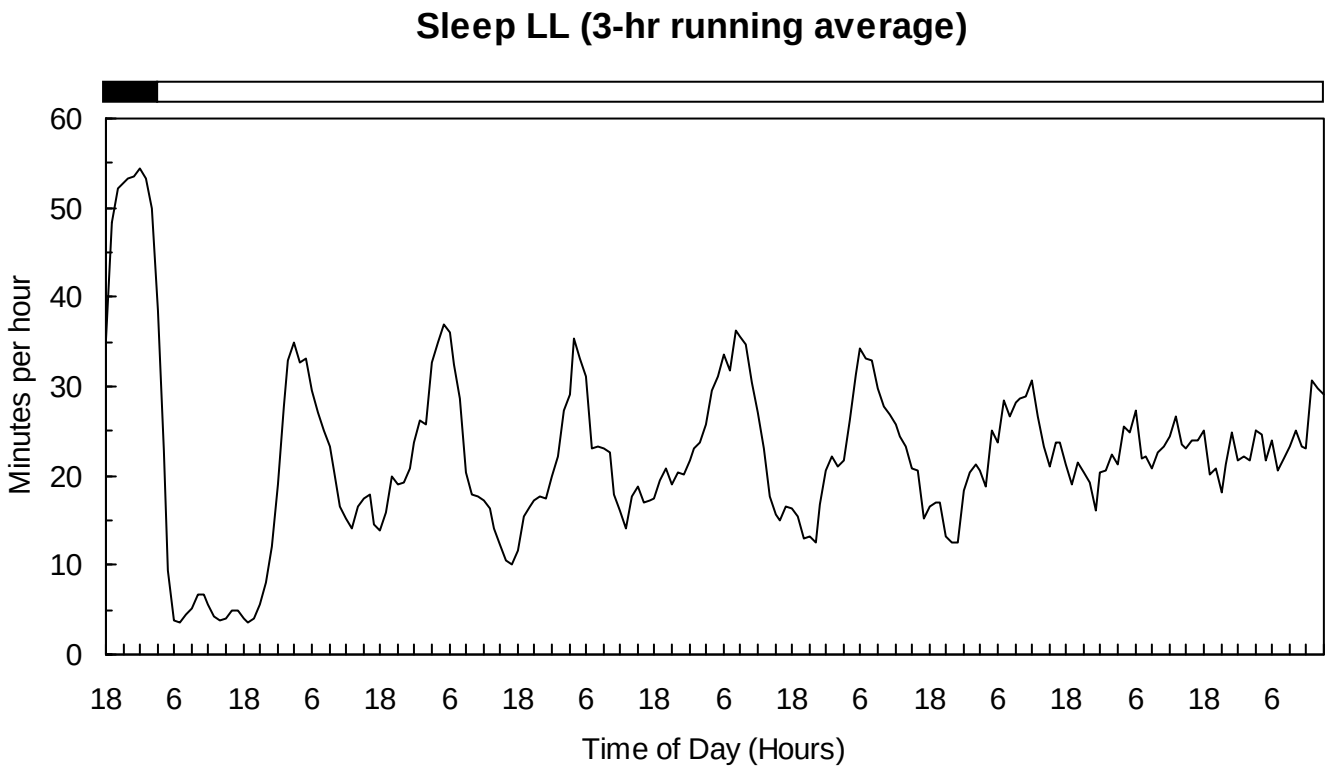


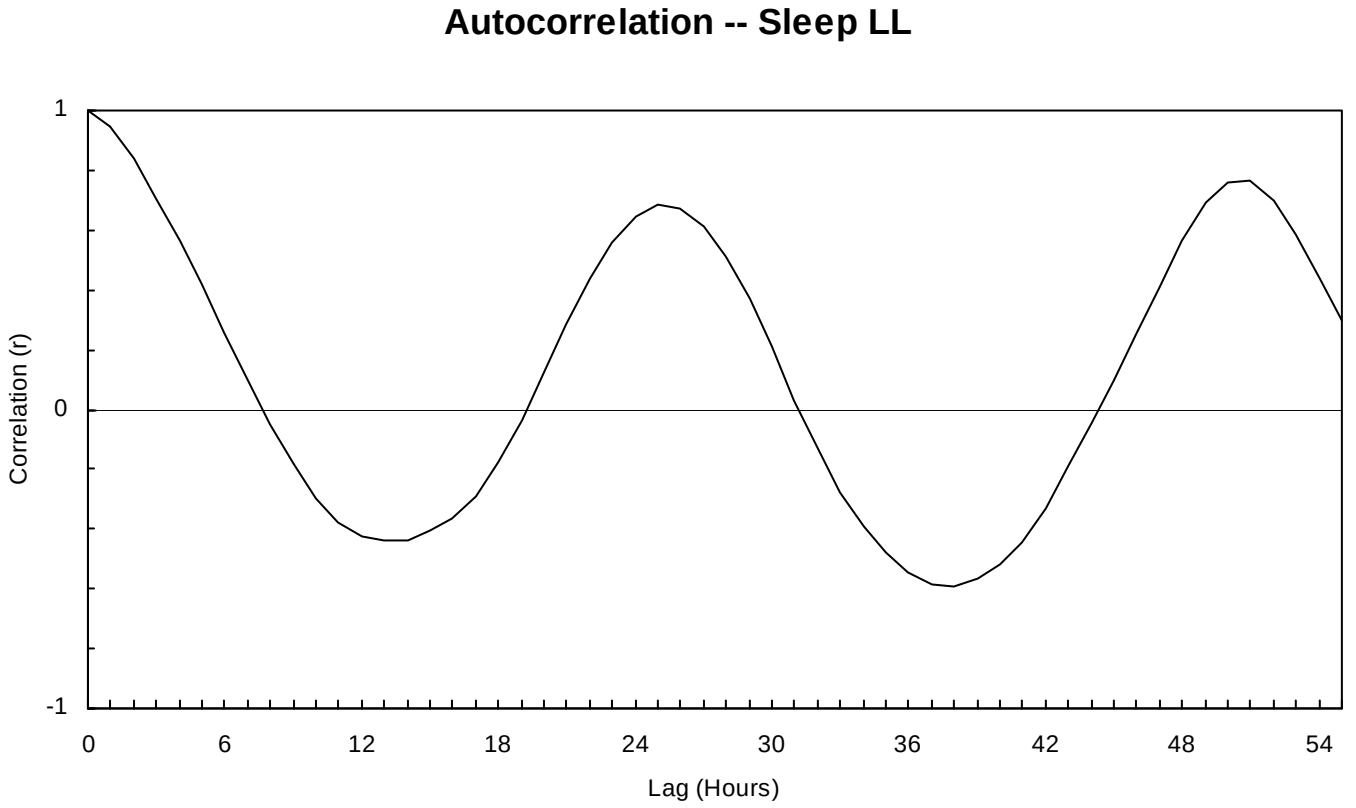
Sleep (and Dustbathing) Experiments

Chicks placed individually (rather than in pairs) into experimental cages (80-liter aquaria)

