Study on Effective Parameters for Autonomic Stress Estimation Using Light Reflex Caused by Display Luminance Change

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The pupil light reflex (PLR) is widely used for evaluating the autonomic nervous system (ANS). In this study, we investigate parameters useful for a stress evaluation system by using the change in personal computer screen brightness in an actual use environment. In our experiment, the subject's light reflex was induced by flash of the screen before and after conducting a mental arithmetic (MA) task that activates the sympathetic nervous system (SNS). From the experimental results, we found that the minimum pupil diameter (Min PD) and relative constriction amplitude (RCA) can be effective parameters of the PLR for evaluating SNS activity. Also suggested is the feasibility of realizing a daily stress monitoring system that utilizes PLR caused by the change in personal computer screen brightness.

CCS CONCEPTS • Human computer interaction (HCI)

Additional Keywords and Phrases: Pupil Light Reflex, Stress Monitoring System, Ambient Sensing

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1 INTRODUCTION

In recent years, technologies for simple daily stress-measurement have attracted more attention. Since the stress response can generally be observed as a response of the autonomic nervous system (ANS), measuring physiological responses associated with ANS is important to monitor stress states. Many of the methods for measuring physiological responses use contact sensors. However, contact sensors require users to wear some devices. Non-contact methods use RGB cameras, near-IR cameras, thermal cameras, millimeter waves, microwaves, etc. [3]. These methods measure pulse waves, respiration, and blood vessels. Therefore, they take a long time to measure physiological responses. Compared with these methods, methods can be used to measure the dynamic characteristics of the pupil light reflex (PLR) in a short amount of time without the need for wearing devices Therefore, we propose a system for measuring ANS by PLR with devices used on a daily basis as shown in Figure 1. We focus on personal computers and smartphones, which have a screen that can be used to present light stimuli to the eye and a near-infrared camera that can be used as a pupil measuring device. When the screen brightness is changed, the light intensity applied to the eyes changes. The change in pupil diameter is measured by the near-infrared camera mounted on a device, and PLR parameters are analyzed. In this study, to confirm the feasibility of our measurement system, we examine the relationship between PLR parameters and cognitive stress status with devices used on a daily basis that have a screen and a near-IR camera.

2 PUPIL LIGHT REFLEX

The dilator muscle and the sphincter muscle adjust the pupil diameter. The innervation of the dilator muscle involves the sympathetic nervous system (SNS), and the innervation of the sphincter muscle involves the parasympathetic nervous system (PNS). Figure 2 shows a schematic illustration of PLR. After latency, which is the delay from receiving a light stimulus to the reaction, the pupil starts to constrict. The baseline pupil diameter (BPD) is the pupil size before constriction starts. The maximum constriction velocity (MCV) is characterized by the largest first derivative of the pupil trace during the constriction. After the pupil is completely constricted and the pupil diameter is at the minimum (Min PD), the pupil gradually dilates, and the largest pupil-dilation velocity is the maximum dilation velocity (MDV). The amplitude from the BPD to the Min PD is called the absolute constriction amplitude (ACA), and the relative constriction amplitude (RCA) is calculated by dividing ACA by BPD.

3 RELATED WORK

Many studies on PLR evoked by computer screens aim to investigate the relationship between changes in high-context images and PLR [2, 3, 4, 5, 6, 7, 8, 9]. The study of Naber et al. [10] examined the effect of screen-induced PLR on age. These studies are not aimed at investigating the relationship between the PLR and the subject's internal state. A study by Wang et al. [11] investigated the relationship between the internal state of the subject and the PLR parameters. In this study, they compared the characteristics of the PLR parameters evoked by LED and the screen

