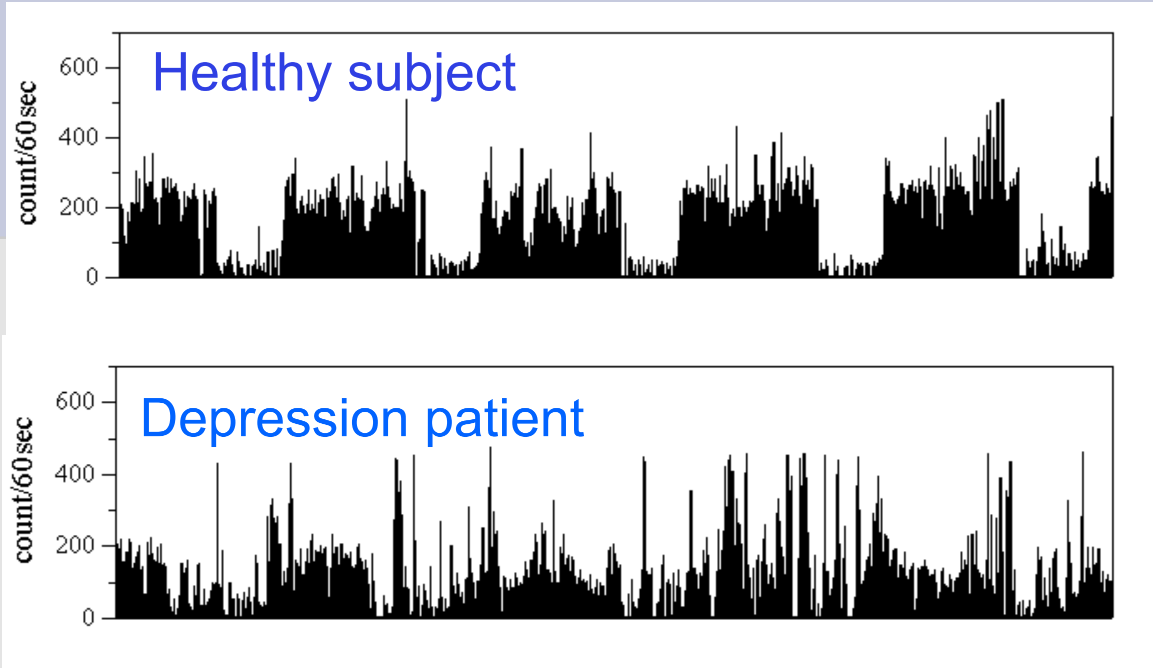
The Origins of Behavioural Organisation in Humans

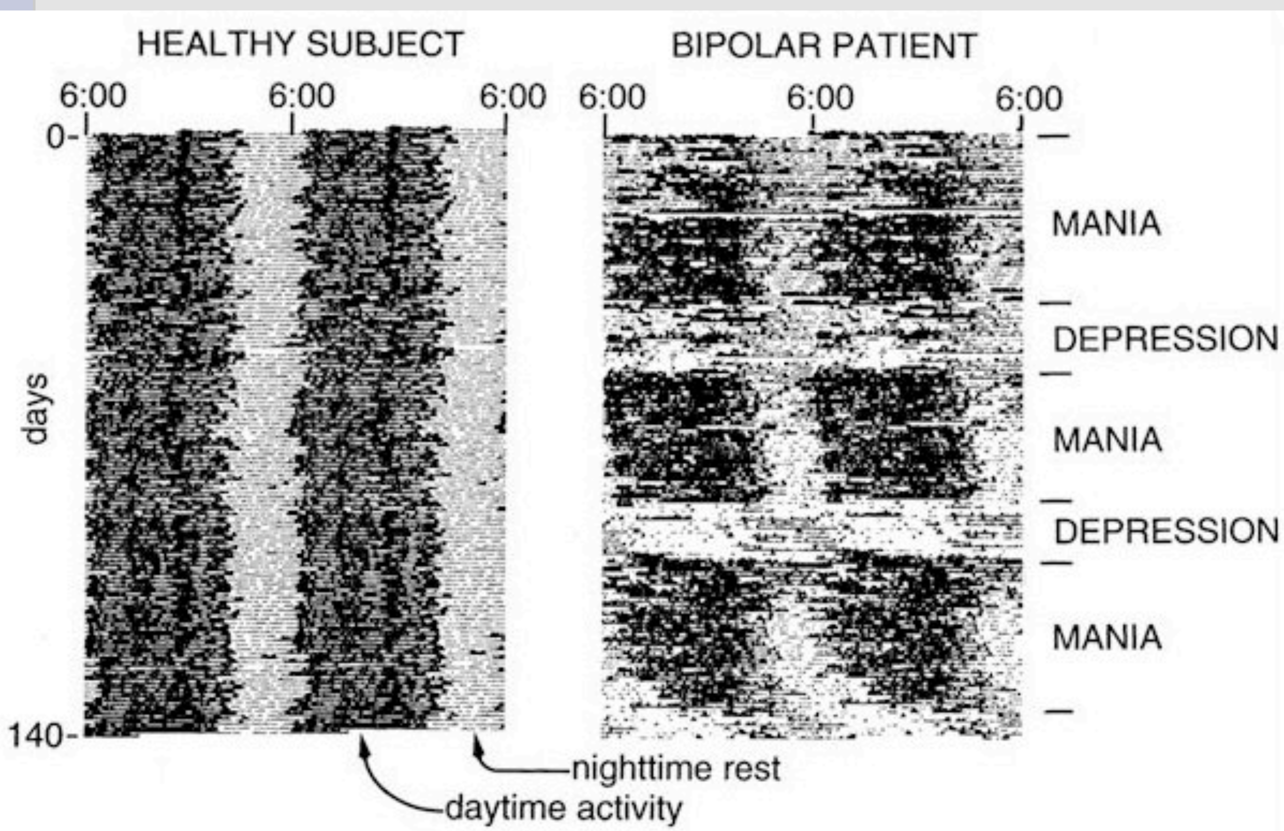
Toru Nakamura
Center for Advanced Medical Engineering and Informatics
Osaka University
Osaka, Japan

Zbigniew R. Struzik
Educational Physiology Lab
Graduate School of Education
Tokyo University
Tokyo, Japan

Yoshiharu Yamamoto
Educational Physiology Lab
Graduate School of Education
Tokyo University
Tokyo, Japan

Physical activity and its alternation in psychiatric and psychosomatic disorders

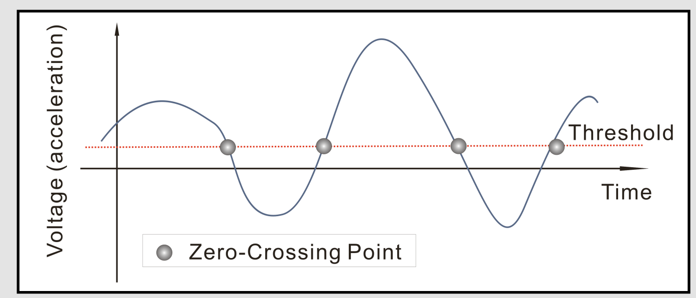




(Kaplan & Sadock's Comprehensive Textbook of Psychiatry, 7th Ed.)

