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Doctoral Dissertation

DISSERTATION OUTLINE

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The dissertation entitles "a study of attentional modulation in pupillary response" and belongs to the field of vision science. The dissertation comprises the table of contents, tables of figures, tables of equations, abstract, six chapters, acknowledgment, and reference. The dissertation starts with the introduction in chapter 1, followed by chapters 2–5, wherein the experiments conducted are included. In chapter 6, the general discussion is included. In the following, the six chapters will be introduced separately in detail. As a general experimental method to manipulate the attentional conditions of participants, the classical Posner cueing paradigm was deployed throughout the whole dissertation.

Chapter 1 is the introduction. It depicts the critical knowledge for vision science. The nervous system and one of its sub-systems, the visual system, are introduced separately. Then, the gates of the visual system, that is, the pupil and attention, are further introduced separately. Last, the objective and structure of this dissertation are also introduced separately.

Chapter 2 includes the experiments concerning luminance. There are two different parts. The first part depicts the experiments examining the effects of attention (broad and narrow attention) on different components of the pupillary light response (PLR). It was examined by using a concentric stimulus pattern. I found that although there were different processing systems for different components of PLR, attention per se seemed not to affect these systems differently. The second part depicts the experiments examining the effects of divided attention on PLR. I found that pupillary dilation was elicited by attending to two disks with different luminance. Furthermore, the dilation amplitude was controlled by the relative difference of luminance between the attended two disks.

Chapter 3 includes the experiments concerning spatial frequency. There are two different parts. The first part depicts the experiments examining the effects of selective attention on pupillary spatial frequency response (PSFR). Three types of stimuli, including sine wave grating, Gabor patch, and filtered natural images, were used. I found that both spatial attention and object-based attention could affect PSFR. The pupillary response was smaller when attending to a stimulus with an intermediate spatial frequency range (2–8 c/d) than lower and higher spatial frequencies. The second part depicts the experiment examining the effects of divided attention on PSFR. I found that pupillary constriction was elicited by attending to two gratings with different spatial frequencies.

Chapter 4 includes the experiments concerning color. The effects of selective attention and divided attention on the pupillary color response (PCR) are examined. A red disk and a blue disk were used. I found that there were no effects of selective attention and divided attention on PCR. The pupillary responses among conditions when attending to the red disk, when attending to the blue disk, and when attending to both disks were indistinguishable from each other.

Chapter 5 includes the experiments concerning arousal. The effects of attention and arousal on pupillary response are examined. The arousal levels of participants were manipulated by using multiplying tasks with different difficulties (cognitive load). I found that the effects of attention and cognitive load on pupillary response could co-occur, whereas they were independent of each other. Irrespective of the arousal level of participants, the pupillary response was smaller when attending to a bright disk compared to a dark disk; irrespective of the attentional conditions of participants, the pupillary response was larger for participants with high arousal levels (cognitive loads) compared to normal arousal levels.

Chapter 6 is the discussion. First, a summarization of the experiments is made. After that, the models regarding the function and physiology of the attentional modulation in pupillary response are proposed, respectively. Regarding the function, I presume that attentional modulation (selective) in pupillary response can accelerate the PLR and PSFR to protect the eye and improve processing efficiency, respectively. The attentional modulation (divided) in pupillary response can allow different attributes to be processed simultaneously. I presume that the reason why there is no attentional modulation in PCR may lie in the long latency of PCR compared to PLR and PSFR. Regarding physiology, I presume that the superior colliculus (SC) and mesencephalic cuneiform nucleus (MCN) are involved in the effects of selective attention and divided attention on pupillary response, respectively. Then, the practical application of pupillary response on Human-computer Interaction and clinical diagnosis, and the implications brought by my results are discussed. Next, the future directions that may help examine my models regarding the function and physiology of attentional modulation in pupillary response are listed. After that, the current study's limitations are pointed out, and the ways to solve these limitations are also introduced. At last, a simplified conclusion with the most important findings of this dissertation is written as the take-home message.

In the following, the conclusions of the doctoral dissertation are listed. First, selective attention can affect PLR and PSFR, whereas it did not affect PCR. Second, pupillary dilation and constriction were elicited by attending to two stimuli with different luminance and spatial frequencies, respectively, whereas there were no effects of divided attention on PCR. Third, attention per se did not affect the different components of the pupillary response. Fourth, the effects of selective attention and arousal (cognitive load) on pupillary response could co-occur, but they were independent of each other. For the model regarding function, I proposed that the effects of selective attention on the pupillary response (PLR and PSFR) were to accelerate the pupillary response before the saccade, and the effects of divided attention on the pupillary response (PLR and PSFR) were to allow different attributes to be processed simultaneously. Furthermore, the lack of attentional modulation in PCR was due to the long latency for PCR compared to the saccadic latency. For the model regarding physiology, I proposed that different pathways were innervating the PLR, PSFR, and PCR, respectively. Furthermore, the SC and MCN were involved in the effects of selective attention and divided attention on pupillary responses, respectively.