Linking Dynamics Between Pupil and Lens

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Abstract- This article aims to measure pupil variations through real physical stimuli in a real world; and to link them with lens accommodation theories. It is concluded that pupil dilation is linked to rounded lens, and pupil constriction is linked to faltered lens.

Introduction

Both Helmholtz and Schachar agreed about the lens adaptation from distant vision to close one; namely, the lens become more rounded due to ciliary muscle contraction. They, however, had different perspective about the physiological processes for this accommodation. According to Shachar, when ciliary muscle contracted, central zonules become tight, however, peripheral zonules relaxed and curled. Helmholtz, on the other hand, believe that all of the zonules must be relaxed and curled to have rounded lens. The opposite operation is, lens unaccommodation, in which the transition is from close vision to distant one. This process flatters the lens by tightening the zonules fibers. Collectively, I here report whether there are possible communications between the dynamics of human iris and the lens, through the lens accommodation/unaccommodation processes.

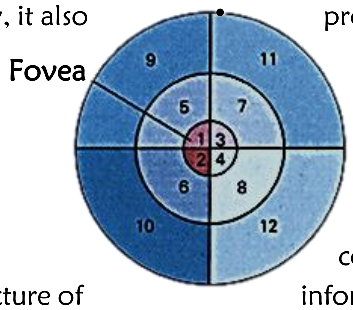
Instrumentation

Two typical 32mm black dices (with white dots) had been place at distances of 0.5 (lens accommodation), and 3.5 meters (lens unaccommodation), both of them are localized in a horizontal line that's orthogonal on the pupil distance (PD) line, and originates exactly from the center of the PD. 240 frames per second, 1080p camera had been used to collect the pupil dynamics; data analysis followed the method offered by Peridis, etal. 2013. The luminance has equal distribution on the two dices.

Method

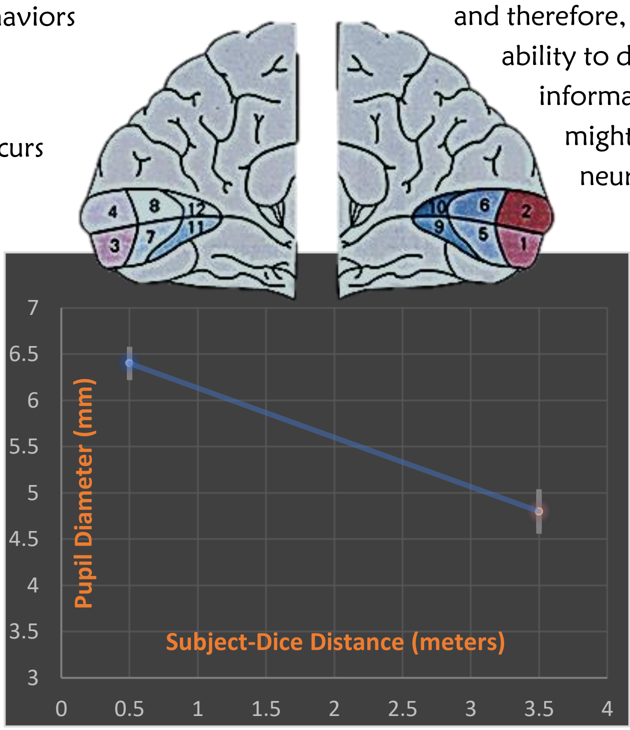
Eight human subjects had been carefully selected to perform the experiment. Selection was manual, and based on pupil size, namely, subjects should have dilated pupils to ease the estimation of the pupil variations. The dices also have high contrast to maintain the dilation, and for further easiness to the collection of the data. The apparent view of the dices to all of the human subjects is only number five throughout the experiment. High contrast visual stimulation used to dilate the human pupil, (Wang, etal, 2014). Importantly, the closer dice subtends 3.662- degree visual angles (DVA) in the retina, however, the distant one subtends 0.00914 DVA ≈ 0.01 DVA. The purpose of using small objects is to carefully study the accommodation, and whether the pupil has contributions in this process.

Each 10 seconds, every human subject has to hear a beep, and his/her task is to switch their focus from the distant dice to the closer one, and vice versa after each beep. For data validation and quality control, this process has to be repeated for 10 times, that's 200 seconds (3 minutes, and 20 seconds in total). Collected pictures are then analyzed for data extraction, namely, pupil diameter variations. Pupil size is then estimated for each epoch, 10 seconds. All of the accommodation's epochs are then summed and divided by ten "the number of epochs". Similar steps are followed for the unaccommodation process, basically, it also has ten epochs, and all of these epochs are averaged. These average values, which are collected from the eight human subjects, are afterwards processed to produce a mean average value, and a standard deviation, that represents holistic picture of all of the subjects' pupil behaviors collectively.