Measurement device

Actigraph Mini-Motionlogger (Ambulatory Monitors Inc., Ardsley, NY)

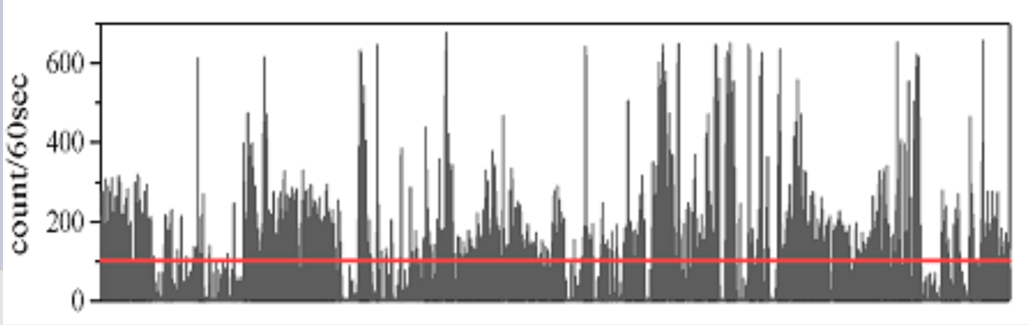


Record the numbers of zero-crossing counts for every specific time-interval

Disorder of Circadian rest-activity rhythm

Depression (Teicher, 1988), Alzheimer (Satlin, 1991)
Seasonal Affective Disorder (SAD) in adults (Glod, 1990), SAD in child (Glod, 1997)

Definition of Resting/Active period durations

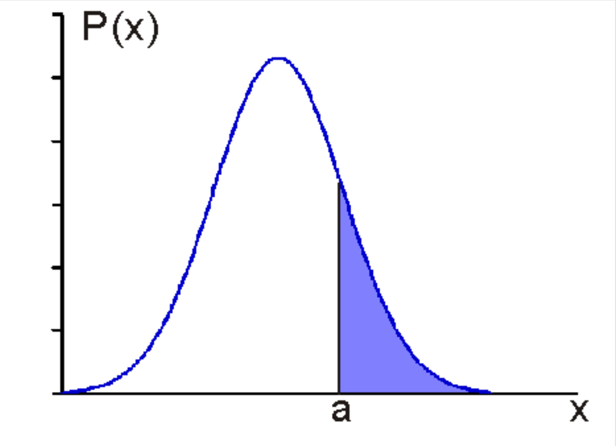


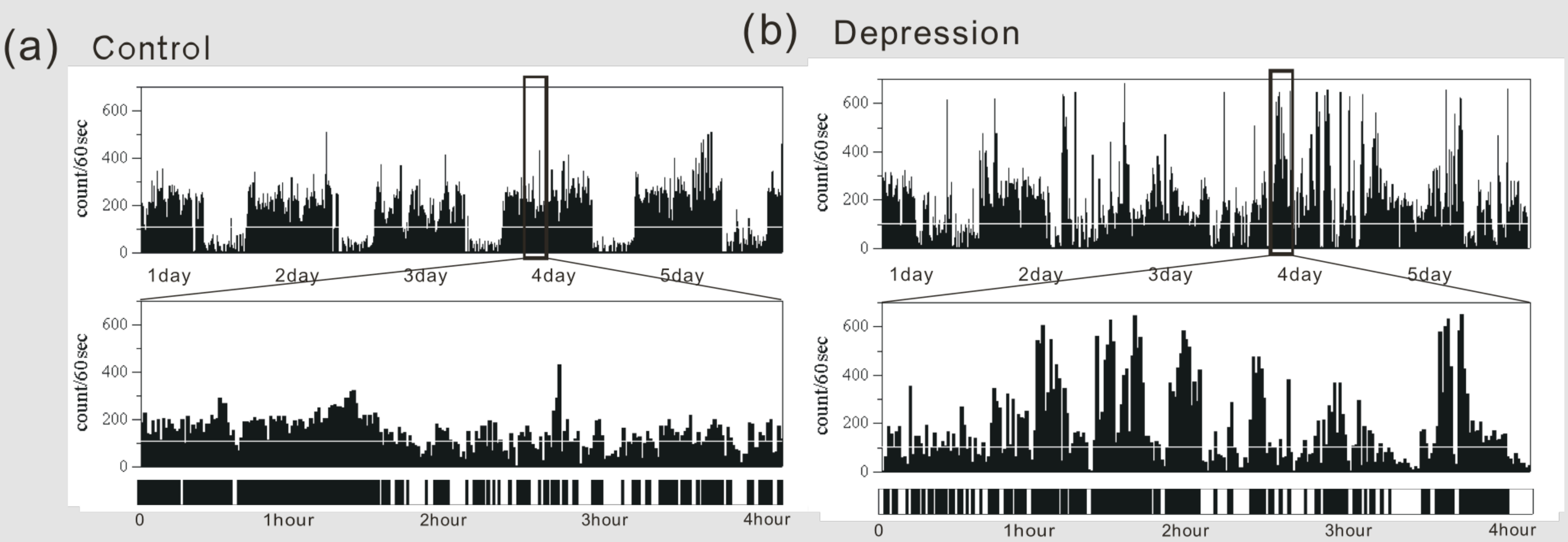
The activity counts are successively
- lower than : Resting period (laminar phase)
- higher than : Active period (burst phase)

a certain predefined threshold value

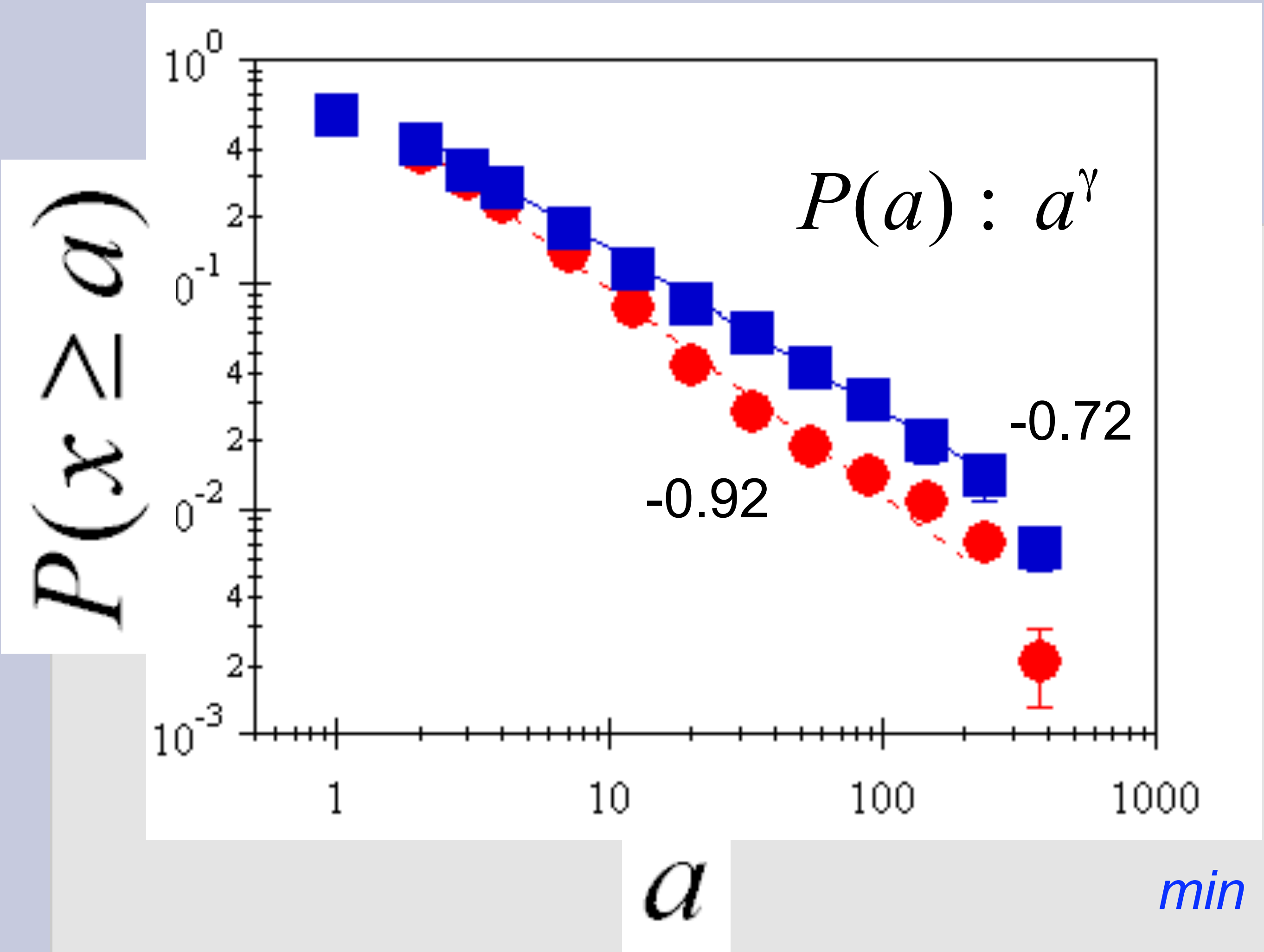
Cumulative Distribution of both resting and active period durations

