Immersive Reaction of Medaka to Omnidirectional Aerial Display

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Keywords: Omnidirectional aerial display, immersive sensation, Medaka

Abstract

This paper reports the responses of medaka that is surrounded by rotationg stripes shown on an omnidirectional aerial display. We measure the time of reaction in three conditions and compare the difference between one and several medaka. The results suggests omnidirectional aerial display evokes immersive sensation on medaka.

1. Introduction

An omnidirectional display that shows pictures in all directions is supposed to give an immersive sensation by its extremely wide field of view. Aerial imaging by retro-reflection (AIRR) has been proposed to form aerial information screen with a wide viewing angle [1] and has been utilized for an omnidirectional aerial display [2]. Immersive sensation of a viewer was sometimes expressed by the movements of the body center.

In the field of biology, researchers have conducted behavior and genetic analyses of medaka(*Oryzias latipes*) using displays [3-5]. In conventional experiments, it had been confirmed that the medaka reacted to the aerial image [6]. In this experiment, we used the stripe aerial image of the same width. It is considered that there is a change in following when we change the width of the stripe aerial image.

The purpose of this paper is to evaluate the reaction of medaka for the surrounded images. We trace the movements of medaka to investigate immersive reactions of medaka. In this paper, we set multiple conditions in the aerial image, measure the reaction time of the medaka to each condition, and compare differences in response under conditions. Furthermore, it is considered that there is a medaka that does not react to the aerial image. Therefore, we conduct the same experiments with the medaka that reacts under all conditions and medaka that does not react to the aerial image and compare differences in reaction time.

2. Principle of aerial imaging by retro-reflection

The principle of our aerial display is illustrated in Fig. 1. Fig. 1 shows a cross section of the apparatus. Light emitted from a light source goes to a beam splitter and splits in reflected light and transmitted light. The reflected light goes to retro-reflector and goes back to the beam splitter following its optical path in reverse. After transmitting the beam splitter, the light converges to the position of plane symmetry of the display regarding the beam splitter.

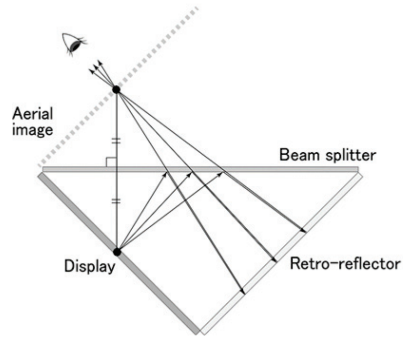


Fig. 1 Cross section of the aerial display.

3. Principle of our omnidirectional aerial display

In our omnidirectional aerial display, a cone-shaped beam splitter is installed at 45 degrees diagonally from the bottom. The principle of our omnidirectional aerial display is illustrated in Fig. 2. In the experiments, a liquid-crystal display (LCD) panel was used for the light source. The optical system shown in Fig. 3 was placed on the LCD panel. We used a cone-shaped beam splitter that is shown in Fig. 4. By using the cone-shaped beam splitter, a cylindrical aerial image is formed. The formed aerial image can be smoothly displayed without interruption because it is formed with passive optics.

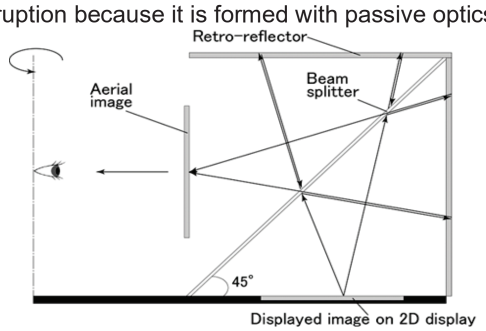


Fig. 2 Cross section of the omnidirectional aerial display.

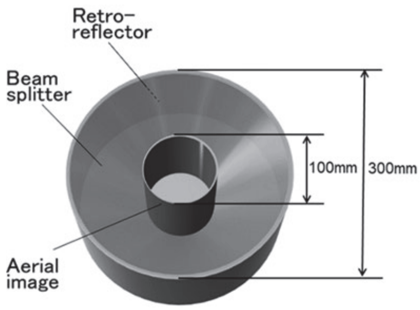


Fig. 3 Structure of the omnidirectional aerial display.

