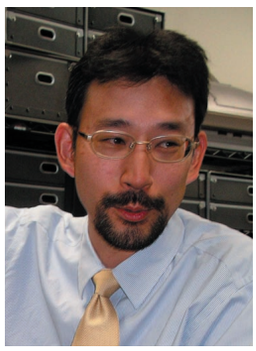
"Even a Pill bug Can Think?!"

For the past three years, NII has been engaged in a study comparing the behaviors of human beings and pill bugs. This study, begun originally as a collaborative effort with Shinshu University and other institutions, is interesting, because it may overturn the commonly held assumption that intellectual behavior is a product of the highly developed brain. We discussed many things with Nobuhiro Furuyama, associate professor of the Information and Society Research Division, about the most recent developments in this collaborative project.



Nobuhiro Furuyama
Associate Professor,
Information and Society Research Division, NII

Are pill bugs intelligent? Few people would answer in the affirmative. But what makes people so reluctant to say, "yes"? When we do something, we make a plan, and, during and/or after executing the plan, verify the performance to see whether the plan was appropriate, whether the action was performed as planned, etc. If there were unexpected troubles with any of the processes, we attempted to revise the plan to make the behavior better suited to the requirement. The ability to adapt to the environment is a hallmark of intelligence, and it is the brain that plays the central role in the process, or so it was assumed for a long time (Fig. 1). In contrast, the behavior of the pill bug has been considered to be mechanical because the creature does not have the brain or its equivalent. For example, if a pill bug initially turns right when it encounters an obstacle, it would turn left when it encounters the next obstacle. This behavioral pattern, known as the "turn alternation," has been considered "mechanical," not intelligent; that is, the pill bugs simply follow their instinct, which happens to be the simplest, yet one of the most efficient ways to escape from enemies.

Breaking the Spell: Intelligence as a product of the brain.

"We strongly believe that human beings are always intellectual," says Furuyama. With psychology as his background, he has conducted research on the human body. He has examined whether it is correct to think that the brain alone controls all human behavior. Meanwhile, in ethology, certain species of animals have long been thought to act only mechanically even though there has not been much basis for this conclusion. The two assumptions, one for humans and the other for pill bugs, are actually two sides of the same coin. This realization opened up the possibility to conduct collaborative research to compare the behaviors of humans and pill bugs. Mr. Furuyama, Hiroyuki Mishima, Associate Professor of Waseda University, and Shin Maruyama, Project Researcher at NII, are in charge of the human behavioral side, and Tohru Moriyama, Assistant Professor of the Young Researcher Empowerment Project at Shinshu University, and Masao Migita, Associate Professor at Shiga University are in charge of the behaviors of pill bugs.

To determine their latent capabilities, Moriyama and Migita put the pill bugs in a specially designed circular corridor. Since both sides of the corridor were filled with water, the pill bugs had to escape from the water so they did not drown in it. As they move along the corridor, however, they come across projections like stepping stones. Since the pill bugs do not like dry environments either, and usually do not turn upward and climb onto projections, they also had to escape the projections. In an environment like this, the pill bugs initially exhibited turn alternation to avoid both obstacles (the water and the projections) (Fig. 2). However, as they kept avoiding the obstacles endlessly for nothing in the circular corridor, some of them started climbing up onto the projections, and swung their antennae to and fro, apparently exploring upward to see if there was a place to escape. Moriyama and Migita found this behavior very intriguing, and thought, "Maybe, pill bugs can think!"

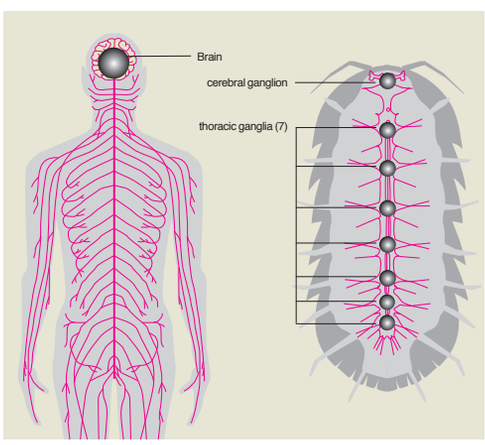


Fig. 1 Nervous System of Human Beings and Pill bugs
A highly-developed brain serves as the center of the nervous system in a human being. Conversely, in a pill bug, the neural ganglia in each section of the thorax (which is divided into seven parts) exerts independent control over the different body parts. The ganglion in the head is not the center, but merely serves to regulate overall balancing.

