Robots learn to share, validating Hamilton's rule (w/ video)

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Small foraging robots used in the experiment supporting Hamil-ton's rule (Image: EPFL/ Alain Herzog)

Using simple robots to simulate genetic evolution over hundreds of generations, Swiss scientists provide quantitative proof of kin selection and shed light on one of the most enduring puzzles in biology: Why do most social animals, including humans, go out of their way to help each other? In next week's issue of the online, open access journal *PLoS Biology,* EPFL robotics professor Dario Floreano teams up with University of Lausanne biologist Laurent Keller to weigh in on the oft-debated question of the evolution of altruism genes.

Altruism, the sacrificing of individual gains for the greater good, appears at first glance to go against the notion of "survival of the fittest." But altruistic gene expression is found in nature and is passed on from one generation to the next. Worker ants, for example, are sterile and make the ultimate altruistic sacrifice by not transmitting their genes at all in order to insure the survival of the queen's genetic makeup. The sacrifice of the individual in order to insure the survival of a relative's genetic code is known as kin selection. In 1964, biologist W.D. Hamilton proposed a precise set of conditions under which altruistic behavior may evolve, now known as Hamilton's rule of kin selection. Here's the gist: If an individual family member shares food with the rest of the family, it reduces his or her personal likelihood of survival but increases the chances of family members passing on their genes, many of which are common to the entire family. Hamilton's rule simply states that whether or not an organism shares its food with another depends on its genetic closeness (how many genes it shares) with the other organism.

Testing the evolution of altruism using quantitative studies in live organisms has been largely impossible because experiments need to span hundreds of generations and there are too many variables. However, Floreano's robots evolve rapidly using simulated gene and genome functions and allow scientists to measure the costs and benefits associated with the trait. Additionally, Hamilton's rule has long been a subject of much debate be-cause its equation seems too simple to be true. "This study mirrors Hamilton's rule re-markably well to explain when an altruistic gene is passed on from one generation to the next, and when it is not," says Keller.

Previous experiments by Floreano and Keller showed that foraging robots doing simple tasks, such as pushing seed-like objects across the floor to a destination, evolve over multiple generations. Those robots not able to push the seeds to the correct location are selected out and cannot pass on their code, while robots that perform comparatively better see their code reproduced, mutated, and recombined with that of other robots into the next generation - a minimal model of natural selection. The new study by EPFL and UNIL researchers adds a novel dimension:

once a foraging robot pushes a seed to the proper destination, it can decide whether it wants to share it or not. Evolutionary experiments lasting 500 generations were repeated for several scenarios of altruistic interaction - how much is shared and to what cost for the individual - and of genetic relatedness in the population. The researchers created groups of relatedness that, in the robot world, would be the equivalent of complete clones, siblings, cousins and non-relatives. The groups that shared along the lines of Hamilton's rule foraged better and passed their code onto the next generation.

The quantitative results matched surprisingly well the predictions of Hamilton's rule even in the presence of multiple interactions. Hamilton's original theory takes a limited and isolated vision of gene interaction into account, whereas the genetic simulations run in the foraging robots integrate effects of one gene on multiple other genes with Hamilton's rule still holding true. The findings are already proving useful in swarm robotics. "We have been able to take this experiment and extract an algorithm that we can use to evolve cooperation in any type of robot," explains Floreano. "We are using this altruism algo-rithm to improve the control system of our flying robots and we see that it allows them to effectively collaborate and fly in swarm formation more successfully."

More information: Waibel M, Floreano D, Keller L (2011) A Quantitative Test of Hamilton's Rule for the Evolution of Altruism. PLoS Biol 9(5): e1000615. doi:10.1371/journal.pbio.1000615

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