別紙４－１（課程博士（英文））

Date of Submission (month day, year) : January 10th, 2020

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Abstract (Doctor)

Title of Thesis	Investigation of the neural mechanisms in illusory glare perception

Approx. 800 words

The perceived intensity of light coming from a given portion of an object (brightness) and the perceptual experiences of a black, grey, or white-colored surface and self-luminosity (lightness) are some of the basic aspects of visual processing. Glare illusion, which is an optical illusion, enhances the perceived brightness of a central white area surrounded by a luminance gradient without any actual change in light intensity. Our experiences of perceptual misunderstanding are sometimes caused by optical illusions that create visual images that may carry deceptive interpretations. Although it seems that optical illusions trick our brains into believing things that may or may not be real, they demonstrate how the brain makes the most probable prediction about an ambiguous visual input. This is not a retina-level process, but a serial processing occurring in the brain, which is valuable for understanding how the brain interprets visual stimuli from the external world.

The pupillary response is mainly a function of retinal illuminance owing to the amount of light energy or quanta entering the eye from the ambient environment. Although one of the main functions of pupil constriction would seem to be the protection of our eyes from being dazzled by intense physical light, previous studies using pupillometry have revealed that the pupil is also constricted by the perceived intensity of light in the absence of any change in light intensity via glare illusion. Because the visual system processes luminance information from a graphical image as if it were a natural scene, colors could play an important role in the perception of brightness. In this study, we first examined whether pupil constrictions to glare illusion are stronger for blue compared to other colors. Our results indicate that blue was subjectively evaluated by participants as the brightest condition, despite all colored stimuli being equiluminant. Moreover, glare-related pupil constrictions for each participant were correlated to each individual's subjective brightness adjustments. Together, these findings show that pupillometry constitutes an easy tool to assess individual differences in color brightness perception.

Second, we tested the hypothesis that the ecological background, where getting dazzled by light is common when one directly looks at sunlight through some occluders, can explain the larger pupil constriction to blue. Interestingly, we found the effect of blue on pupillary constriction occurs only for people with black/brown iris colors. Because the iris color relates to the macular pigment density as a marker for the adaptation to the homogeneous environment, we assumed that the pupillary constriction represents the adaptation response to a probable dazzling sunlight imitated by glare illusion, and the pupil constriction might be similar to the function of macular pigments to filter the blue light projecting to the retina.

Next, we examined two probable factors to modulate the pupil size in glare illusion by using the Kanizsa

triangle with a radial pattern of luminance gradation and a control pattern. We assumed that the pupil constriction to glare illusion represents: (a) the role of 'anticipation' or 'preparation' to probable glare situation from the Sun or scattering light, and (b) the localized stimulus pattern because the averaged luminance of the glare illusion within a small visual field is higher than its control condition, where the rotated luminance gradient pattern. Our results show a larger pupil constriction effect on the Kanizsa triangle with the radial pattern; therefore, we conclude that the pupil constriction to glare illusion is prompted by self-luminosity perception. The effect of the brightness judgment on pupil response shown in previous works is considered additionally to the effect of 'self-luminosity' to the brightness perception but via difference pathway from surface color perception.

We subsequently investigated the correlation between pupil constriction and electroencephalography (EEG) response of the amplitude of the steady-state visual evoked potential (SSVEP) on the illusory brightness enhancement with glare illusion. We found that the SSVEP amplitude was lower in glare illusion than in the control condition (no glare condition), especially under high luminance contrast conditions. The probable correlation of the inhibited SSVEP amplitude to the high luminance contrast of glare illusion accompanied by the greater pupil constriction may be because of the decreased amount of light entering the pupil. Therefore, the brightness enhancement in the glare illusion is already represented at the primary stage of visual processing linked to the larger pupil constriction.

As a conclusion, we have put together the evidence of the larger pupil constriction effect on glare illusion that can be elegantly explained by the ecology of vision that the large pupil constriction on the illusory glare perception may be a prediction of the probable strong light, especially for blue, sky-like, glare illusion makes more powerful effect in causing constrictions.