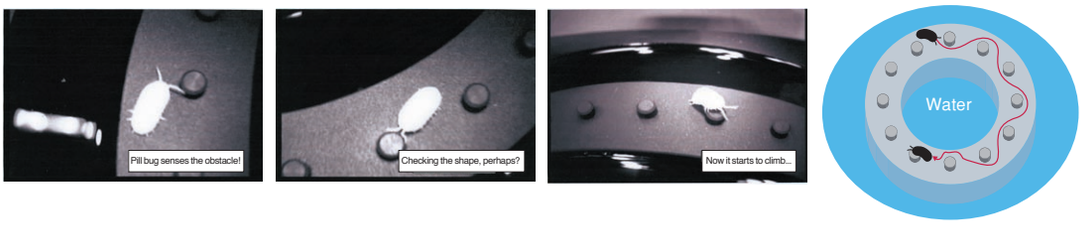


Fig. 2 Changes in Behavior of Pill bugs Walking Along a Circular Corridor
The pill bugs avoid obstacles by means of endlessly alternating their turning responses, but as time goes by, some of them start exhibiting unique behaviors such as climbing up a projection (top). This is the first step in adapting to the environment. (Due to the lighting, the pill bug in the figure appears white.)

Do Pill bugs Use Tools, Too?

In another attempt to induce an idiosyncratic behavior from the pill bugs, Moriyama and Migita covered their antennae with tephlon tubes (Fig. 3). Including the attached tubes, the lengths of the antennae were approximately 1.5 times longer than the bare antennae. As expected, the pill bugs walked clumsily with the tubes. Moriyama and Migita then put the pill bugs with tubes in a stair case and let them climb down the stairs (Fig. 4). The height of the steps increased by 1 mm as the pill bug goes one step down from top to bottom. With tubes attached to their antennae, the pill bugs went down further than the control group without tubes. However, if the pill bugs with tubes were allowed to explore in the environment for 10 minutes before being put in the stair case, their responses were more like the control groups. What implications can we obtain from this?

The behavior of pill bugs is, in general, considered mechanical. If the antennae can reach the bottom of a stair, it means that the stair is safe to descend for the pill bugs. When the tubes were attached and, immediately after, the pill bug was put in the stair case, they recklessly tried to descend a greater distance for they sensed the mechanical vibration at the tip of their extended antenna. However, with exposed to the environment for only about ten minutes, the pill bugs seemed to find out that the attempt was indeed reckless, changed the way they interpreted (or use the information of) the vibration from the tip of their antenna, and changed the way they acted in the environment. “An attempt to do something different than before is the first step toward adaptation to the environment,” says Furuyama. Crucially, their attempts of new behavior seem to be guided by their robust ability to perceive the environment, even when the sensors were experimentally manipulated.

Human Adaptive Behavior

What about human beings? Is human behavior always controlled by the brain? Mr. Furuyama and his group asked people in their 20s and 30s to discriminate between pieces of sandpaper of different roughness by touch. The subjects were each tested under four different conditions: (1) with their bare hands, (2) with Scotch tape on their fingers, (3) with sandpaper wrapped around their fingers, and (4) again with their bare hands. The results showed that the accuracy rate was about the same for all conditions. When the sense of touch was impaired due to attachments to their fingers, their confidence rates greatly decreased. In such cases, however, the subjects would put forth much more effort, instead trying different ways to touch the surface. For example, many subjects pressed harder against the sandpaper when their finger was wrapped with Scotch tape and softer when the finger was wrapped with sandpaper. Human subjects try more different methods of exploration than ever before, but their choice of new methods does not seem to be random, but rather guided by perceptual information.

A Species-independent Knowledge Acquisition Mechanism

The aim of this research group is not only to find out how pill bugs behave. All living things act based on information that they sense about the environment in which they live. A comparison of the behaviors of human beings and pill bugs that have completely different nervous systems may reveal a common, species-independent principle about the mechanism through which living things obtain information from their environment. There certainly seems to be some similarities in how a pill bug with tubes on its antennae moves around in an attempt to obtain information from its environment and how human being furiously move their fingers in an attempt to discriminate the roughness of sandpaper. Mr. Furuyama thinks that this type of behavior does not originate from thoughts in the brain but from the environment.

Research on what the invariants are in perception of the environment has only recently begun, but Furuyama and his colleagues believe that their research will provide new points of view with regard to “perceptually-based information” and “intelligence.” NII’s pill bug research may provide a completely new and unexpected answer to the question, “What is intelligence?”

(Written by Akiko Ikeda)

Fig. 3 Pill bug with a Straw-like Teflon Tube on its Antennae
The antennae are extended by attaching a tube to them that was 1.5 times longer than a bare antenna. (One may wonder whether the pill bug is annoyed...)

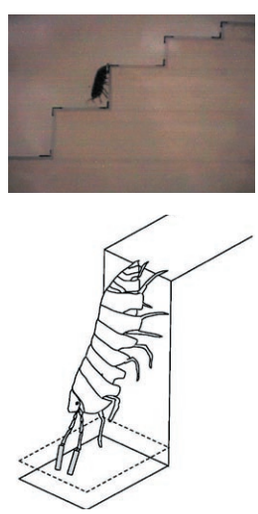


Fig. 4 Pill bug Limit Descent Distance
Normally, a pill bug that is 11 mm in length can only descend up to 12 mm. With the tubes attached to its antennae, it can descend up to 15 mm. This is only temporary, however. An exposure to the environment for ten minutes before the start of the test allowed the pill bugs to revert to the 12 mm limit.