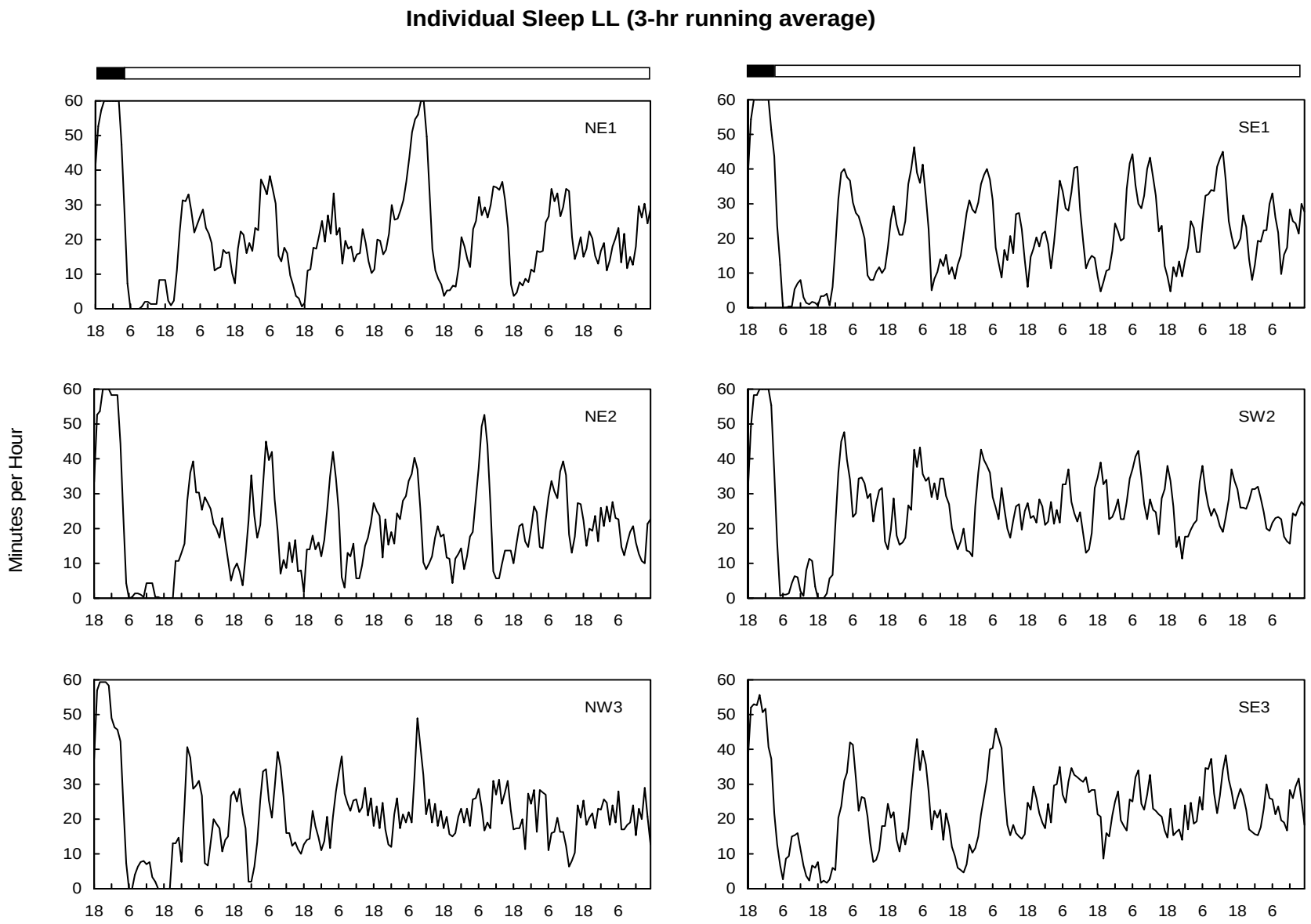
All behavior observed on video tapes

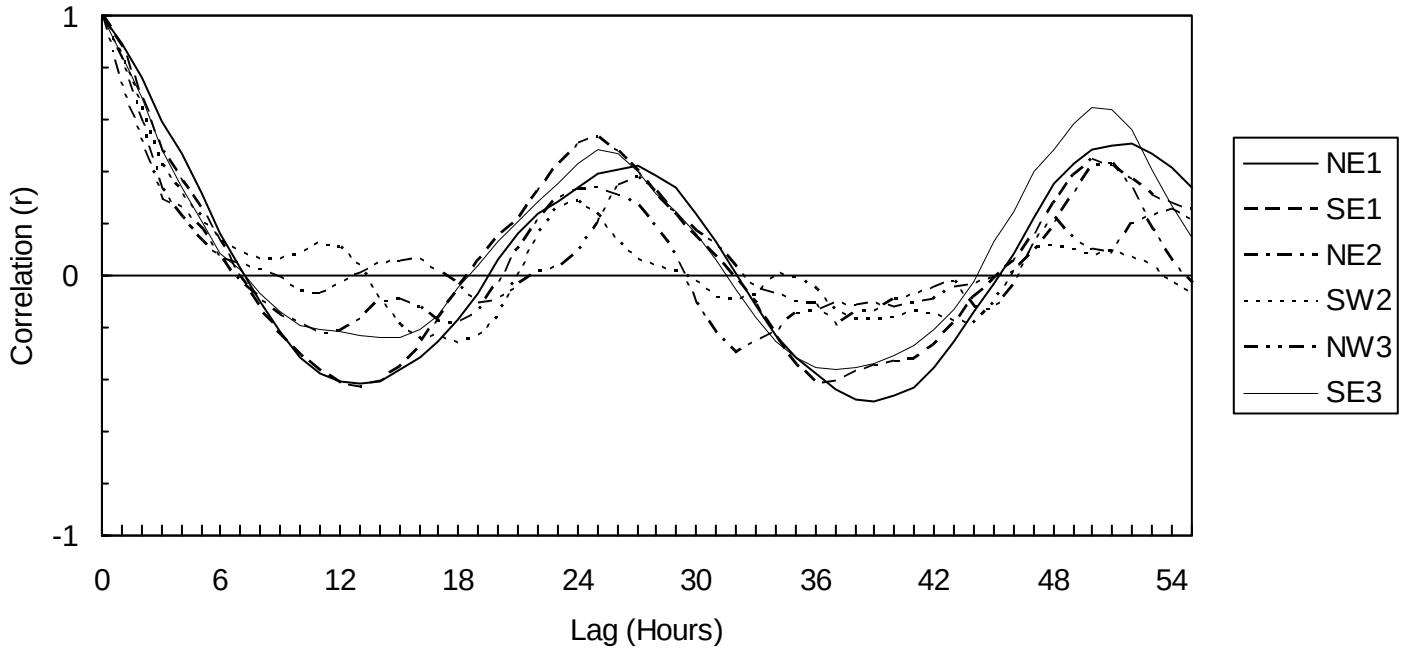
Two experiments: free run and development