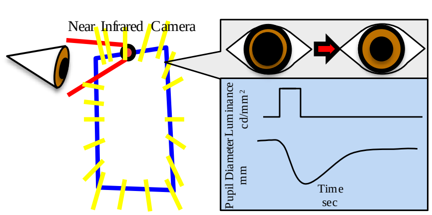

Figure 1 The Proposed system overview

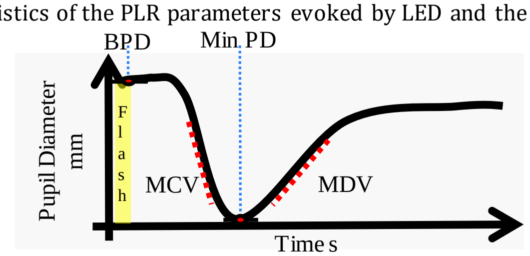

Figure 2 Schematic illustration of PLR

of a personal computer. They also analyzed the correlation between a questionnaire survey of chronic fatigue and the PLR parameters. The results indicated that the parameters of PLR evoked by the LED and the screen differed in absolute value, but there was good reliability on amplitude-related parameters. They also confirmed that the results of chronic fatigue were correlated with some parameters (ACA, BPD, DV1). However, this experiment was conducted in a darkroom, and the subjects' faces were fixed with a chin rest. Therefore, the situation was different from an actual environment. Moreover, questioner survey is unclear that ANS activity changes of subjects.

4 EXPERIMENT

In this study, we assumed a daily mental-health check of office workers as a use case, and we confirmed whether there are parameters that can estimate the stress state from the parameters of PLR caused by changes in screen brightness in an environment imitating an office. To imitate an office environment, the experiment was conducted in a lit environment (560 lux) without fixing the subject's head. The screen was changed from black to white (370 cd/m2), and the light stimulus for PLR was presented for 500 ms. An overview of the experiment system is shown in Figure 3. The system consists of a laptop computer and a pupil measuring device. The laptop was an LG gram 17 (LG Electronics, 17 inches), and the pupil measuring device was a Tobii Pro Nano (Tobii Technology, 60 Hz). The distance between the subject and the screen was 45 to 65 cm. In this experiment, mental arithmetic (MA) was performed as a stressor. Some studies [12, 13] suggest that MA works as a mental stress that appears in the response of the ANS. The subject was given two tasks, a MA task and a dummy task. In the MA task, we asked them to solve a two-digit addition problem displayed on the screen and input the answer on the keyboard. The brightness of the display during the MA task was kept from changing significantly by displaying gray characters while the screen was black. In the dummy task, the screen displayed the MA task, but we asked the subject to look at the screen with their eyes relaxed, and they did not need to perform any calculation. Considering the influence of the task order, we set two patterns (PT1, PT2) in which the order of the dummy task and the MA task was changed. Figure 4 shows the experimental procedure for each condition. As is shown, one session consisted of an experiment overview explanation (Ex1), MA task explanation (Ex2), dummy task explanation (Ex3), calibration (CAL), flash stimuli before tasks (Flash A), flash stimuli after MA task (Flash B), flash stimuli after dummy task (Flash C), MA task (Task1) and dummy task (Task2). Considering the effects of circadian rhythm, the experiments were conducted for each subject on the same day in the morning (9:50-10:10), around noon (11:00-13:15), and the evening (16:30-17:15). The subjects were 35 people in their 20s to 40s (mean age: 37.6 years).

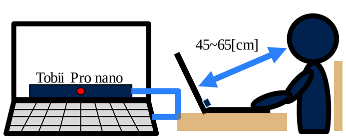

Figure 3: Experiment system

	1 session								
	60 sec		20 sec		180 sec		20 sec	180 sec	
PT1	Ex1	CAL	Ex2	Flash A	Task 1	Flash B	Ex3	Task 2	Flash C
PT2	Ex1	CAL	Ex3	Flash A	Task 2	Flash C	Ex2	Task 1	Flash B