$$P(x \geq a) = \int_{a}^{+\infty} p(\tau)d\tau$$

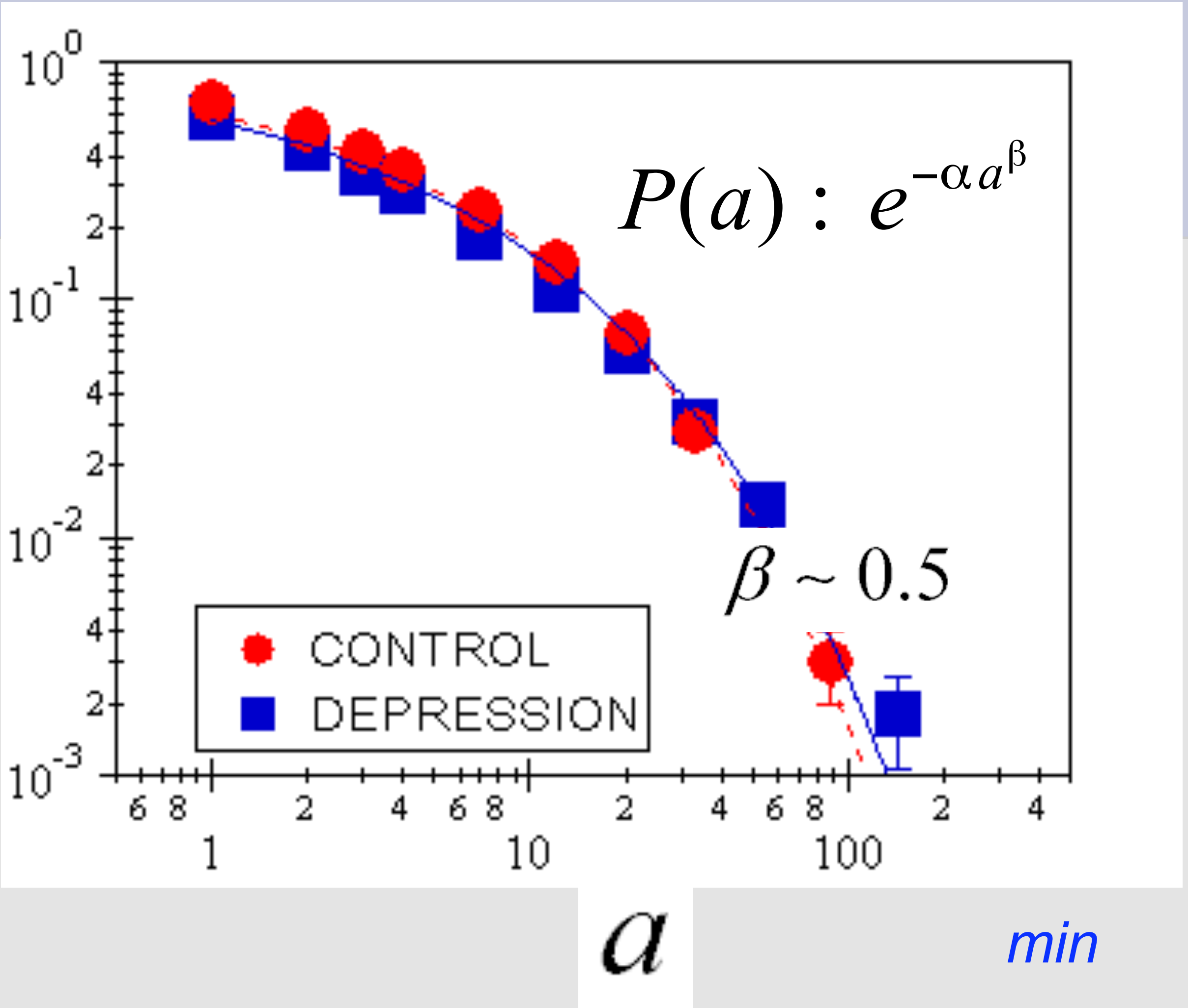




Resting Period



Active Period

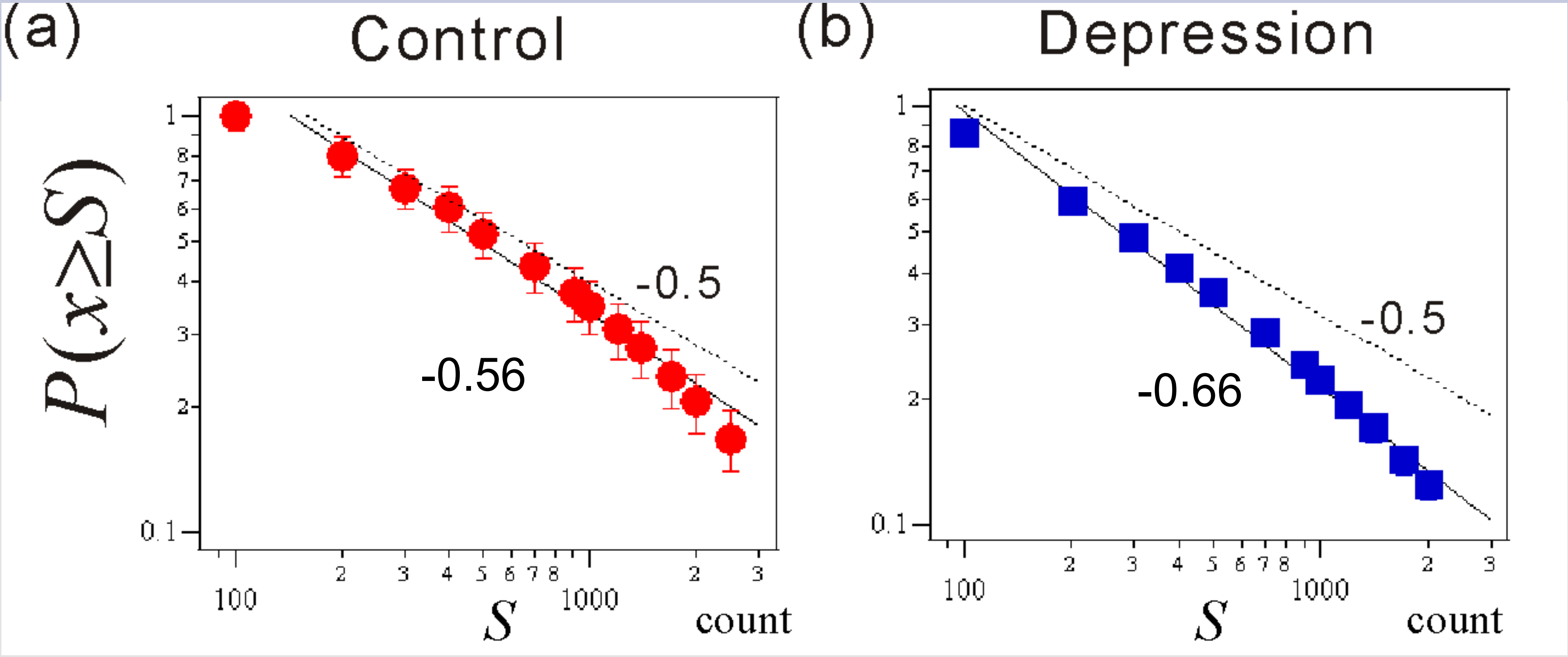


- The resting period distributions take a power law form, with different scaling exponents 0.92 (Control) and 0.72 (Depression) $p<0.0001$