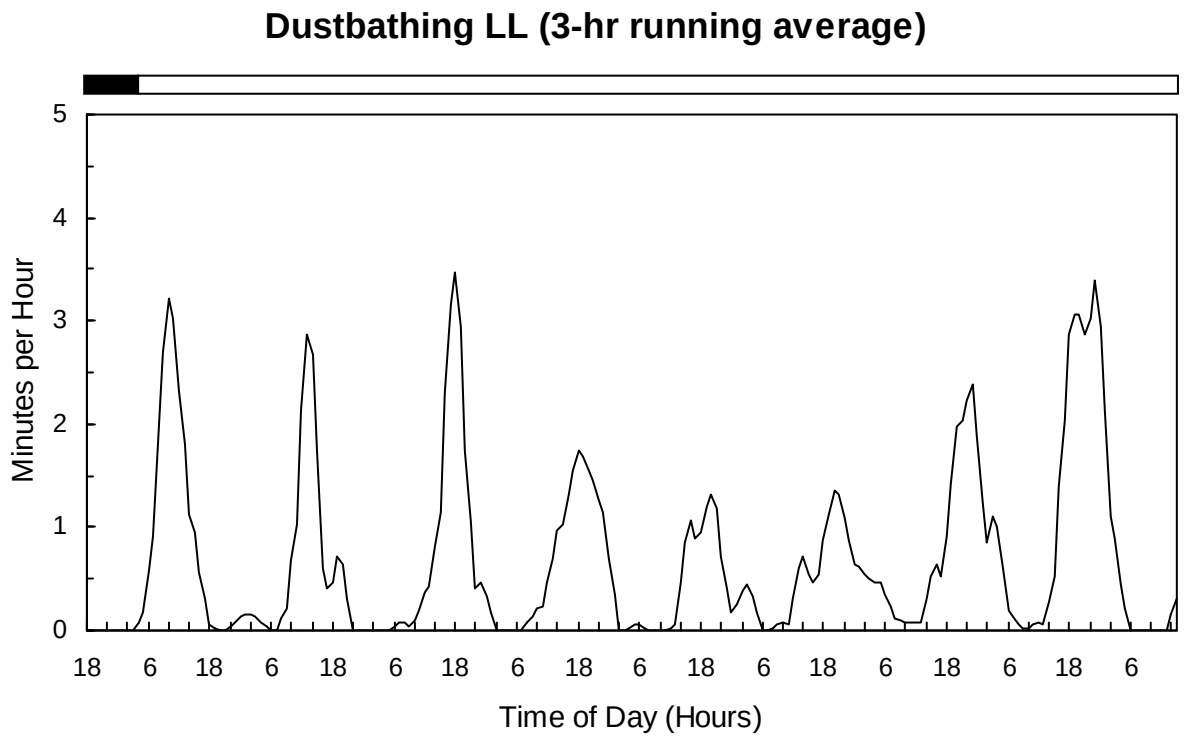

Sleep LL (3-hr running average)
Minutes per hour
60
50
40
30
20
10
0
18
6
18
6
18
6
18
6
18
6
18
6
18
6
18
6
Time of Day (Hours)

