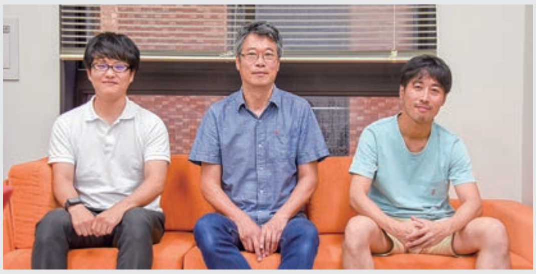
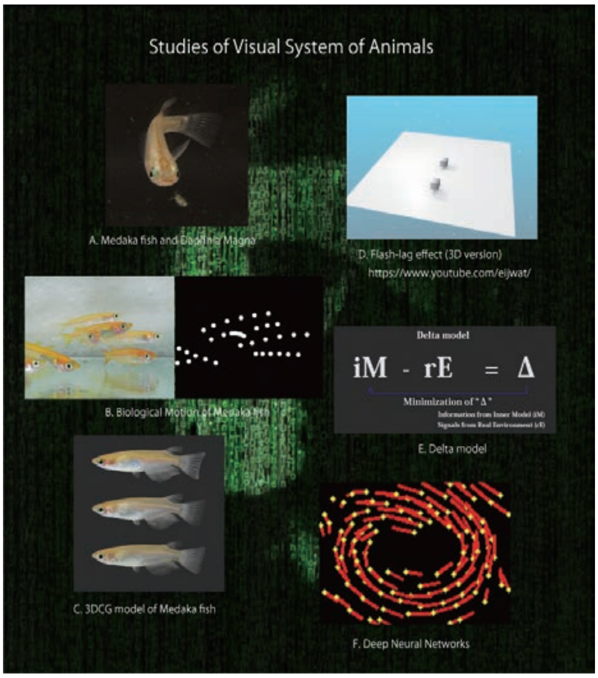
Laboratory of Neurophysiology

Associate Professor
WATANABE, Eiji

Specially Appointed Assistant Professor : KOBAYASHI, Taisuke
JSPS Postdoctoral Fellow: NISHIUMI, Nozomi
Technical Assistant: WATABE, Mihoko
TSURUMARU, Mayumi



We believe that the best way to understand mechanisms underlying a certain system is to reconstruct the system as it exists. By utilizing novel computer technologies, we are accordingly trying to build the systems based on psychophysical and ecological viewpoints in particular to understand systems of animal perception and behavior. This type of methodology based on computers will pave the way for biology in the future.



Visual overview of this lab's work.

I. Psychophysical study of medaka fish

One of our major subjects is the psychophysical and computational study of medaka (*Oryzias latipes*, Matsunaga & Watanabe, 2010). We have recently made progress in studies of prey-predator interaction using both these organisms and zooplankton. Visual motion cues are one of the most important factors for eliciting animal behaviors, 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 we analyzed the predation behavior in response to computer-generated plankton. To achieve this, virtual plankton models were programmed on a computer and presented to predator medaka. As a result of this analysis, we confirmed that medaka exhibited predation behavior against several characteristic movements of the virtual plankton, particularly against a swimming pattern that could be characterized as a pink noise motion. The analysis of predator-prey interactions via pink noise motions will be a research field of great interest moving forward (Matsunaga & Watanabe, 2012).

In recent years, we have made progress in the study of schooling behaviors of Medaka. Many fish species are known to live in groups, and visual cues have been shown to play a crucial role in the formation of shoals. By utilizing biological motion stimuli, which in this case was the depiction of a moving creature by using just a few isolated points, we examined whether physical motion information is involved in the induction of shoaling behavior. We consequently found that the presentation of virtual biological motion can clearly induce shoaling behavior, and 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 further enhance our understanding of how non-human animals extract and process information which is vital for their survival (Nakayasu & Watanabe, 2014).

Additionally, 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 has been difficult to achieve in studies of their behavior. However, computer graphics allow us to systematically manipulate morphological and motion cues. Therefore, we have constructed 3D computer graphic animations based on tracking coordinate data and photo data obtained from actual medaka (Figure 1). These virtual 3D models will allow us to represent medaka more faithfully as well as 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

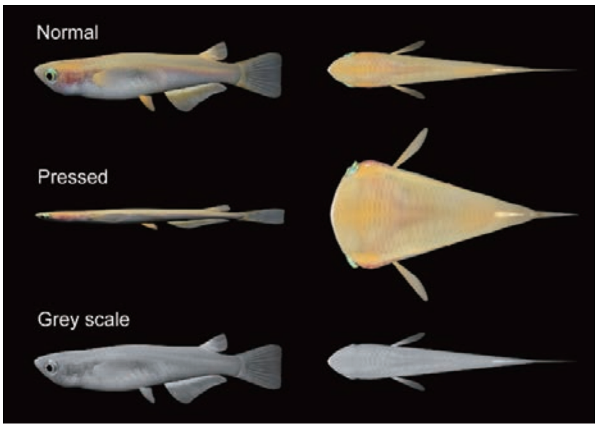


Figure 1. Virtual medaka fish.

seasonal changes in color perception in medaka (Shimmura *et al*., 2017), and on underwater imaging technology (Abe *et al*., 2019 and Yamamoto *et al*., 2019).