Figure 4: Experiment schedule

5 ANALYSIS

The experiment data contained a lot of noise and defects. Therefore, sessions that contained data with defects for the constriction period were removed. As a result of the removal, in PT1, the number of sessions changed from 51 to 26, and the number of subjects remained unchanged at 17. In PT2, the number of sessions changed from 54 to 30, and the number of subjects changed from 18 to 14. The reason the experiment data contained many defects is considered to be that the pupil diameter was measured with the head unfixed in order to imitate an office environment. Therefore, it became necessary to perform linear interpolation as described later, but since MCV and MDV are differential values, they are considered to be greatly affected by the interpolation method. Therefore, they were excluded from the parameters to be examined. After removing outliers and performing smoothing [14], the missing part was complemented by the linear interpolation applied in the previous study. Figure 5 shows the changes in the PLR parameters for each session, which were measured three times in each session under PT1 and PT2. Both parameters show the difference based on the value at Flash A in each session to make the description easier to understand. Under both conditions, the RCA and Min PD after the MA task tended to be larger than those before the task and after the dummy task. Regarding RCA, the session with the maximum value for Flash B was 16/26 (61%) in PT1 and 15/30 (50%) in PT2. Regarding Min PD, the session with the maximum value for Flash B was 21/26 (81%) in PT1 and 25/30 (83%) in PT2. As a result of a Friedman test, the p-value was <0.05 in all cases for RCA and Min PD.

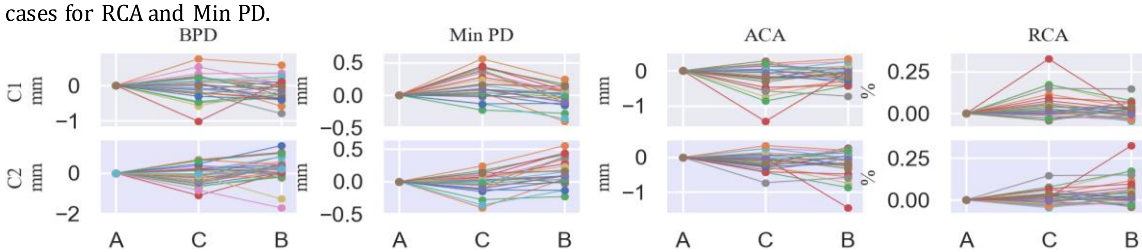

Figure 5: Changes in parameters of PLR for each subject

6 DISCUSSION

After the MA task, the tendency for the two parameters of RCA and Min PD to increase compared with before the task and the dummy task could be confirmed experimentally under both PT1 and PT2. The reason is considered below. In a study by Sercan et al. [15] comparing heart rate variability and PLR, a positive correlation was reported between LF/HF and RCA, which are indicators of SNS in the heart rate. Therefore, when the SNS is activated, the RCA is also considered to increase. The result indicating that the RCA after the MA task was larger than the other PLR parameters is also considered to be due to the SNS activation. Since pupil constriction is performed by the PNS and pupil dilation is performed by the SNS, it is possible that the pupil did not constrict much because the dilator muscle was tense due to the activation of the SNS by the MA task. Alternatively, it is possible that the activation of the SNS interfered with the activity of the PNS and reduced the tension of the sphincter.

7 CONCLUSION

Using a screen and a near-infrared camera, we evaluated PLR parameters in a real environment to evaluate the relationship between the dynamic characteristics of PLR and stress. As a result, it was experimentally confirmed that the Min PD and RCA changed significantly after a MA task that activated the SNS. This suggests the possibility of developing a daily stress-monitoring system that utilizes PLR caused by devices used on a daily basis. In this experiment, we used a MA task as a stimulus to activate SNS. Since the pupil is affected by the MA task, it is necessary to further investigate whether it is due to SNS activity or cognitive load during the task. In this study, the experiment was conducted in an environment where the lighting intensity was constant. Therefore, it should be clear whether our method is effective in situations where the lighting intensity changes. We will explore PLR parameters sufficiently to estimate ANS activity even in environments with different levels of light brightness and create a model of PLR parameters that respond to changes in the lighting environment.

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