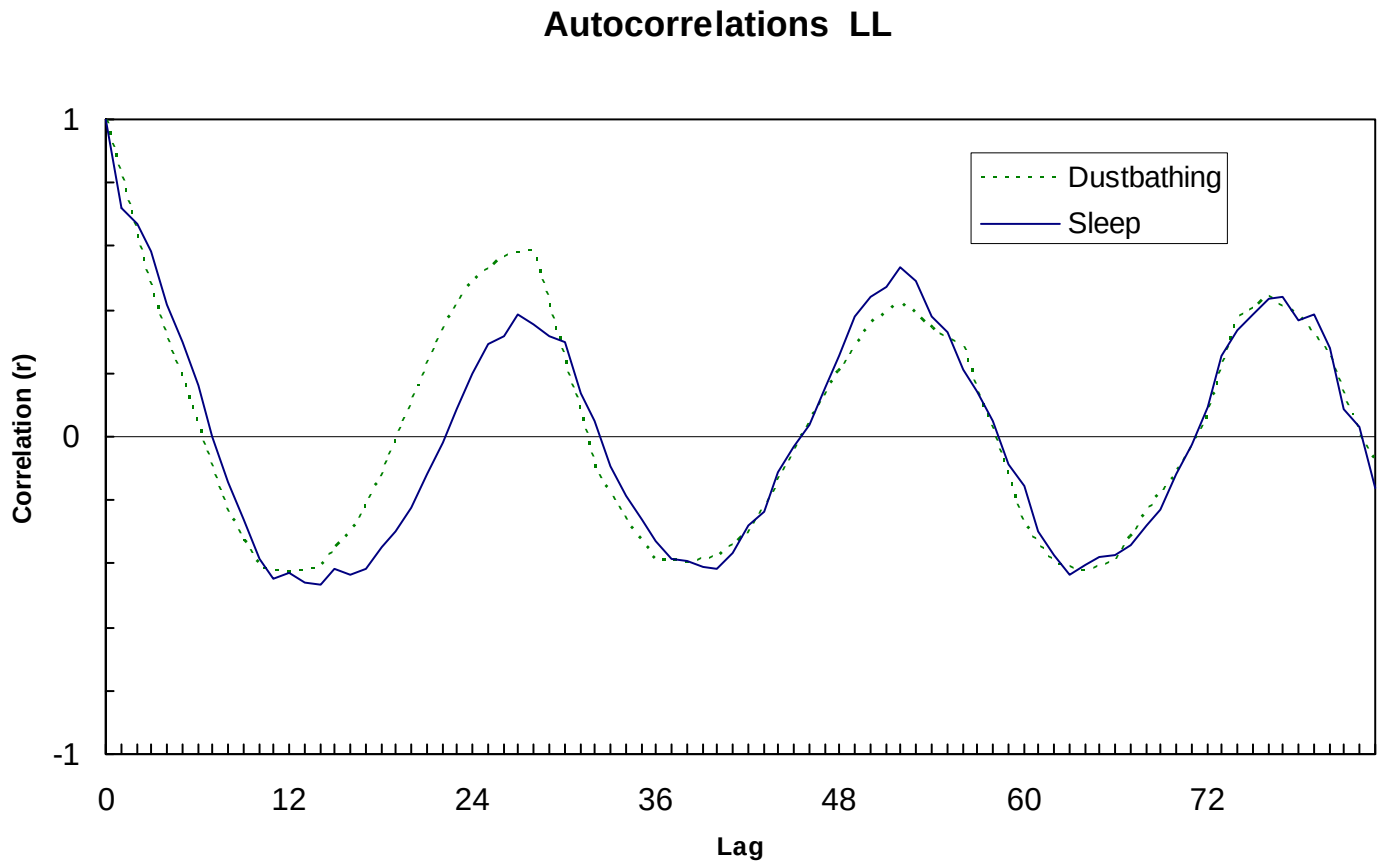


$\tau \approx 25.5$ hr


Individual Sleep LL (3-hr running average)
NE1
SE1
NE2
SW2
NW3
SE3
Minutes per Hour
Time of Day (Hours)
0
10
20
30
40
50
60
18
6


Individual Autocorrelations -- Sleep LL
1
0
-1
Correlation (r)
0
6
12
18
24
30
36
42
48
54
Lag (Hours)
NE1
SE1
NE2
SW2
NW3
SE3


Dustbathing LL (3-hr running average)
Minutes per Hour
0
1
2
3
4
5
18
6
18
6
18
6
18
6
18
6
18
6
18
6
18
6
18
6
Time of Day (Hours)


Autocorrelations LL
1
0
-1
Correlation (r)
0
12
24
36
48
60
72
Lag
Dustbathing
Sleep

Free run experiments: Conclusions

In constant light (LL), feeding, dustbathing, and sleep all show a free-running rhythm with a period of about 25.5 hours. Thus, there is definite circadian control of these behaviors, probably by the same clock.

For feeding and sleep, but not for dustbathing, rhythm damps out after about 6 days.

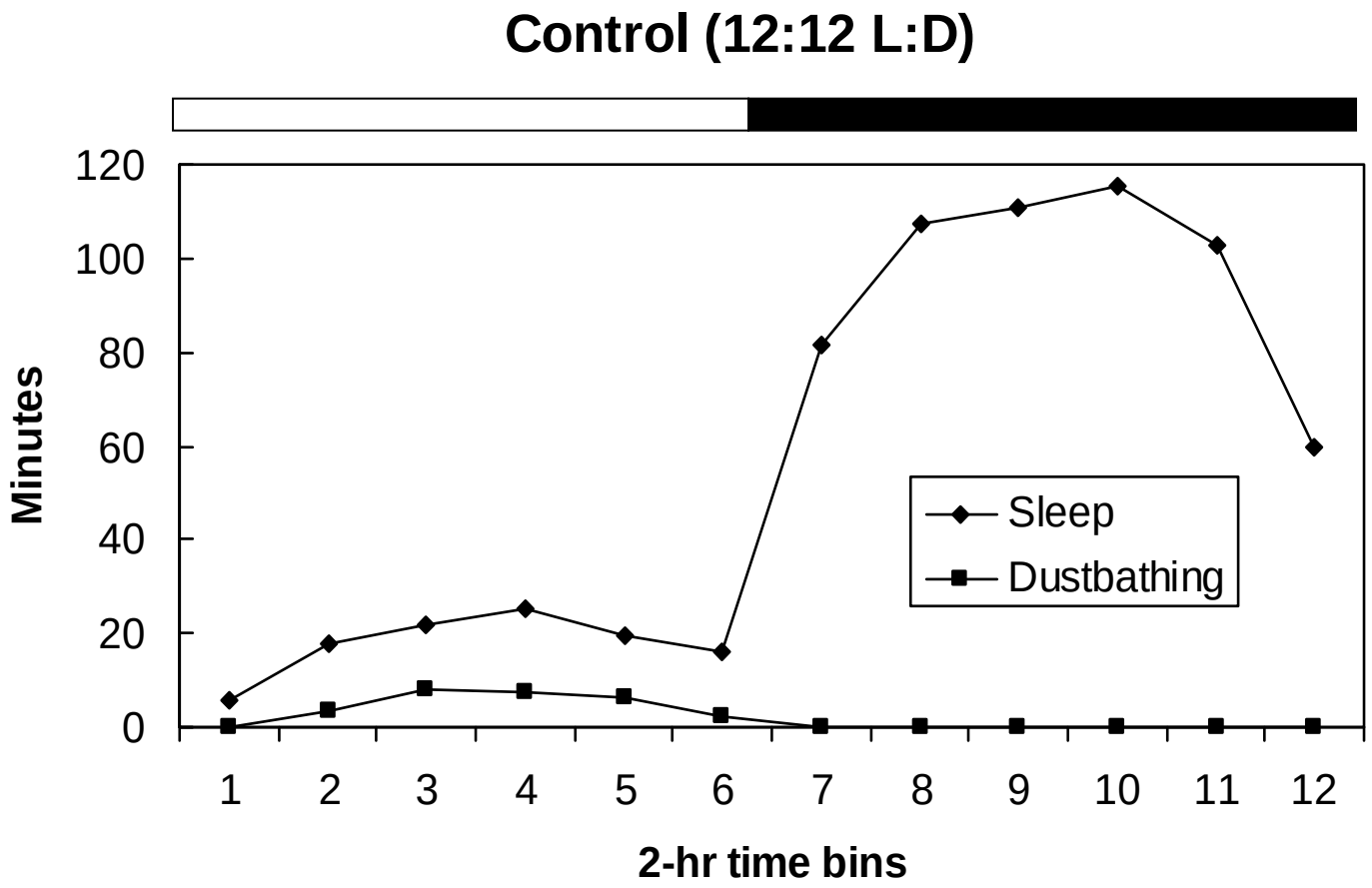
Individual variability greater than averaged variability

