The Effect of Luminance Change for OOW’s Visual Cognition

Ryo FUKUDA*, Masso FURUSHO**, Yoshiki ISHIMARU*** and Ken-ichiro KAWAMOTO****

1. Introduction

According to the Japan Coast Guard findings of 2014 (1), vessels’ number of marine accidents in 2014 was at an all-time minimum, yet a significant percentage of these is due to improper look-out (22%). The highest number of accidents is due to improper look-out every year. Therefore, a decrease in instances of improper look-out will have a significant effect in decreasing vessels’ number of marine accidents. Japan Coast Guard categorizes improper look-out into 3 types. (2)

1) No look-out
2) The OOW performed look-out, but he/she did not perceive any danger of immediate collision.
3) The OOW noticed other ships, but he/she did not pay attention her course and speed.

In this study, authors focused on type 2). There are possible factors for this: For example, a blind spot, restricted visibility and effect of luminance of sky, sea surface, and target.

2. Objectives

The OOW must find the target (e.g., other ships or islands) as soon as possible, and he/she must avoid collision. Therefore, look-out is indispensable for safe navigation.

The horizon is a very important barometer for OOW when he/she guesses the distance for target while on look-out. If there are visibility difficult area on the horizon, OOW cannot guess the distance accurately, which adversely affects the look-out. Our objective is to measure the luminance distribution of the sky and sea surface by using a two-dimensional luminance colorimeter (CA-2000 (Konica Minolta)) at sea, and to attest that if there is an area where the horizon is not visible on look-out.

3. Luminance difference threshold and visibility level

In this study, the luminance difference threshold was used to evaluate visibility. For visual cognition of a target in a field of vision, the target’s luminance ($L_t$ in cd/m²) and the background luminance ($L_b$) should be different, and the luminance difference ($\Delta L = |L_t - L_b|$) must higher than the minimum luminance difference for cognition by human eye ($\Delta L_{\text{min}}$), which is called the luminance difference threshold.

In this study, the luminance difference threshold calculated by the following empirical formula proposal by Bodmann.

$$\Delta L_{\text{min}} = 0.05936 \times (1.639 L_b^{0.64} + 1)^2 \times L_b$$

For visual cognition of a target in a field of vision, the following condition should be satisfied: $\Delta L \geq \Delta L_{\text{min}}$. If $\Delta L$ is higher than $\Delta L_{\text{min}}$, we can visual cognition of the target. Therefore, $VL = \Delta L / \Delta L_{\text{min}}$ called visibility level (VL), i.e., target’s visibility. If the luminance difference between the background and target increases or decreases, VL also increases or decreases, respectively. $VL = 1$ is the threshold of visibility for the human eye.

4. Measurement outline

Measurements were performed on Fukae Maru (Kobe University training ship) from Mar. 11 to 19 in 2015. The navigation route was from Kobe to Hakata.

A two-dimensional luminance colorimeter was set in the bridge left forward and fixed a tripod such that it did not move during measurement term. And two-dimensional luminance colorimeter was adjusted it height that about height of human eye on the bridge (about 7.5 meters from the surface of the water).

5. Analysis method

The 249 data were collected in the research period, but they neglected any data when the horizon was not clearly visible (e.g., fog or when it was out of focus). There were 32 images selected particularly which are with little luminance difference between the sky and sea surface.

Further, 40 pixels area in a range of 1 deg were set and one sampling point’s average luminance were determined, it was defined as the luminance of the area. Human eye receives much visual information narrow line of sight range (central vision), the area is regarded as the area where we can see targets color and form clearly. The 24 sampling points and another 24 sampling points were set along the upper and lower of the horizon symmetry.

The two-dimensional luminance colorimeter measured 980 by 980 pixels with the range of 24.8 by 24.8 deg. The 1 deg corresponds to about 39.5 pixels, so the sampling area diameter of 1 deg was set 40 pixels in the analysis. When the sampling area was set on the sky, if there is another thing (e.g., island, ship) in the image, these things were neglected because background condition differs if they are considered.
6. Results
We focused on the relation the sky and sea surface luminance, and the visibility level. And we introduce Sun glitter in this paper. Sun glitter is a situation when the sea surface is bright due to the solar light. In the usual situation without sun glitter, sky luminance is higher than the sea surface luminance. However, in the case of sun glitter, the sea surface luminance could be higher than the sky luminance. In previous research by Furusho (2000), the sun glitter results in more photic stimulation than that under normal conditions. The photic stimulation is minimum of 4 times and a maximum of 100 times higher.

Our results suggest that sun glitter affects the OOW's visual cognition and hampers the look-out, to consider the aspect of visibility of the horizon, where the sun glitter is visible on picture, the \( V_L = 105.7 \pm 39.0 \), so the visibility with the horizon is good. On the other hand, the end point of sun glitter has bad visibility (\( V_L \approx 1 \)). This means the visibility of the horizon is low.

7. Discussion
Three conclusions can be arrived by analyzing the sky and sea surface luminance to evaluate the horizon’s visibility.
1) Visibility is low in the area at the end of the sun glitter zone, and in some cases, below \( V_L \approx 1 \), i.e., the area that is not clearly visible to human eye.
2) An average visibility level in the sun glitter zone is higher than at other points, which does not have a significant effect on visibility.
3) Sky luminance distribution is almost same regardless of the point, and the sea surface luminance distribution have large difference depending on the points; especially on the sea surface in the sun glitter zone, the sea surface luminance is sometimes higher than the sky luminance.

If the OOW’s first observation of the target is late due to the difficult in seeing the horizon, the collision evasive will be late too, this could lead to marine accidents. Our results show that there is a difficult-visibility area at the end of the sun glitter zone. Therefore, look-out should involve not only visual observation but also must combine the use of all information (e.g., radar, AIS).

As I mentioned before, a range of sun glitter has a big amount of glare, which causes discomfort to the OOW. Therefore, it must be an appropriate care (e.g., installation light cut filter with the window glass or wearing sunglasses). However, polarizing glass that is used in general cannot be used in the bridge due to the interference window glass because a striped pattern emerges. The development of sunglasses that optimized look-out on ship is desirable.

The results also suggest that there may be bad visibility when the OOW thinks fine visual conditions. It has not been generally recognized that the horizon is difficult to see in the daytime. Our results indicating difficult-visibility areas can contribute to the prevention of maritime accidents.

8. Conclusion
Our objective is to measure the luminance distribution of the sky and sea surface by using a two-dimensional luminance colorimeter at sea, and to attest that if there is an area where the horizon is not visible on look-out. It was confirmed that the visibility of the sea surface depends on condition, e.g., sun glitter that caused by solar altitude and relative direction.

The distribution of sky luminance is substantially constant regardless of the area, the distribution of sea surface luminance appeared to significantly differ due to the difference in points.

If sun glitter appeared, there are difficult-visibility areas at the end of the sun glitter zone, and surprisingly the visibility level was high in the center (the sun glitter itself).

The luminance of the sun glitter zone is higher than that of other parts of the sea, so the OOW is expected to be hesitant to watch the sun glitter because of the glare. To develop tools for performing the appropriate look-out is necessary.

Acknowledgements
Authors would like to express special appreciation to the Japan Coast Guard for supporting the several kinds of data to us.

References
(2) Hearing Information given by Japan Coast Guard (July, 2015)
(3) The color science association of Japan (1999): Handbook of color science (second edition), 53