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. One recent focus of this debate is the flash-lag effect, in which a moving object is perceived to head towards a flashed object when both objects are aligned in an actual physical space. We developed a simple conceptual model 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 (3rd Award of the 5th Illusion Contest, https://doi.org/10.6084/m9.figshare.6137558), the Monstre Benham illusion (2nd Award of the 11th Visual Illusion and Auditory Illusion Contest, https://doi.org/10.6084/m9.figshare.10046534), and the Morning Monster Illusion (https://doi.org/10.6084/m9.figshare.13125518, Figure 2).

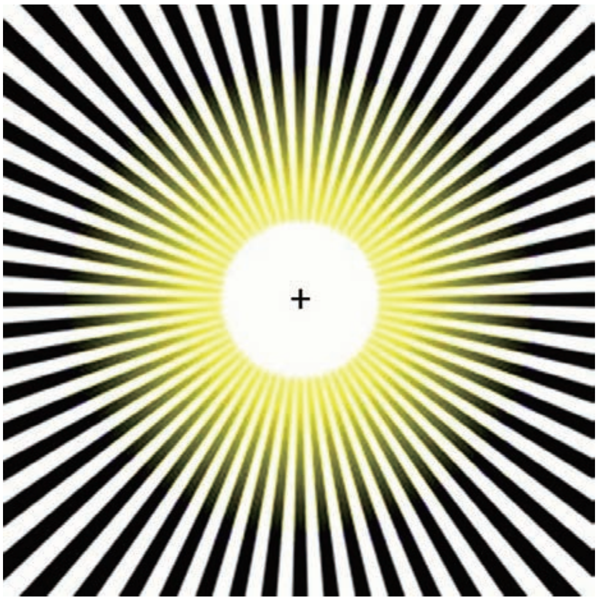


Figure 2. Morning Monster Illusion. Watanabe (National Institute for Basic Biology) and Sinapayen (Sony CSL) got 10th place at the 12th Visual Illusion and Auditory Illusion Contest, for the Morning Monster Illusion. Itis one of the color aftereffect induced by glare effect.(demo, https://ewatanabe.blogspot.com/2020/11/monstre-matin-illusion-10th-award-of.html).

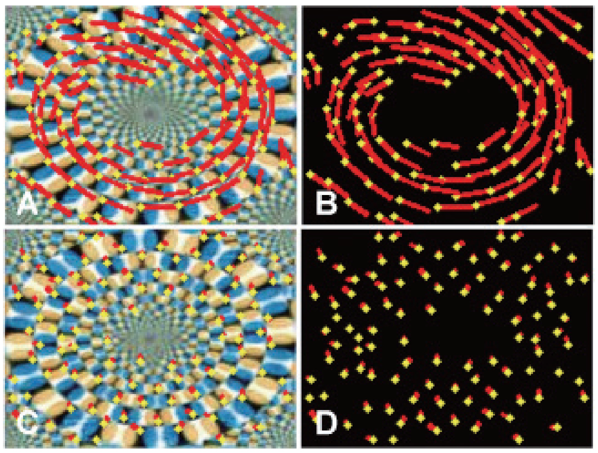


Figure 3. Optical flow vectors detected in the illusion. Red bars denote the direction and magnitude of vectors, yellow dots denote the start points of the vectors. A and B: Illusion, C and D: Non-Illusion.

In 2018, we successfully generated deep neural networks (DNNs) that represent the perceived rotational motion for illusion images that were not physically moving, yet similar to what we experience in human visual perception. (Figure 3, Watanabe *et al*., 2018). These DNN computer models will help to facilitate our future work on perception science. This experimental system was applied to studies on evolutionary illusion generator in collaborating with Dr. Lana Sinapayen (Sony CSL). (EIGen, https://github.com/LanaSina/evolutionary_illusion_generator. Sinapayen and Watanabe, 2020). Currently, a variety of research is being conducted using these AI systems (https://arxiv.org/abs/2106.09979, https://arxiv.org/abs/2106.12254).

III. Ecological study of tactics in predators and prey

We are interested in behavioral interactions between predators and prey not only concerning the psychophysical aspect but also concerning the ecological aspect. In the process of the co-evolution, predators and prey have developed various tactics to overcome each other. To elucidate the sophistication of these tactics, we have examined the mechanisms and efficacies of predatory and antipredator behaviors of several animals such as snakes, frogs, fish, dragonflies and bats. In 2020, we published a paper, which outlined the vulnerability of preemptive actions of both predator snakes and prey frogs, and the possibility that this vulnerability instigates a 'waiting game' between these animals (Nishiumi & Mori, 2020). Several on-going studies were also presented at conferences, which were about the tactics of predatory bats regarding echolocation. In addition, we have developed experimental technologies for those studies, which present interactive virtual predators to prey animals based on animation (Figure 4) or robotics. These technologies do not require specific uncommon hardware or software as previous technologies have required (*i.e.* The present technologies work in Windows and Mac OS with low-price webcams and several free computer libraries), and thus, are expected to contribute wider range of animal research.

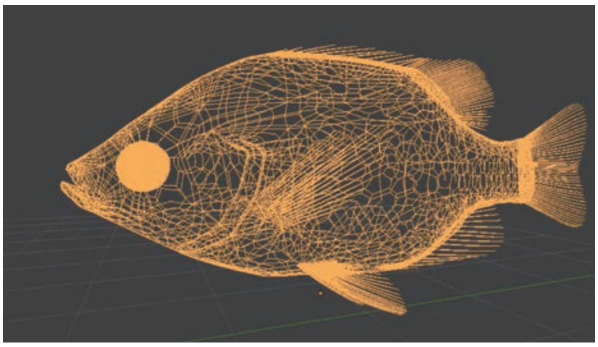


Figure 4. A computer animation of the virtual predatory fish.