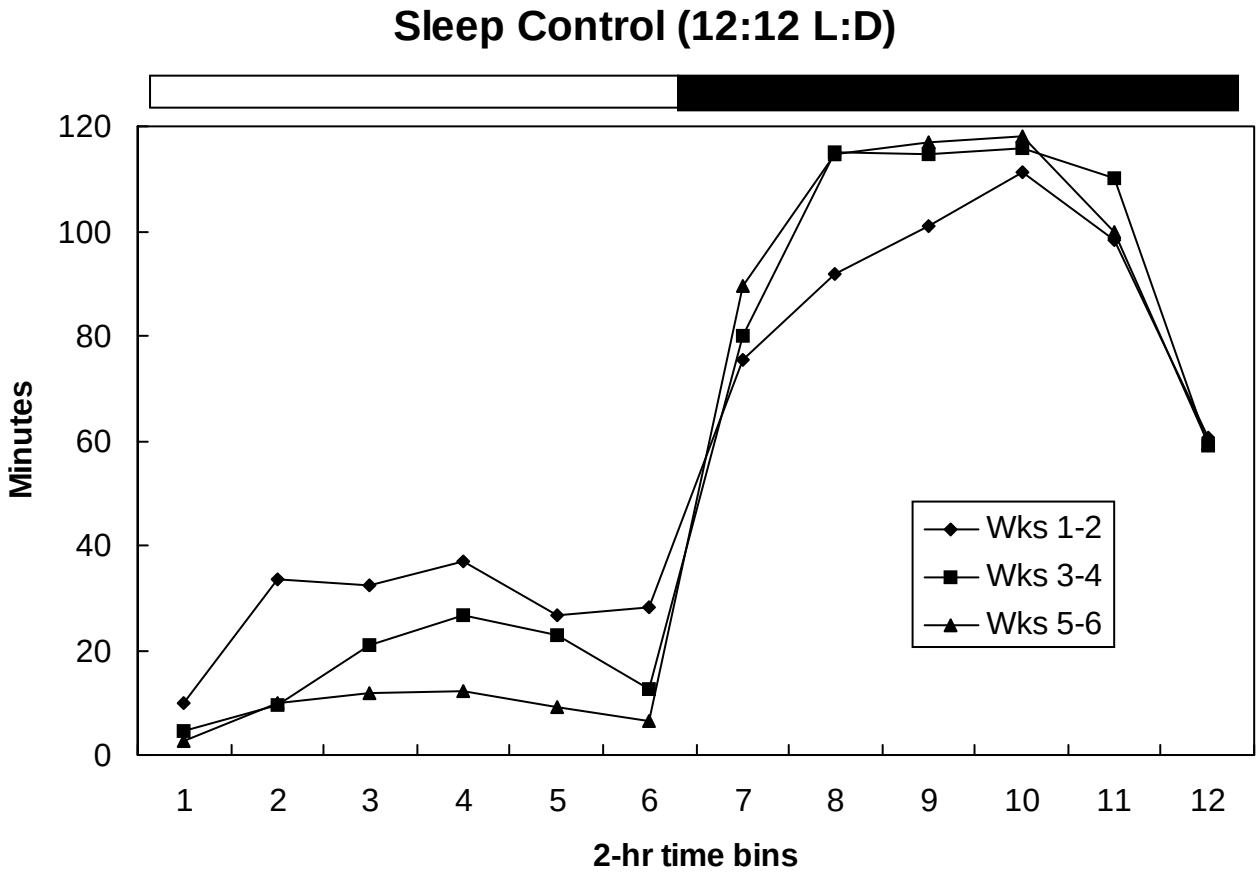
Feeding and sleep seem only “loosely” connected to the circadian system.

