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NEUROPHYSIOLOGICAL STUDY ON VISUO-VESTIBULAR CONTROL OF POSTURE AND MOVEMENT IN FISH DURING ADAPTATION TO WEIGHTLESSNESS
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We can stand upright and walk smoothly without paying any particular attention to it. This is because we have established in ourselves an integration center that controls our body subconsciously in response to input from eyes, muscles, joints, foot soles, and also from the gravity sensor in the inner ear (the otolith organ). It has been shown that the cerebellum plays an important role for the establishment of the integration center and that the control pattern is comparable to that of a highly sophisticated computer system.

The programming for the control, however, may well be acquired for the 1-g ground condition and does not cover the 0-g in space. Although each of the above organs function as it does on the ground, the signal pattern sent to the center must be different under 0-g and, in addition, complementary signals from the otolith organ are missing, leading to confusion in the integration center and causing a variety of symptoms similar to those of car-sickness or sea-sickness. After exposure to microgravity an immediate process of re-programming will begin and be completed in 2-4 days. There is strong supporting evidence for this sensory conflict theory as an explanation for space motion sickness (SMS) episodes.

Fish were selected as test organisms for this investigattion because they swim around freely in three dimensions and have well-developed organs for vision and gravity detection. They also have an innate nature to orient their back toward a light source. Actually, on the ground, the fish tilts its vertical axis toward the light when illuminated laterally, and the tilt angle is a function of the intensity of light and the magnitude of gravity, while its posture is completely light-dependent in the low-gravity environment produced by aircraft parabolic flight or when the otolith organs are removed. This implies that fish posture is entirely under visual and otolithic control. In this case, the cerebellum will also contribute to the control.

In the space shuttle experiment, two fish (one with the otolith-removed and the other with intact otoliths) are onboard for 7 days. The arrangement of the experiment is shown in Figure 1. Lamps illuminate each fish alternately from different directions at a duration of 20 seconds for 10 minutes totally, twice a day. The video images and the brain waves from the cerebellum are analyzed later. If the sensory conflict theory is acceptable, then the confusion at the onset and the following recovery process will be manifested both in the light-dependent behavior and also in the cerebellar activity. In addition, there should be some variation in response between the two fish.

Even if the results are positive in the present fish experiment, they would not be extensive enough to allow us to understand the complete mechanism of SMS. However, what is currently needed is a collection of evidence based on animal experiments on which to base future investigations.

Countermeasures for SMS are mandatory since SMS-induced vomiting occurring within a space suit could be fatal for a crew member during extravehicular activities. We expect that countermeasures will be developed before the space station era starts, and that the results of these studies will be applied to improving human welfare.

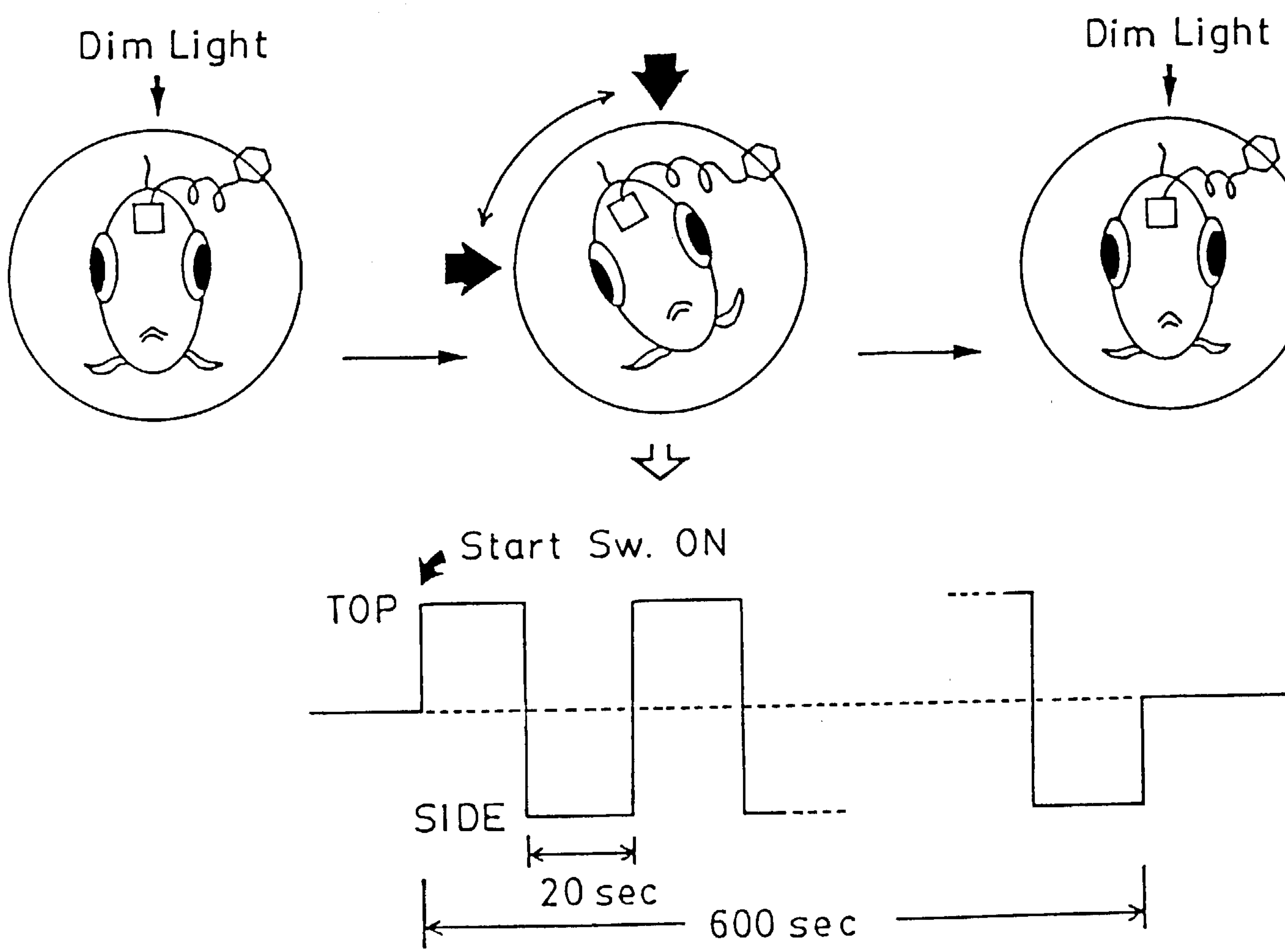

Figure 1. Carp experiment in space. Ten-minute recordings of light-dependent carp behavior and the electrical activity of the cerebellum are collected twice a day during the 7-day mission.