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Illustrating Affordance and Skilled Performance Using Results from Plankton Behavior Studies

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Focusing on *affordance* as our keyword we suggest investigating skilled performances within the realm of zooplankton behavior. Studies on both skilled performances and on human brain activities suggest that mechanisms in model formation of a skill within the brain and of its sensory-motor processing should be examined. Using results from studies on copepod behavior, we address the need for considering (1) sensor-motor processing of less complex organisms within their environment, and (2) the construction of models based on emergent rules describing skilled performances.

1. Introduction

A study on the acquisition of a physical skill by Shadmehr and Holcomb [Shadmehr 97] supports the idea that the brain creates over time a model for the performance of a particular task. The brain uses it as a guide for controlling the movement of muscles. Once the skill is mastered and performing the task becomes *automatized*, the brain doesn't need to use its higher centers of thinking for the task. Instead, a small number of specific brain sites related to sensory-motor processing become responsible for the activity [Schneider 03]. Hence, these studies indicate that constructing a model to describe a skill, as well as understanding its sensory-motor processing is important for the study of skilled performance.

Affordance, implying the complementarity between the perceiver and the environment [Gibson 79], is another element to be included in the research of physical skills. A person interacts with the environment to obtain information while acquiring a physical skill, or performing a task with a mastered skill. Gibson notes that the same environment can provide different affordances for different organisms. Environmental stimulus affects the internal condition of an organism to make one kind of a response, which appears as the behavior of this organism. Thus, internalizing environmental changes bridges the selection of a behavior.

Beer [Beer 96] introduced the concept of *minimally cognitive behavior*, which he defined as the simplest agent-environment system that raises issues of genuine cognitive interest. Beer and his colleagues implemented this concept in their experiments [Slocum 00]. They experimented with an agent with short-term memory and a narrow visual range to show that the perception of body-scaled affordance can evolve to more complex affordance. Their results in these experiments indicate that the description of underlying behavior patterns is necessary to understand and illustrate more complex behaviors. Additionally, the input for creating modules of skilled performance could come from biological observations on animals of lesser complexity.

In this paper, we would like to illustrate affordance in relation to results from behavior studies on zooplankton. We also would like to suggest issues that the research results could raise for the study of skilled performance in engineering.

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2. Zooplankton Research

Contrary to the meaning of the word, "plankton" is not comprised of merely floating objects. Zooplankton move autonomously and react to the various changes in their environment. They constantly alter their behavior in response to environmental variation [Strickler 85]. The behavior of planktonic copepods (they are the most abundant members of the zooplankton community) has been studied in relation to their environment and their sensory systems. Sensory input, central processing, and behavior as the output in this research area have been extensively examined [Weatherby 00].

2.1 Copepod behavior

Most copepods are between about 0.5 and 10 millimeters in size. They have antennae which allow them to sense food and environmental changes, as well as to distinguish mates from prey and predators. Because of the relative simplicity of their nervous systems, their similar body plans, and the great diversity of their ecologically relevant behaviors, they can be considered appropriate animals for neuro-ecological studies.

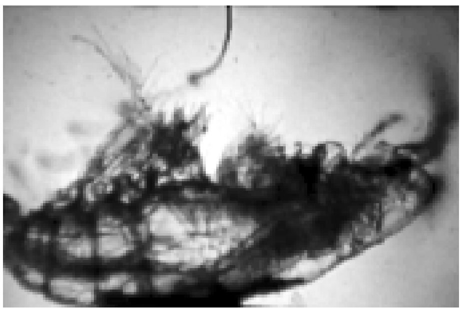

Fig. 1: A copepod generating currents around its mouth to capture food. From [Koehl 81].

In his microscopic studies, Strickler has shown that copepods choose paths according to their environment [Strickler 85]. Koehl and Strickler [Koehl 81] found that a copepod managed to catch food by moving its mouth parts skillfully while generating flow around the parts (Fig. 1). This catching movement was made only when food was within a certain volume in front of the animal. It also used its current-generating "skills" to navigate food into this volume.

Studies on copepod mating showed that when a male copepod crosses the trail of a female copepod, he will successfully pursue the trail to catch up with the female (Fig. 2). Moreover, while tracking her chemical trail, the male will disturb the signal skillfully to prevent another mate or a predator from following the trail as well [Yen 03]. These observational results show that the fast and skillful performances of copepods appear to be very complex despite their rather simple sensory systems.

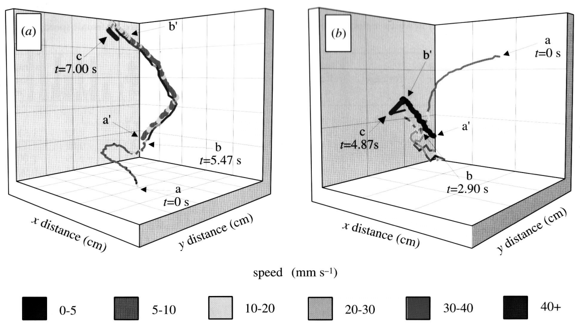

Fig. 2: Mate-tracking by a copepod. From [Yen 03].

2.2 Copepod Behavior Modeling

We constructed a model to simulate the behavior of copepods in relation to their external and internal changes, based on results from observational studies on their behaviors. Even though the adaptive part of the model was limited, comparison of the results from the simulations with the ones from the observational studies suggested that fine-tuning the different relations among the internal states is a good basis for simulating the adaptive nature of behavior [Yamazaki 03]. The study also indicated the need for a scheme in which simple behavior can be simulated as an emergent outcome from interactions among internal and external components by connecting factors associated with behaviors. From this view of behavior modeling, affordance should be characterized as the interconnection among internal and external factors, which should be formulated in explicit rules. Yet, the outcome of the system should be emergent, and not governed only by upper-level rules.

3. Discussion

Neural systems, even in small animals, contain ascending pathways through which sensory information reaches the "brain", and descending pathways relay motor commands from the "brain" to the motor neurons. This schematic illustration is far simpler than the process of acquisition and performance of a skill by a person. However, if we look at a complex process as an integrated coordination of much more primitive biological functions, the study of behavioral components, as seen in lower organisms, should provide models for the functional components, which can be described with less complicated schemata than those required for human activities.

Therefore, research results from observing and modeling the behavior of lower animals will provide the framework of how to illustrate each piece of the integrated components. When a person performs an automatized skill, real-time decision making derived by the motor-sensory system is required [Schneider 03]. Quick responses produced by the sensory system of a primitive organism, such as a zooplankter or an insect, should be considered as an example for a constructive element in a more complicated sensory-motor system.

From the above, we can suggest several issues concerning the study of skilled performance. Particularly, in order to illustrate and replicate a skilled performance, we need to consider: (1) describing stimuli from the environment in terms of internal state changes – in other words, describing internalized affordances; (2) defining a skill as an integrated collection of primitive behavioral elements; (3) constructing a model which illustrates a physical skill as an emergent outcome of lower-level rules; and (4) considering sensory-motor processing of a primitive organism as an underlying model. We believe that the input from biological studies may play an important role in realizing these objectives.

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