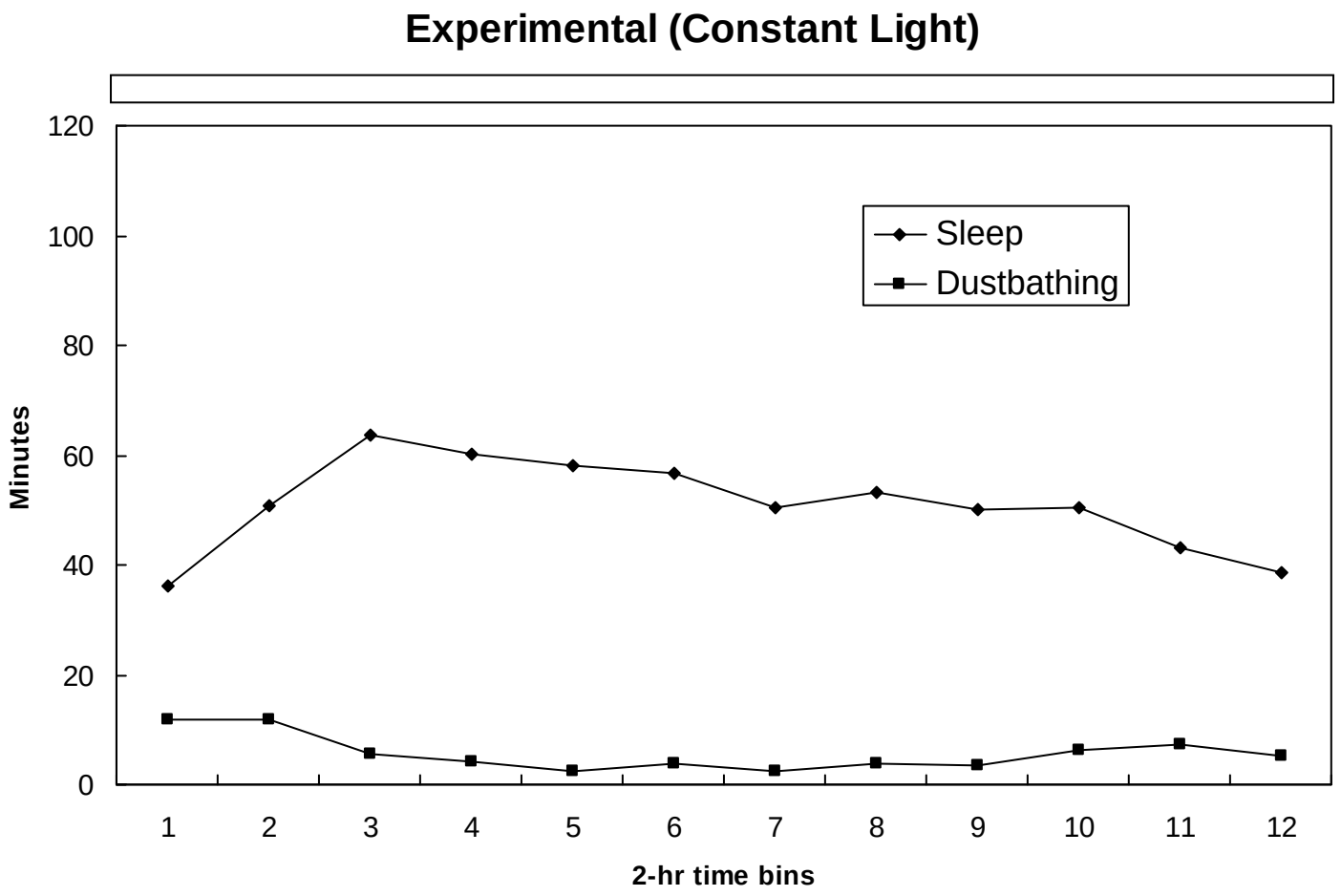
Development of sleep (and dustbathing)

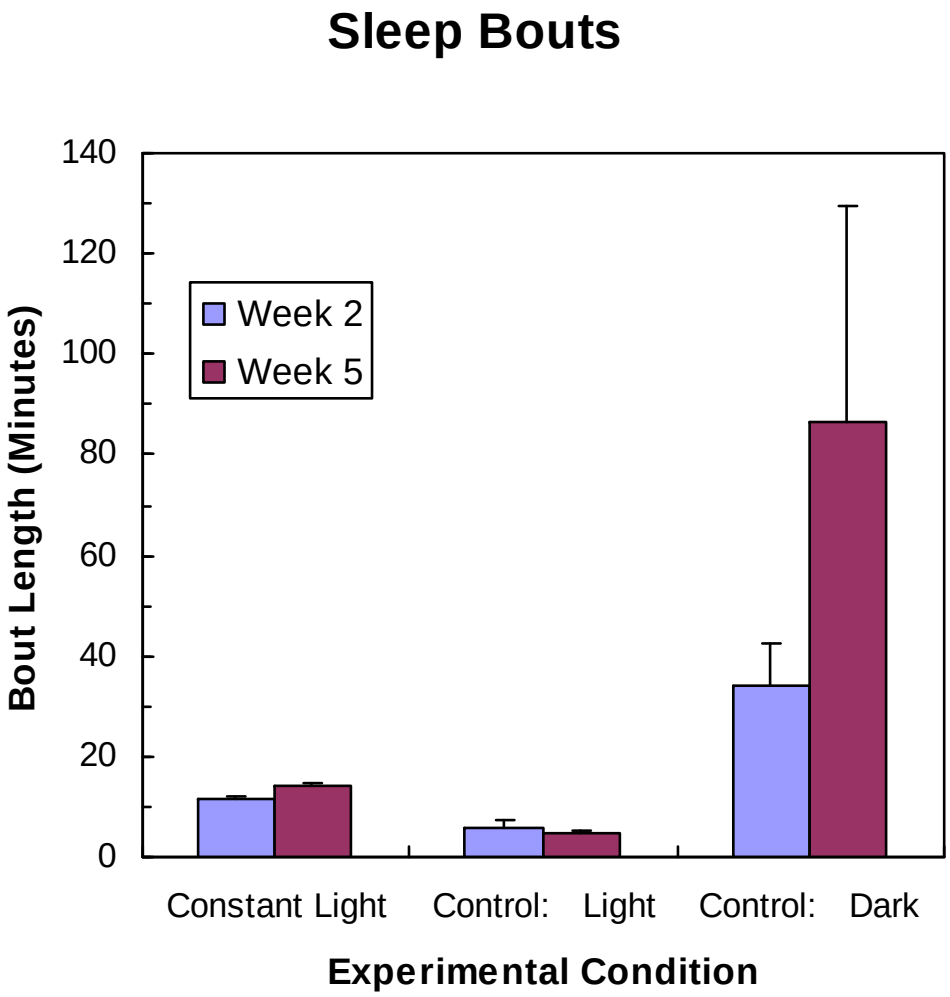
Chicks raised from hatching either under 12:12 L:D conditions (control) or under constant light (LL) conditions (experimental) for 6 weeks.