  more episodes of slowing down of movement in the patients

- The active period durations obey a stretched exponential functional form: without significant differences $\beta = 0.53$

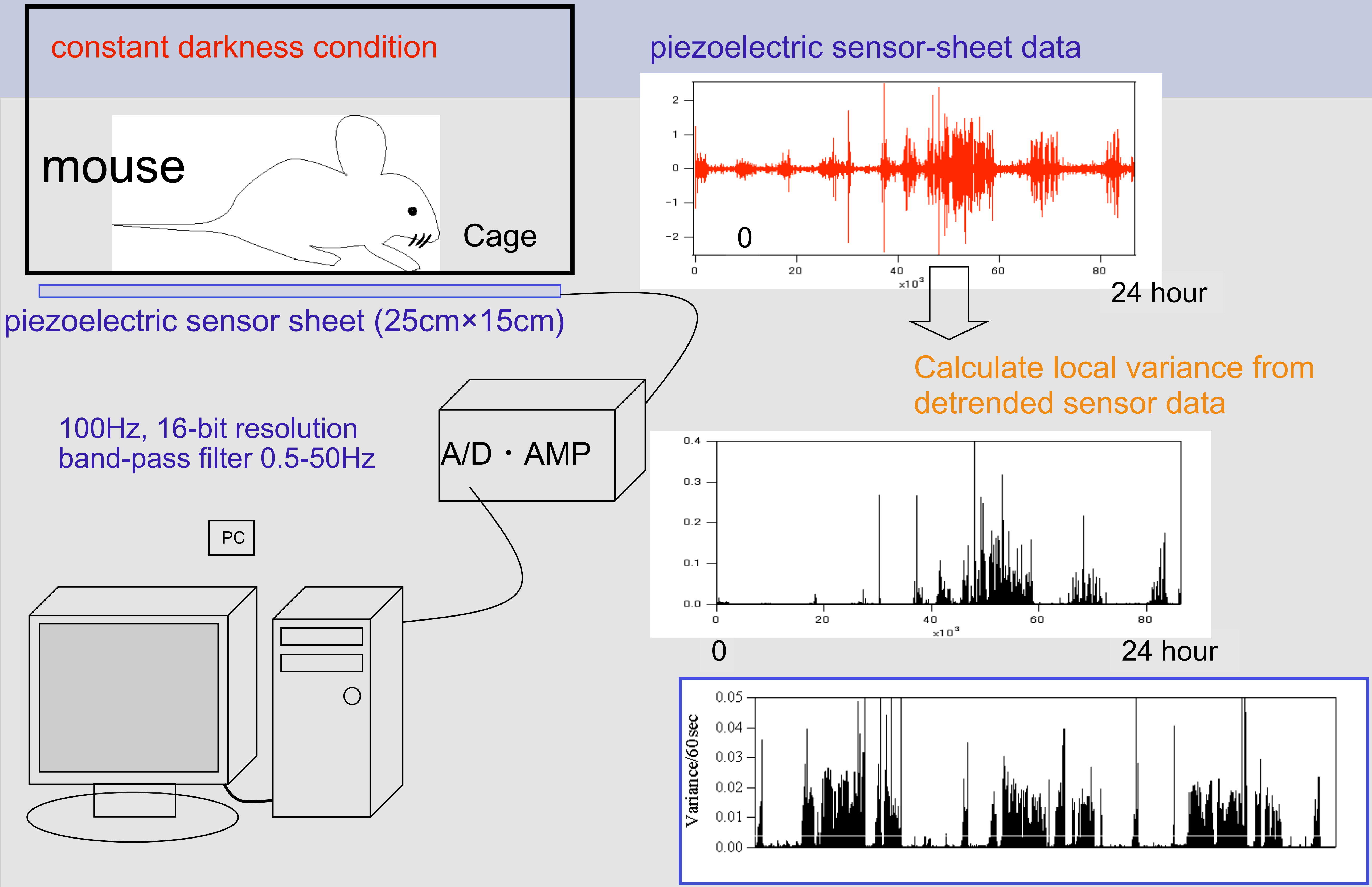
Cumulative Distributions of the burst size