Empirical Results

Significant pupil dilation occurs for lens accommodation, namely, an increase of 1.6 millimeters in pupil diameter. As shown in the infographic, the differences between the human subjects is not significant. Namely, the standard deviation is 0.18mm for the distant dice condition, and 0.24mm for the closer one. Perhaps because I have chosen all of the subjects with dilated pupils, as I mentioned earlier; the selection process was carefully made to reveal the correlation's significance, if there is any.



Discussion

Fovea subtends greater retinotopic map in the brain (compare areas 1 - 4 to 9 - 12 in infographic; retina is above, and the brain is below). This is because the cones in the fovea are much smaller than the cones in the retinal peripheries. Smaller cones allows the retina to create greater visual awareness for high spatial frequencies visual stimulations (for better understanding of how the visual awareness might be generated, please see reference 5). More importantly, distant objects have 'higher spatial frequency' visual awareness compered to their close identical peers. Collectively, the lens unaccommodation process might therefore perform two physiological processes to ensure greater visual awareness for the distant objects: 1- It flatters the lens to make the focal point of the light rays closer to the retina, and therefore, the light rays will not reach the retinal peripheries. 2- It constricts the pupil, to reduce the visual information from the distant environments, and therefore, the fovea will have great ability to deal with a fewer information. Pupil constriction might be an evolutionary neurological feedback from the brain; as if the brain is highly activated, it will request the pupil to minimize the received visual information (distant places always carries greater visual information than closer places). Oppositely speaking, the lens accommodation achieves two process: 1- Through assistance of zonules, the lens become more rounded; and therefore, greater accessibility to the retinal peripheries. 2- The pupil dilates, which again assist the light rays to access the retinal peripheries by widening the eye's opening.

It must be mentioned that the two aforementioned scenarios are not the only scenarios, but they are likely the most common ones when human subjects deal with natural experiences. Accommodation reflex, however, has another scenario; namely, it has rounded lens, constricted pupils, and converged eyes. It's opposite to what I have just concluded; but why this scenario might be happened? Very close objects are always seen very blurry. This might be due to a retinal protection mechanism that defuses the object's light rays through a rounded lens (lens accommodation); and this will direct a lot of light rays to retinal peripheries, and accordingly the sensible spatial frequency will be reduced. The retinal peripheries also tend to reduce the contrast (Robert Rosén, etal., 2014). According to contrast sensitivity function (Campbell, 1968), low contrast, plus low spatial frequencies increase the invisibility (blurriness). In addition to protecting the retina, the brain therefore will order the pupil to constrict, to prevent the retina from achieving unnecessary processes, namely, some ganglion cells that are attached to the photoreceptors of the retinal peripheries might not be able signal the brain at all (see; lateral inhibition of center-surround antagonism). I therefore think that the pupil constriction caused by accommodation reflex process is a very special scenario of lens accommodation, and it should not disturb our conclusion, mainly because it happened under special circumstances with seemingly extreme conditions. In short, viewing far objects, will constrict the pupil, and flatter the lens to minimize the information received from the distant environments. Viewing closer environments, however, will dilate the pupil, and make the lens more rounded, mainly because they might have lower amount of information with lower spatial frequencies (for deeper comprehension of how contrast sensitivity function affects human vision based on the distance, see hybrid images, reference 8). Interestingly, the cones in the retinal peripheries signal the brain 30 milliseconds faster than the central cones (Masland, 2017); the brain therefore, for closer surroundings, might accommodate the lens and dilates the pupil to enable additional light rays to access a bigger area of the retinal peripheries; in which humans will have 'faster' visual awareness. Faster perceptual awareness assist in creating faster actions; as if it is an evolutionary defensive mechanism to allow humans to act timely in unexpected situations. Psychology may have better explanations of these situations. Noticeably, pupil dilation has the ability to estimate emotional arousal and autonomic activation, (Bradley, 2008). It also betrays the timing of decisions, (Einhäuser, 2010); represents the surprising events, (Preuschoff, 2011); and it can reflect individual upcoming choices and biases, (Gee, 2014). We have to stop here for a moment, and questioning ourselves, why pupil dilates in such events? According to my findings, when pupil dilates, the lens become more rounded, and this gives the external stimuli greater accessibility to the retinal peripheries, namely, faster visual awareness that seems to be very important for all of the aforementioned situations.

Finally, out of this paper scope, I should advise the readers about the inaccuracy of the visual angle measurements, because it considers the pupil as a pinpoint. The dynamics of the pupil and the lens should be considered, and therefore, the visual angle will be not static, but dynamic and effective.

Transactional References

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