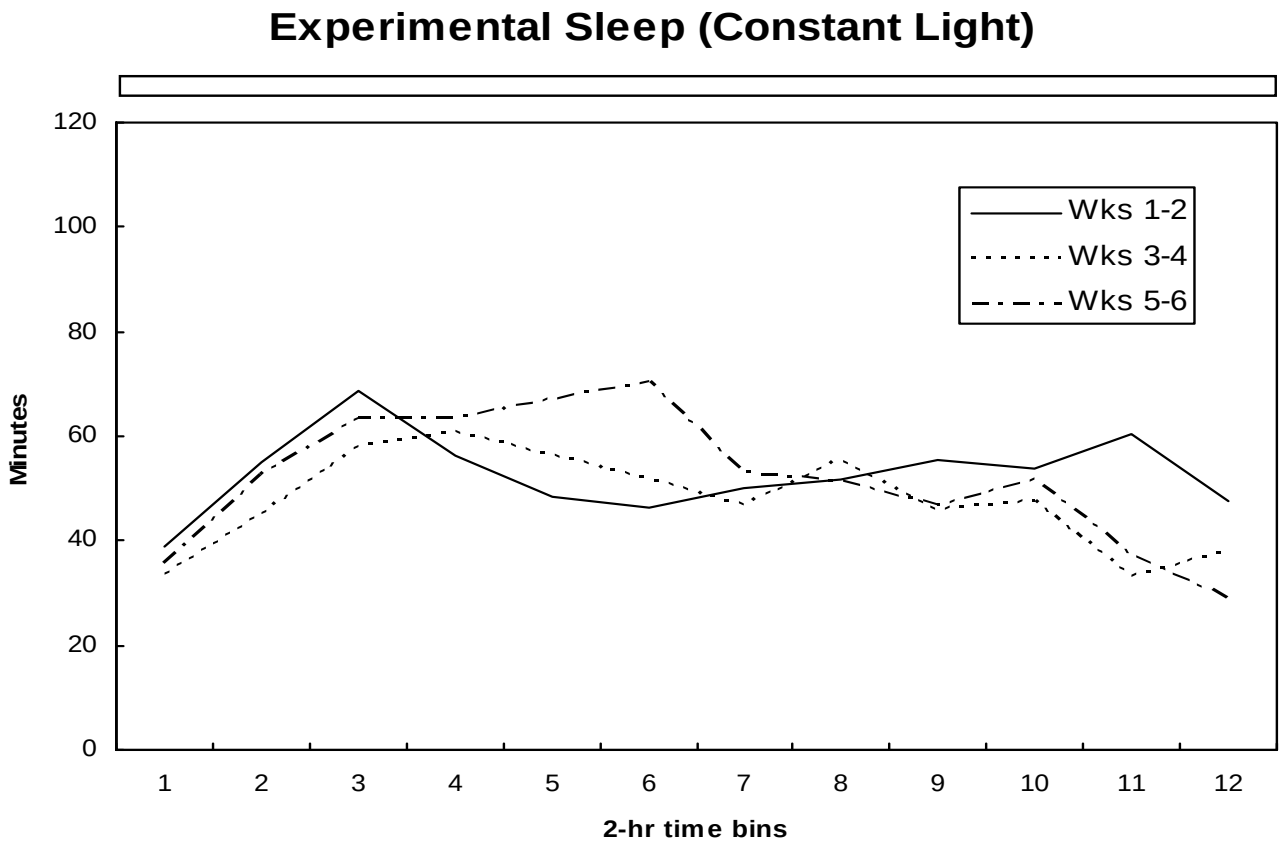
Each chick was monitored, and sleep (and dustbathing) recorded, for 24 hours once each week from video tapes.