The cumulative distribution of burst size ***S*** takes a power law form

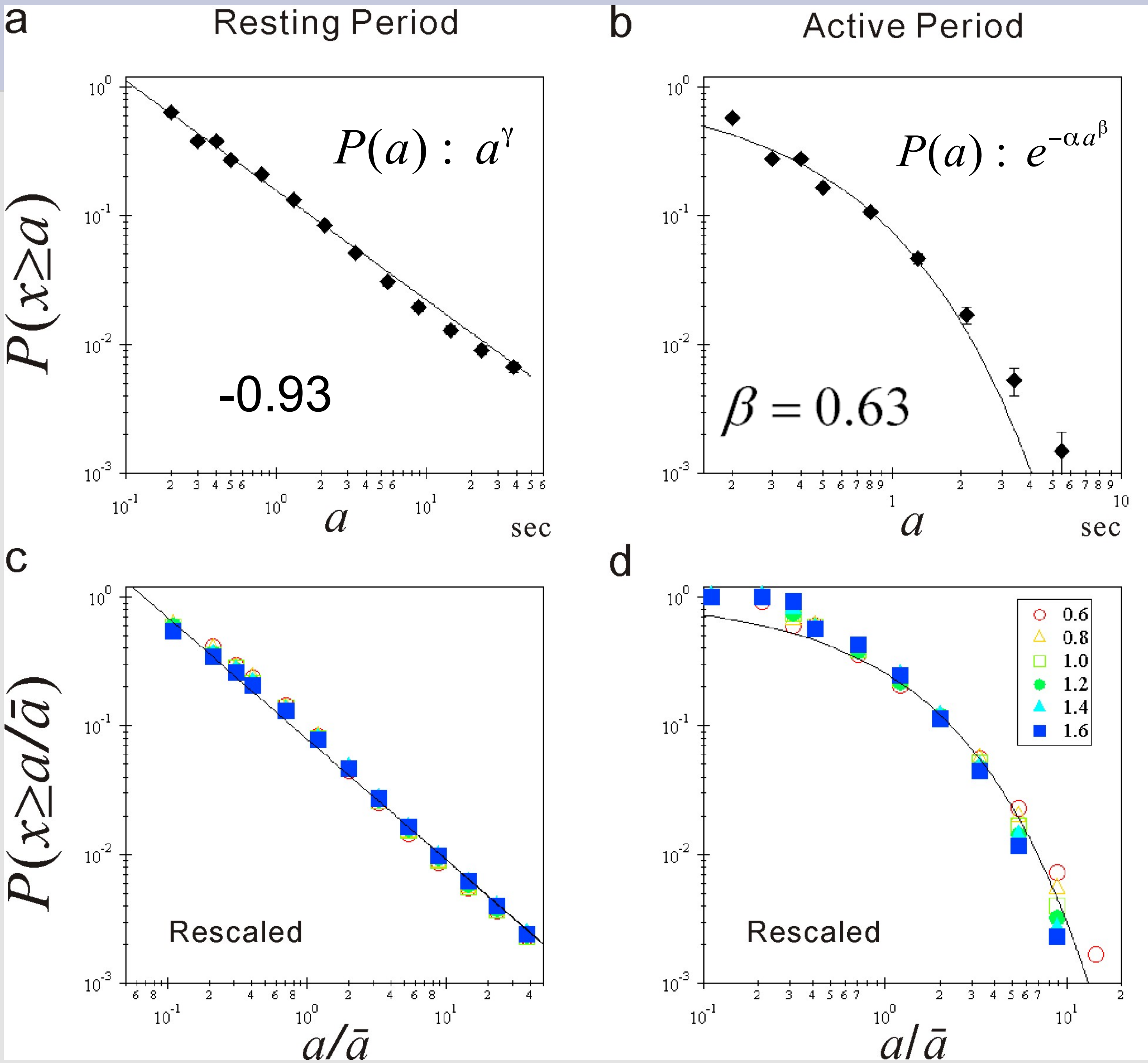
$$P(x \geq S) \sim S^{-0.5}$$

Locomotor activity in mouse

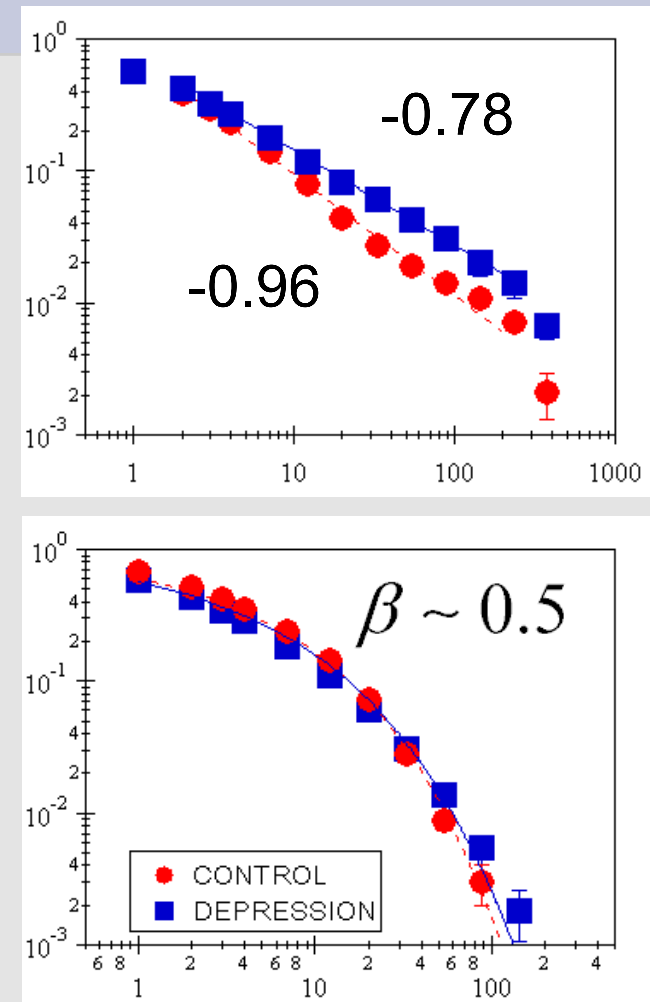


Cumulative Distributions of Resting and Active Periods in Wild-type Mouse

12 Wild-type mice (Male BL6/J) over 3 days



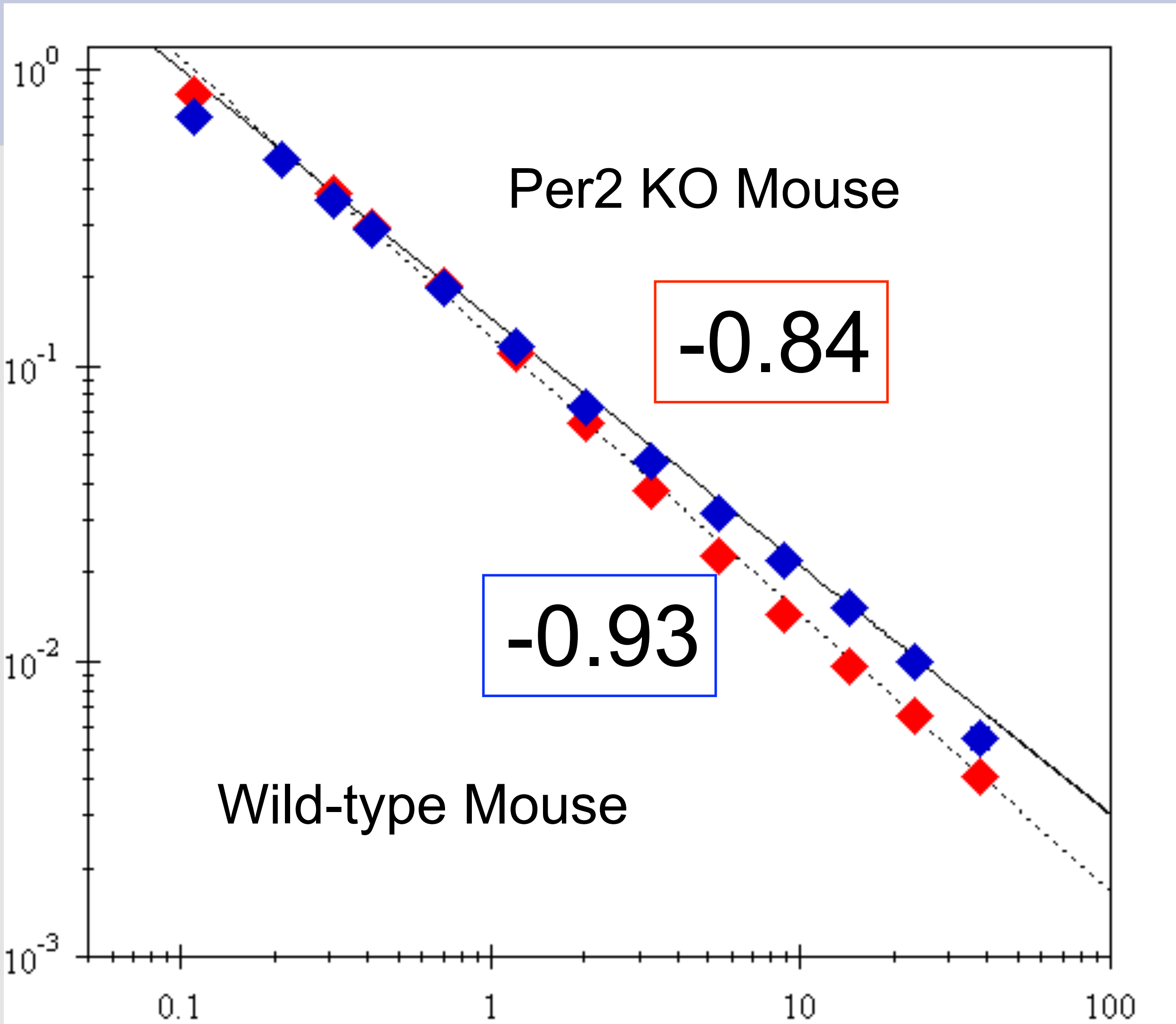
HUMAN



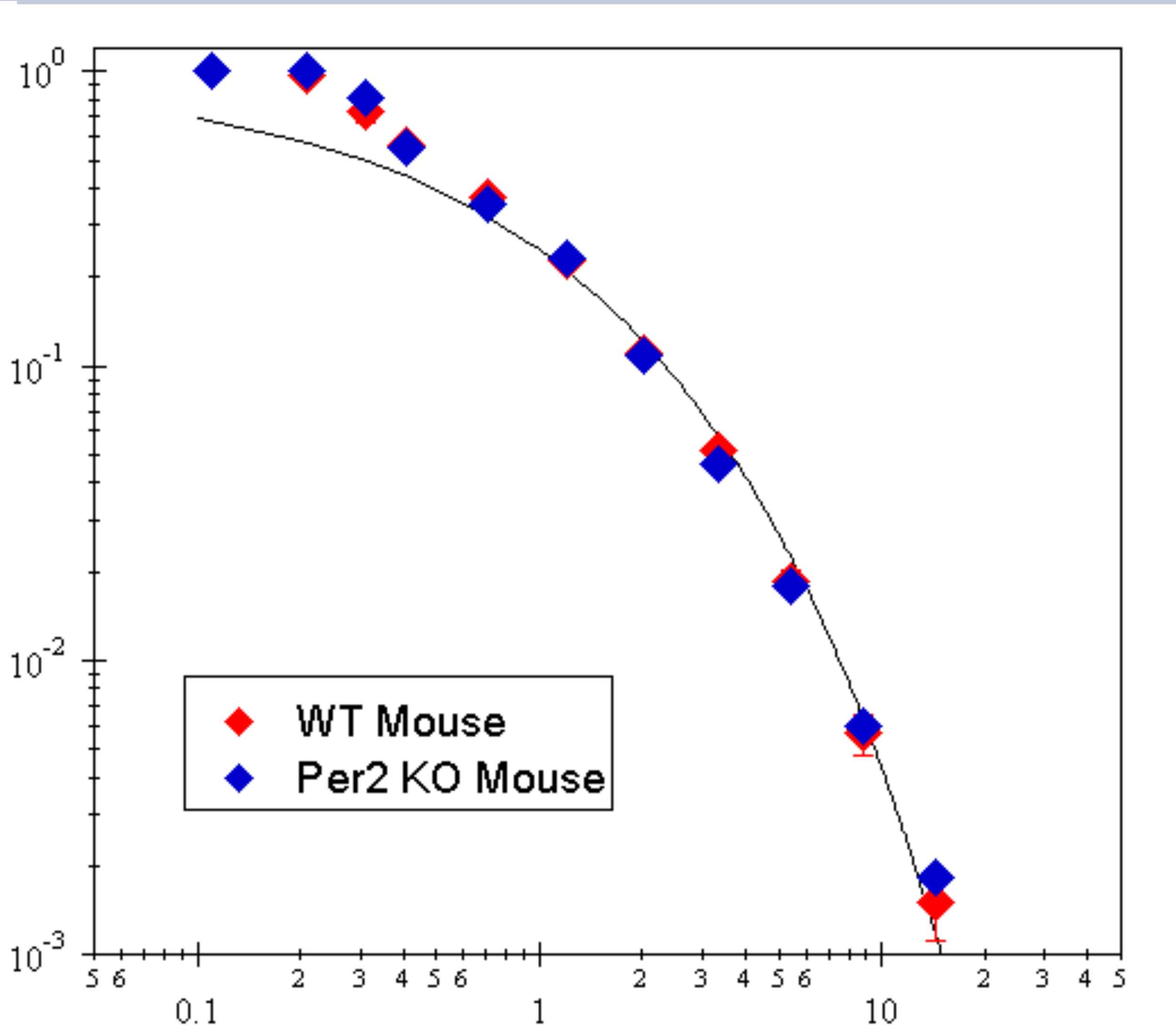
- **The resting period distributions take a power law form**
- **The active period durations obey a stretched exponential functional form**

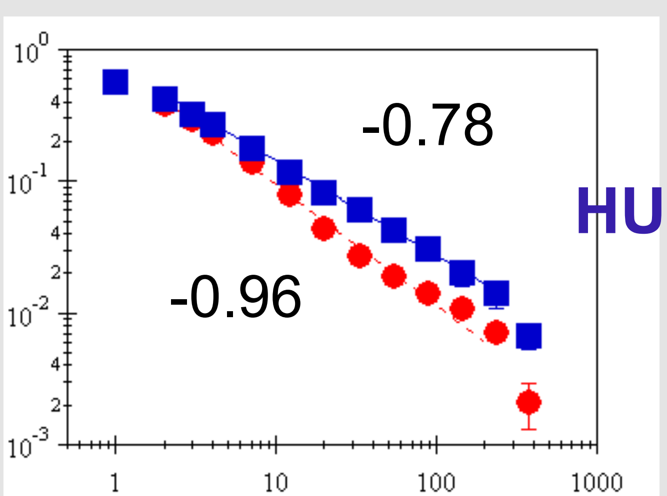
Depressive mice? (Period2 KO Mouse)

Resting Period



Active Period





HUMAN

- New animal model of depression
- Evaluation of effectiveness of medication

A possible interpretation: priority list model

(Barabasi, Nature 2005, Vazquez et al PRE 2006)

Task List

Task 1	x1
Task 2	x2
Task 3	x3
…	…
Task L	xL

A person has a list with L active tasks that he/she must do.

Priority parameter "x" is assigned to each task with a probability density function $\rho(x)$

At each discrete time step, the task in the list with the highest priority is selected with probability p and with probability 1-p another task is selected at random from a distribution: $\prod(x) \sim x^{\gamma}$

Two limit cases can be considered:

- random selection protocol, for p=0 and $\gamma = 0$

and:

- highest priority first selection protocol, p=1, $\gamma = \infty$

$$P(\tau) \sim \tau^{-(1+1/\gamma)}$$

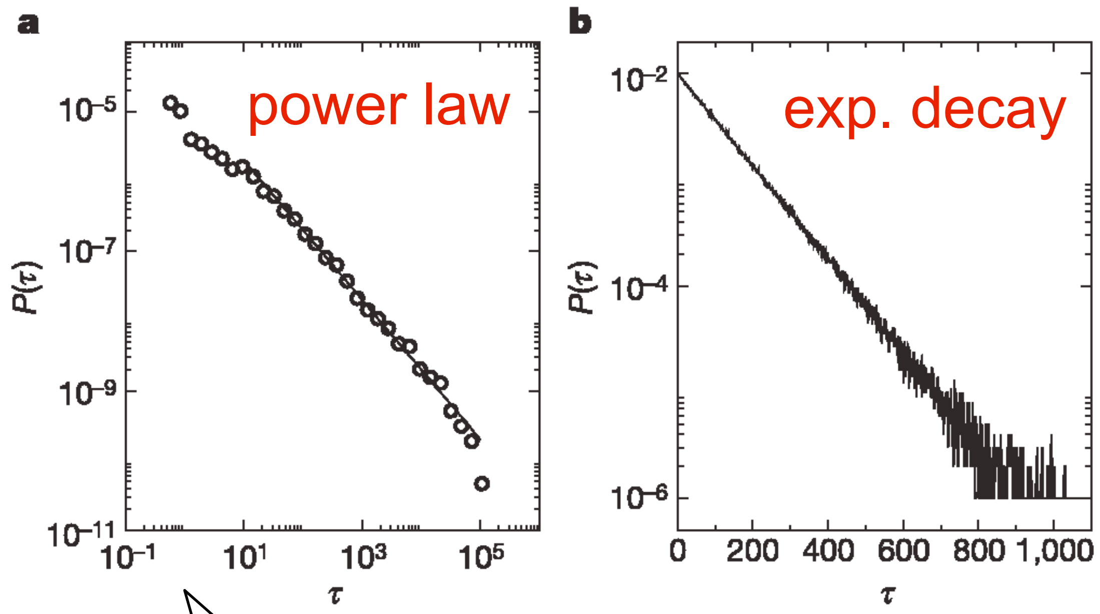
A possible interpretation: priority list model

(Barabasi, Nature 2005, Vazquez et al PRE 2006)

average waiting time: $\tau(x) = \sum_{t=1}^{\infty} t f(x,t) = \frac{1}{\Pi(x)} \approx \frac{1}{x^{\gamma}}$

$$P(\tau) \approx \frac{\rho(\tau^{-1/\gamma})}{\tau^{1+1/\gamma}}$$

analytical formula for P(tau)

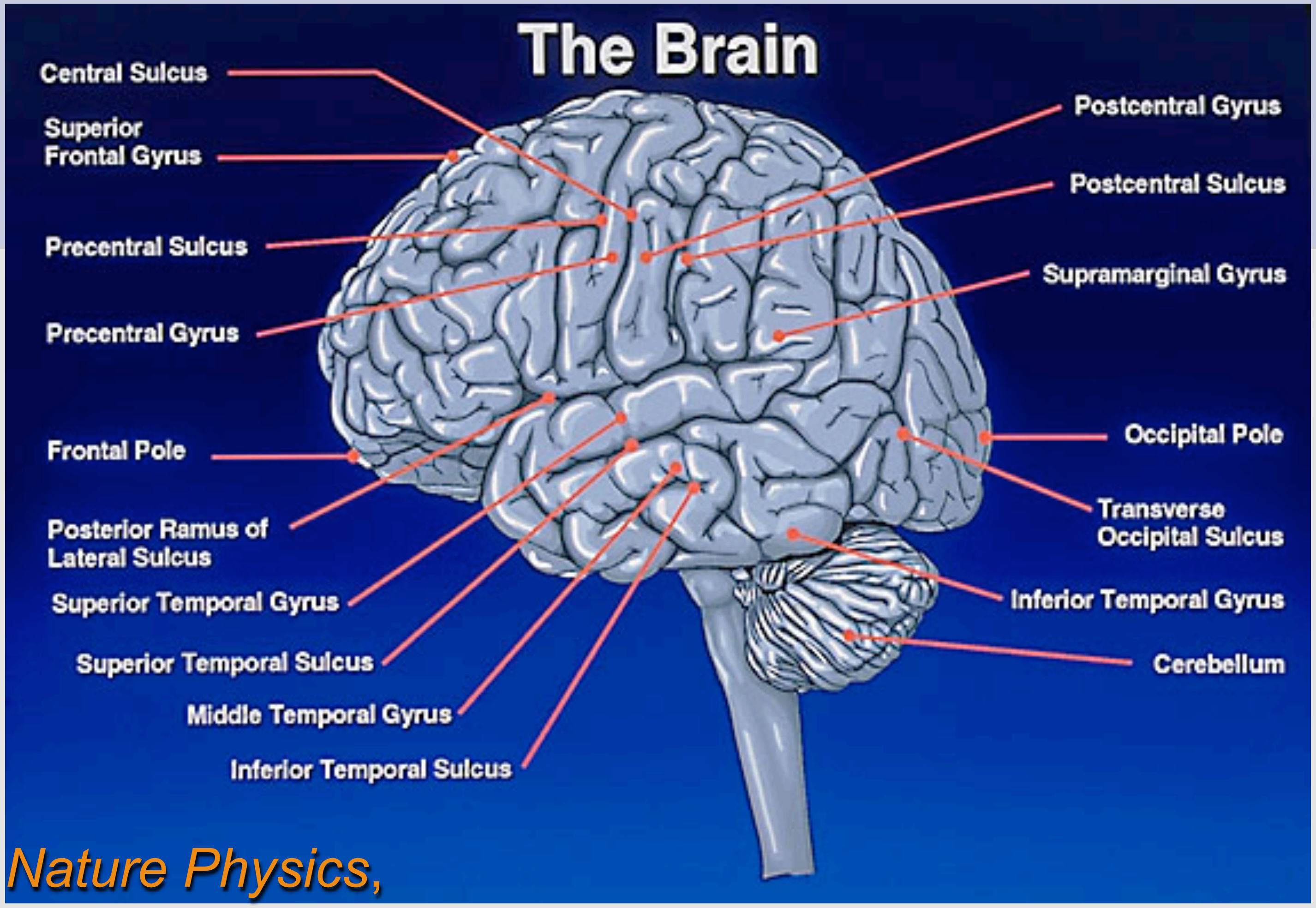


random limit
p=0.00001

deterministic limit
p=0.99999

The waiting time distribution predicted by the investigated queuing model. The priorities were chosen from a uniform distribution $x_i \in [0,1]$, and I monitored a priority list of length $L = 100$ over $T = 10^6$ time steps. **a**, Log–log plot of the tail of probability $P(\tau)$ that a task spends τ time on the list obtained for $p = 0.99999$, corresponding to the deterministic limit of the model. The continuous line of the log–log plot corresponds to the scaling predicted by equation (2), having slope -1, in agreement with the numerical results and the analytical predictions. The data were log-binned, to reduce the uneven statistical fluctuations common in heavy-tailed distributions, a procedure that does not alter the slope of the tail. For the full curve, including the $\tau = 1$ peak, see Supplementary Fig. 3. **b**, Linear-log plot of the $P(\tau)$ distribution for $p = 0.00001$, corresponding to the random choice limit of the model. The fact that the curve follows a straight line on a linear-log plot indicates that $P(\tau)$ decays exponentially.