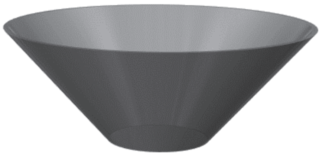
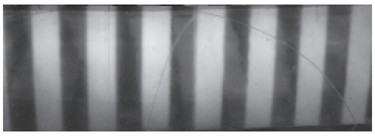


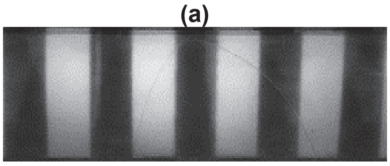
Fig. 4 A cone-shaped beam splitter.

4. Experiments

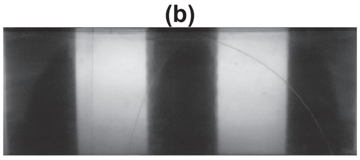
We have conducted experiments under the following conditions. We changed the width of the stripes from 10 mm to 50 mm in 10 mm increments. The aerial images are shown in Fig. 5. In order to observe the omnidirectional aerial image, we used an omnidirectional camera (Ricoh Theta Spherical Digital Camera, THETA SC, RICOH, 2016.10, 910740). Then, we changed the angular velocity in four stages: 1.3 rad/s, 2.1 rad/s, 3.1 rad/s, and 6.3 rad/s. Furthermore, we changed the direction of rotation: clockwise and counter-clockwise. We rotated the aerial image for 1 minute. Note that we conducted experiments after showing medaka the aerial image for 20 minutes in advance to keep habituated medaka to the aerial image.



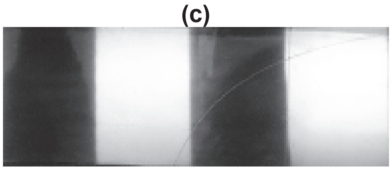
(a)



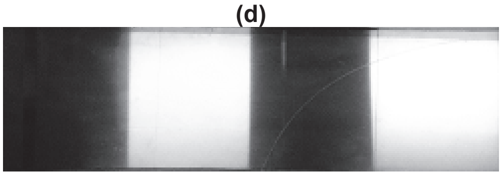
(b)



(c)



(d)



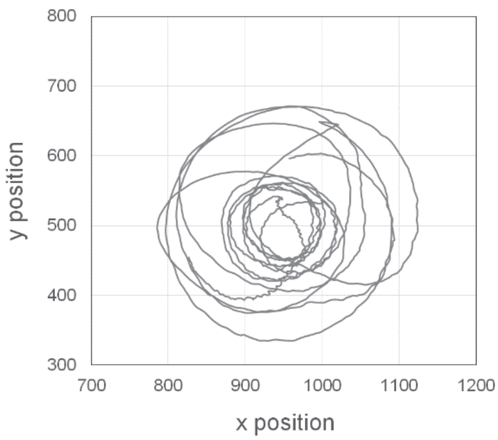
(e)

Fig. 5 Formed aerial stripes of which width is (a) 10 mm, (b) 20 mm, (c) 30 mm, (d) 40 mm, and (e) 50 mm.

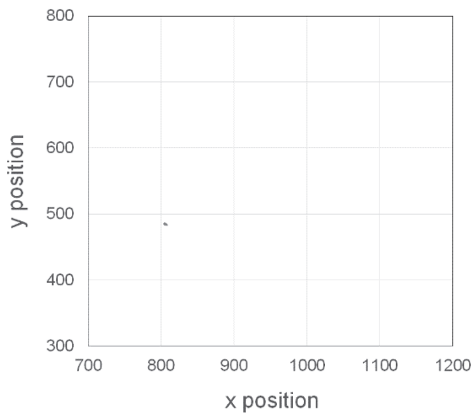
5. Results

We have conducted experiments showing medaka the aerial image of stripes in a clockwise and counter-clockwise rotations. The experimental conditions are shown in Fig. 6. The medaka followed the aerial image even when we changed the rotation. Then, the trajectory based on data when we tracked the behavior of the medaka is shown in Fig. 7. From the trace, it is possible to confirm whether the medaka followed the aerial image.

Fig. 6 Results showing the aerial image of the striped pattern in (a) clockwise rotation, (b) counter-clockwise rotation.



(a)



(b)

Fig. 7 Results of tracking the behavior (a) when the medaka reacted and (b) when the medaka didn't react.

In this experiment, we measured the time in three conditions, the time until the medaka starts following the aerial image, the time while the medaka keeps tracking the aerial image, and the time until the medaka stops tracking after stopping the aerial image. The shorter the time until the medaka starts following the aerial image, the longer the time while the medaka keeps tracking the aerial image, and the shorter the time until the medaka stops tracking after stopping the aerial image, the closer it is to the ideal value.