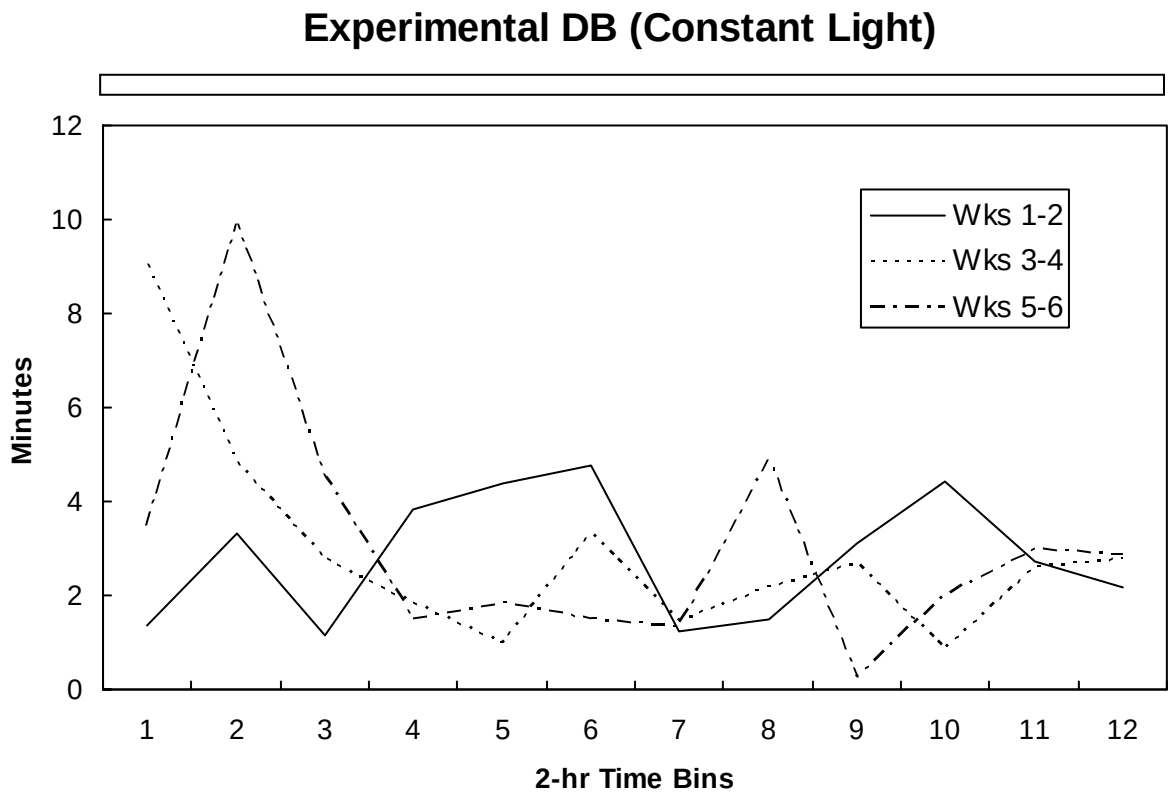

Control (12:12 L:D)
Minutes
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
2-hr time bins
Sleep
Dustbathing


Sleep Control (12:12 L:D)
Minutes
120
100
80
60
40
20
0
1
2
3
4
5
6
7
8
9
10
11
12
2-hr time bins
Wks 1-2
Wks 3-4
Wks 5-6


Experimental (Constant Light)
120
100
80
60
40
20
0
Minutes
Sleep
Dustbathing
1
2
3
4
5
6
7
8
9
10
11
12
2-hr time bins


Sleep Bouts
140
120
100
80
60
40
20
0
Bout Length (Minutes)
Week 2
Week 5
Constant Light
Control: Light
Control: Dark
Experimental Condition


Experimental Sleep (Constant Light)
120
100
80
60
40
20
0
Minutes
1
2
3
4
5
6
7
8
9
10
11
12
2-hr time bins
Wks 1-2
Wks 3-4
Wks 5-6


Experimental DB (Constant Light)
Minutes
0
2
4
6
8
10
12
1
2
3
4
5
6
7
8
9
10
11
12
2-hr Time Bins
Wks 1-2
Wks 3-4
Wks 5-6

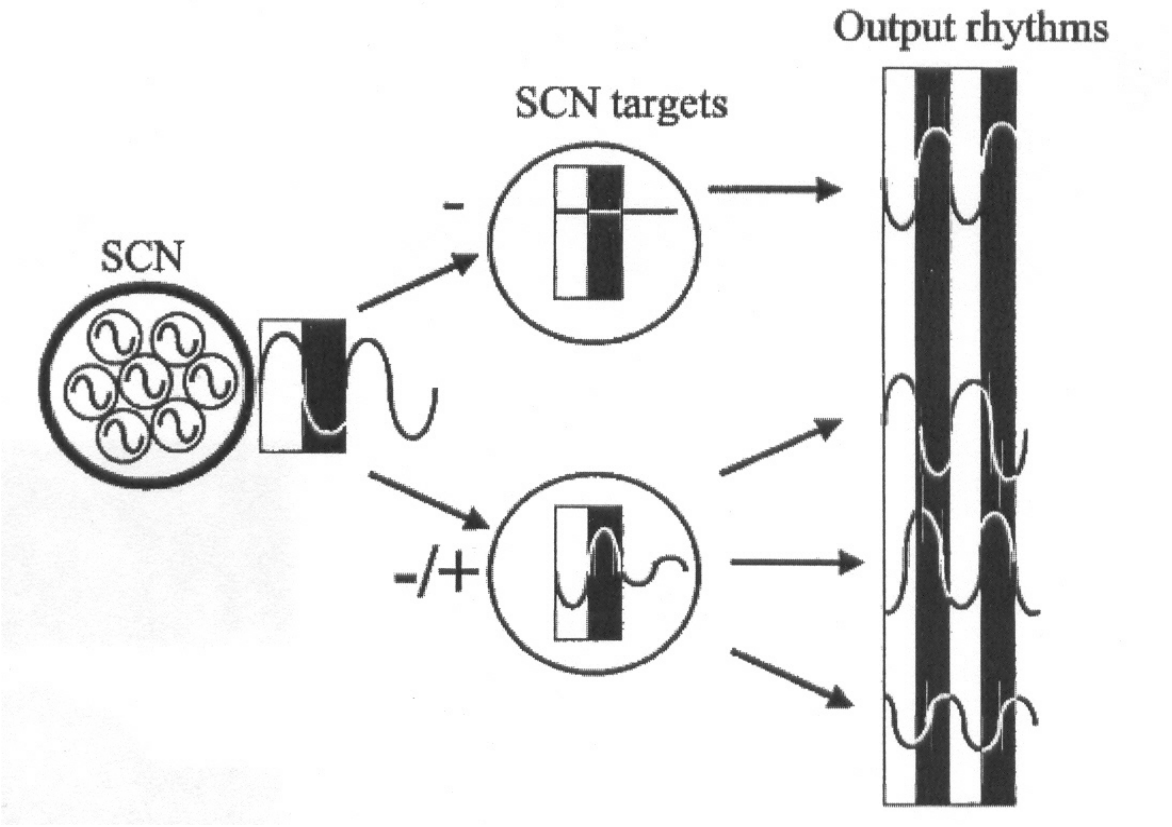
Development experiment: Conclusions

Under 12:12 L:D conditions, chicks sleep primarily during the dark hours from the first week, and this pattern grows stronger with age

Chicks raised under constant light show only weak signs of circadian control of sleep, and sleep in bouts of about 15 minutes throughout the 24-h day

The results suggest that periodic disturbance can entrain the clock, but without a light:dark cycle sleep is controlled primarily by its own specific internal causal factors

Model of organization of mammalian circadian system



Herzog & Schwartz, 2002

Discussion

How does the circadian system control behavior?

What kind(s) of experience is necessary for sleep and feeding to become “attached to” or “detached from” the circadian system?

Why is dustbathing different from sleep and feeding?

How is sleep controlled in humans?

How do normal sleep patterns develop in infants?

What does this all mean?