Alternative hypothesis - critical dynamics in neural circuits of the brain

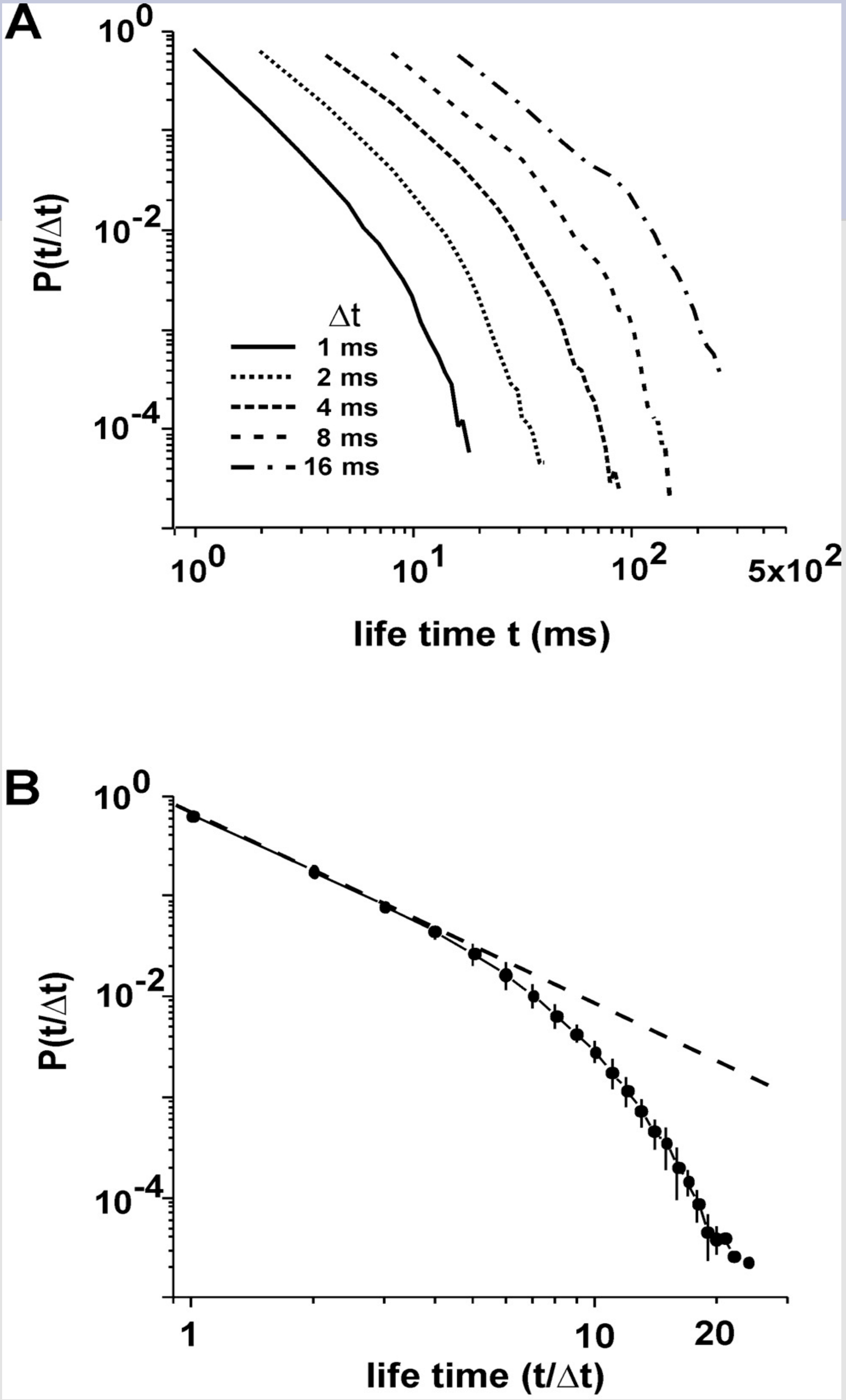


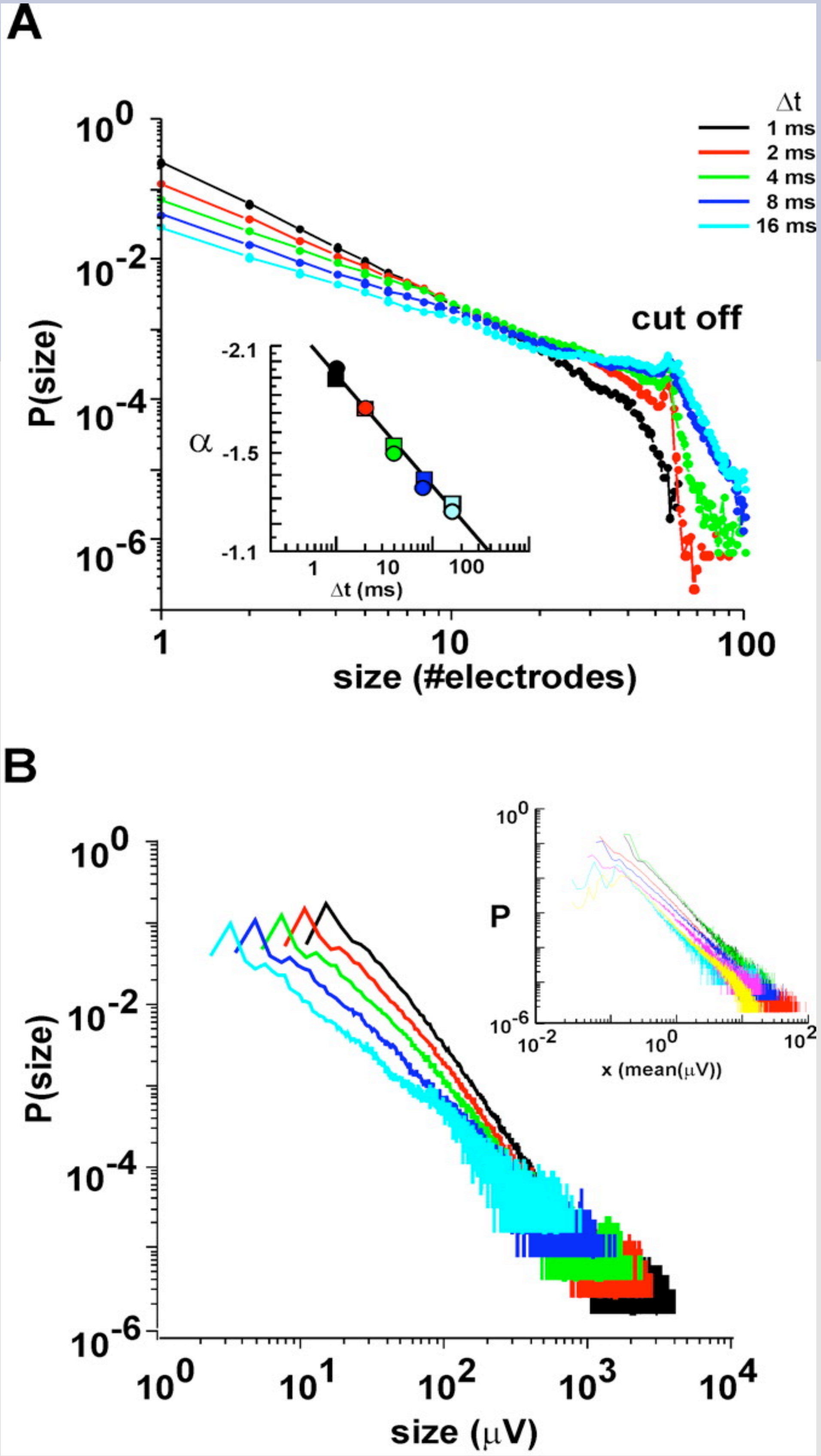
Psychophysics: Are our senses critical?, *Nature Physics*, 2, 301-302 (2006) Dante R. Chialvo

Optimal Dynamical Range of Excitable Networks at Criticality, *Nature Physics*, *2, 348 - 351 (2006)* Osame Kinouchi and Mauro Copelli

Neuronal Avalanches in Neocortical Circuits, *The Journal of Neuroscience*, *23(35),11167-11177 (2003)* John M. Beggs and Dietmar Plenz

Lifetime distributions of avalanches display a power law slope of -2 and exponential cut-off





Size distributions for avalanches follow power laws independently of bin width

Beggs, J. M. et al. J. Neurosci. 2003;23:11167-11177