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In order to interact successfully with the environment, animals must deduce their surroundings based on sensory information. The visual system plays a particularly critical role in such interactions with the environment.

"Why can we see?" This question is fundamental for a thorough understanding of vision-dependent animals, including human beings. In order to better understand the visual system of animals, we are researching animal behaviors through psychophysical and computational methods.

I. Psychophysical study of medaka fish

One of our major subjects is the psychophysical and computational study of medaka (*Oryzias latipes*, Matsunaga and Watanabe, 2010). Recently, we made progress in studies of prey-predator interaction using medaka and zooplankton. Visual motion cues are one of the most important factors for eliciting animal behavior, including predator-prey interactions in aquatic environments. To understand the elements of motion that cause such selective predation behavior, we used a virtual plankton system where the predation behavior in response to computer-generated prey was analyzed. Virtual prey models were programmed on a computer and presented to medaka, which served as predatory fish. Medaka exhibited predation behavior against several characteristic virtual plankton movements, particularly against a swimming pattern that could be characterized as pink noise motion. Analyzing prey-predator interactions via pink noise motion will be an interesting research field in the future (Matsunaga & Watanabe, 2012).

In recent years, we have made progress in studies of the schooling behaviors of medaka. Many fish species are known to live in groups. Visual cues have been shown to play a crucial role in the formation of shoals. Using biological motion stimuli, depicting a moving creature by means of just a few isolated points, we examined whether physical motion information is involved in the induction of shoaling behavior. We found that the presentation of virtual biological motion can prominently induce shoaling behavior. We have shown what aspects of this motion are critical in the induction of shoaling behavior. Motion and behavioral characteristics can be valuable in recognizing animal species, sex, and group members. Studies using biological motion stimuli will enhance our understanding of how non-human animals extract and process information which is vital for their survival (Nakayasu & Watanabe, 2014).

We have developed a novel method for behavior analysis using 3D computer graphics (Nakayasu et al., 2017). The fine control of various features of living fish have been difficult to achieve in studies of fish behavior. However, computer graphics allow us to manipulate morphological and motion cues systematically. Therefore, we have constructed 3D computer graphic animations of medaka based on tracking coordinate data and photo data obtained from real medaka. These virtual 3D models will allow us to represent medaka faithfully and to undertake a more detailed analysis of the properties of the visual stimuli that are critical for the induction of various behaviors. This experimental system was applied to studies on dynamic seasonal changes in color perception in medaka (Shimmura et al., 2017).

II. Psychophysical study of human vision

Another of our major subjects is the psychophysical and theoretical studies of the visual illusions experienced by human beings (*Homo sapiens*). One recent focus of this debate is the flash-lag effect, in which a moving object is perceived to lead a flashed object when both objects are aligned in actual physical space. We developed a simple conceptual model (predictive coding, Figure 1) explaining the flash-lag effect (Watanabe et al., 2010). In recent years, we have made more developed novel visual illusions, such as the shelf-shadow illusion. This year, we began studying deep neural networks (DNNs) that represented the perceived rotational motion for illusion images that were not moving physically, much like human visual perception. (Figure 1). These models of DNNs will lead us in future work on perception science.

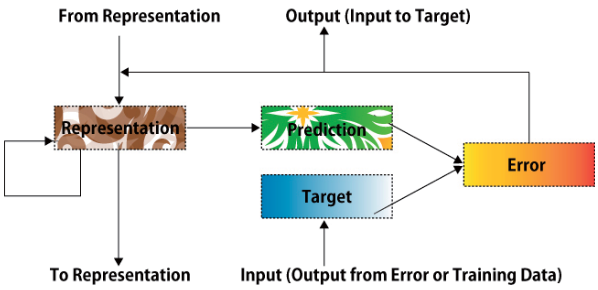

Figure 1. A schematic diagram of a predictive coding model of the brain. Illustration of information flow within a single layer is shown. Vertical arrows represent connections with other layers. Each layer consists of "Representation" neurons, which output a layer-specific "Prediction" at each time step, which is subtracted with "Target" to produce an error, which is then propagated laterally and vertically in the network. External data or a lower-layer error signal is input to "Target". In each layer, the input information is not processed directly, and the prediction error signal is processed.

Publication List:

〔Original papers〕

- Nakayasu, T., Yasugi, M., Shiraishi, S., Uchida, S., and Watanabe, E. (2017). Three-dimensional computer graphic animations for studying social approach behaviour in medaka fish: Effects of systematic manipulation of morphological and motion cues. PLoS ONE *12*, e0175059.
- Shimmura, T., Nakayama, T., Shinomiya, A., Fukamachi, S., Yasugi, M, Watanabe, E., Shimo, T., Senga, T., Nishimura, T., Tanaka, M., Kamei, Y., Naruse, K., and Yoshimura, T. (2017). Dynamic plasticity in phototransduction regulates seasonal changes in color perception. Nat. Commun. *8*, 412.