Do Fruit Flies Have Free Will?

Scientists Measure Spontaneity in Drosophila.

Free will and true spontaneity exist … in fruit flies. This is what scientists report in a groundbreaking study in the May 16, 2007 issue of the open-access journal PLoS One.

"Animals and especially insects are usually seen as complex robots which only respond to external stimuli," says senior author Björn Brembs from the Free University Berlin. They are assumed to be input-output devices. "When scientists observe animals responding differently even to the same external stimuli, they attribute this variability to random errors in a complex brain." Using a combination of automated behavior recording and sophisticated mathematical analyses, the international team of researchers showed for the first time that such variability cannot be due to simple random events but is generated spontaneously and non-randomly by the brain. These results caught computer scientist and lead author Alexander Maye from the University of Hamburg by surprise: "I would have never guessed that simple flies who otherwise keep bouncing off the same window have the capacity for nonrandom spontaneity if given the chance."

The researchers tethered fruit flies (*Drosophila melanogaster)* in completely uniform white surroundings and recorded their turning behavior. In this setup, the flies do not receive any visual cues from the environment and since they are fixed in space, their turning attempts have no effect. Thus lacking any input, their behavior should resemble random noise, similar to a radio tuned between stations. However, the analysis showed that the temporal structure of fly behavior is very different from random noise. The researchers then tested a plethora of increasingly complex random computer models, all of which failed to adequately model fly behavior.

Only after the team analyzed the fly behavior with methods developed by co-authors George Sugihara and Chih-hao Hsieh from the Scripps Institution of Oceanography at UC San Diego did they realize the origin of the fly's peculiar spontaneity. "We found that there must be an evolved function in the fly brain which leads to spontaneous variations in fly behavior" Sugihara said. "The results of our analysis indicate a mechanism which might be common to many other animals and could form the biological foundation for what we experience as free will".

Our subjective notion of "Free Will" is an oxymoron: the term 'will' would not apply if our actions were completely random and it would not be 'free' if they were entirely determined. So if there is free will, it must be somewhere between chance and necessity - which is exactly where fly behavior comes to lie. "The question of whether or not we have free will appears to be posed the wrong way," says Brembs. "Instead, if we ask 'how close to free will are we?' one finds that this is precisely where humans and animals differ".

The next step will be to use genetics to localize and understand the brain circuits responsible for the spontaneous behavior. This step could lead directly to the development of robots with the capacity for spontaneous nonrandom behavior and may help combating disorders leading to compromised spontaneous behavioral variability in humans such as depression, schizophrenia or obsessive compulsive disorder.

The research will appear in the May 16, 2007 issue of the open-access journal PLoS One. *Press embargo in effect until Tuesday, May 15, 5pm pacific time.*

[A multimedia version of this story, with video and illustrations, is available on Björn Brembs' website, at http://brembs.net/spontaneous]

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Manuscript abstract:

Brains are usually described as input/output systems: they transform sensory input into motor output. However, the motor output of brains (behavior) is notoriously variable, even under identical sensory conditions. The question of whether this behavioral variability merely reflects residual deviations due to extrinsic random noise in such otherwise deterministic systems or an intrinsic, adaptive indeterminacy trait is central for the basic understanding of brain function. Instead of random noise, we find a fractal order (resembling Lévy flights) in the temporal structure of spontaneous flight maneuvers in tethered *Drosophila* fruit flies. Lévy-like probabilistic behavior patterns are evolutionarily conserved, suggesting a general neural mechanism underlying spontaneous behavior. *Drosophila* can produce these patterns endogenously, without any external cues. The fly's behavior is controlled by brain circuits which operate as a nonlinear system with unstable dynamics far from equilibrium. These findings suggest that both general models of brain function and autonomous agents ought to include biologically relevant nonlinear, endogenous behavior-initiating mechanisms if they strive to realistically simulate biological brains or out-compete other agents.