We measured the time in three conditions when we experimented to show a medaka the aerial image of stripes in a clockwise. At first, the results for each of the two medakas under three conditions at the angular velocity of 3.1 rad/s are shown in Fig. 8 through Fig. 10. Fig. 9 shows the percentage of the tracking time of the medaka in the measurement time. In Fig. 8, Medaka A reacted the aerial image under all conditions, but Medaka B didn't react when we rotated 10-mm and 30-mm wide stripes. In Fig. 9, Medaka B took more time to react to the aerial image than Medaka A. In Fig. 10, there was almost no difference in the time to stop the reaction between Medaka A and Medaka B.

There were some conditions that Medaka B did not react to the aerial image. Therefore, we did the same experiments on Medaka B with Medaka A. The results at four speeds when only Medaka B and together with Medaka A are shown in Fig. 11 through Fig. 16. Overall, there was more dispersion of the time in three conditions when we used only Medaka B than when we used the Medaka A and Medaka B. In Fig. 11 and Fig. 12, the time until the medaka starts following the aerial image was slightly inversely proportional. In Fig. 13 and Fig. 14, the percentage was slightly proportional when we rotated at 1.3 rad/s and 6.3 rad/s and the percentage was slightly inversely propotional when we rotated at 2.1 rad/s and 3.1 rad/s. In Fig. 15 and Fig. 16, the time until the medaka stops tracking after stopping the aerial image was slightly proportional to the stripe width.

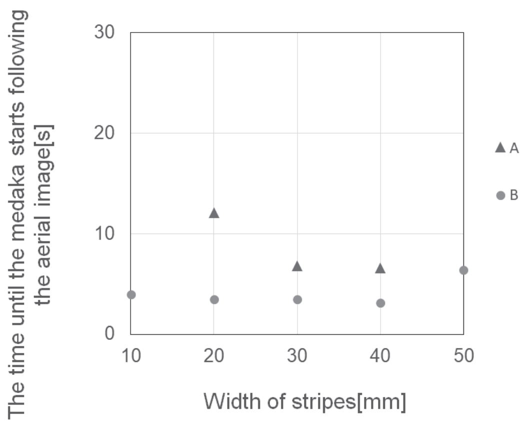


Fig. 8 The time until the medaka starts following the aerial image.

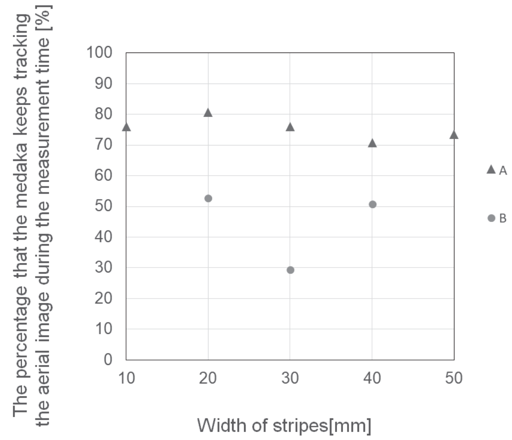


Fig. 9 The percentage that the medaka keeps tracking the aerial image during the measurement time.

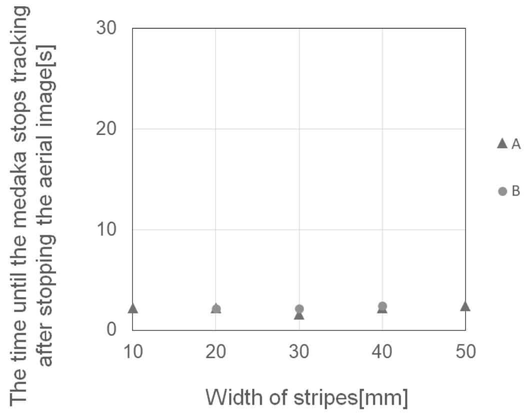


Fig. 10 The time until the medaka stops tracking after stopping the aerial image.

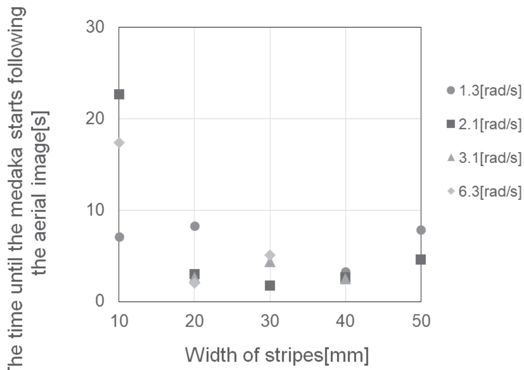


Fig. 11 The time until Medaka B starts following the aerial image.

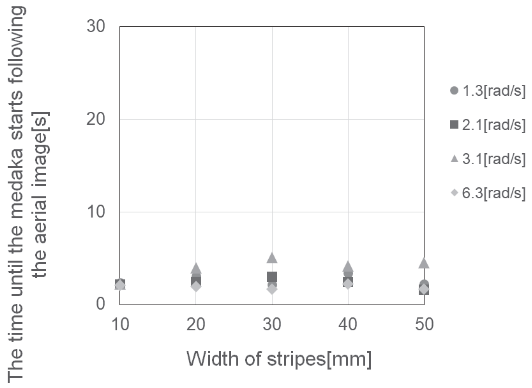


Fig. 12 The time until Medaka B starts following the aerial image with Medaka A.

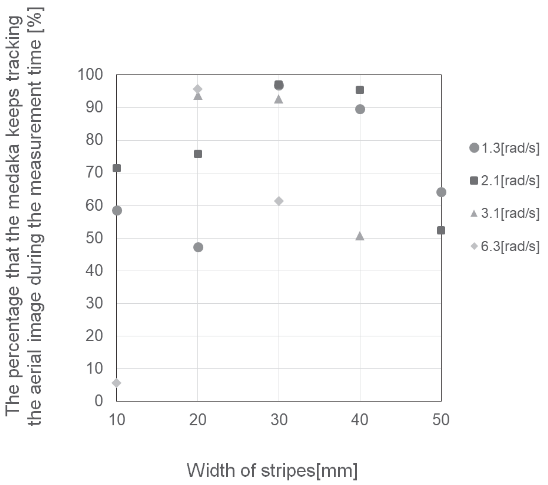


Fig. 13 The percentage that Medaka B keeps tracking the aerial image during the measurement time.

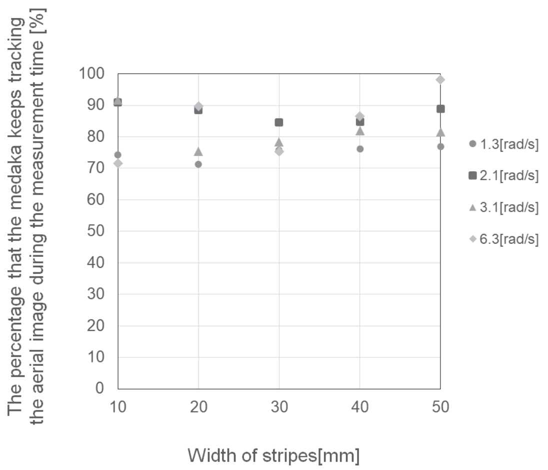


Fig. 14 The percentage that Medaka B keeps tracking the aerial image during the measurement time with Medaka A.

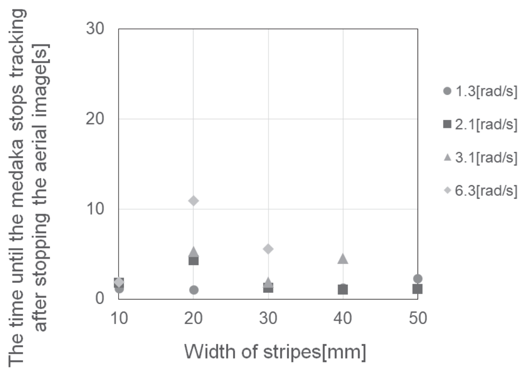


Fig. 15 The time until Medaka B stops tracking after stopping the aerial image.

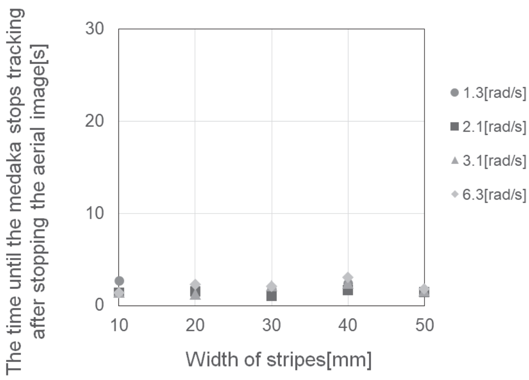


Fig. 16 The time until Medaka B stops tracking after stopping the aerial image with Medaka A.

6. Conclusion

We have investigated the reaction time of the medaka to the aerial image based on the trajectories. We confirmed that the medaka is hard to react the aerial images tend to react to the aerial image when we conducted similar experiments with the medaka that reacts to the aerlai image under all conditions.

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