Analysis of Personality Dependent Differences in Pupillary Response and its Relation to Stress Recovery Ability

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***Abstract*—We focus sometimes on a narrow task, and at other times on a broader array of stimuli. These two kinds of attention are called exploitation and exploration, respectively. Exploitation results in parasympathetic dominance and pupil constriction, whereas exploration results in sympathetic dominance and pupil dilation. This paper presents a pre-study aimed towards finding answers to two questions in the long run: (1) Can we get clues about the personality of a person through his/her psychosensory pupillary response? (2) Can we estimate the stress recovery ability of a person through his/her psychosensory pupillary response? In this study, 13 participants watched a relaxation video embedded with a scary pop-up in between. We aimed at inducing an increase in arousal via the novelty effect. After watching the video, the participants completed the DiSC personality test. Based on the DiSC personality test results, the pupil diameter vs. frame graphs were grouped for each personality. Similarities between graphs belonging to the same personality were examined. We observed the variance between the frames 400 and 1000 (starts shortly before the scary pop-up and ends at the end of the video). The variance was the smallest for the dominant personality, and highest for the inspiring and cautious personality. Between the frames 400 and 625 (shortly before and after the scary pop-up), three distinct pupillary response patterns could be observed: A decrease, a constancy, or an increase in pupil diameter. Based on these observations, a hypothesis regarding stress recovery ability is postulated: A pupil constriction indicates a fast stress recovery ability through parasympathetic dominance, and a pupil dilation indicates a relatively slow stress recovery ability due to sympathetic dominance.**

***Index Terms*—pupillary response, personality, stress recovery**

I. Introduction

The pupillary response is an important physiological indicator of high arousal. Studies showed that emotionally arousing stimuli (both pleasant and unpleasant) caused more pupil dilation than neutral stimuli [1], [2]. Even in infants, pupillary dilation was observed, when pleasant faces were shown to them [3]. Stress is one of the reasons of high arousal in negative valence. There are several studies which show that pupil diameter is a good indicator for stress detection. High frequency in pupil dilation has been found as a stress indicator [4]. Pupillary response has been investigated to detect stress by using wavelet transform and neural networks [5].

In stress detection experiments, different stressors have been used such as auditory and visual. Baby crying and laughing have been used as an negative and positive emotional stressor (auditory) [1] whereas "Pace Stroop Test" has been used as a visual stressor [6].

The size of the pupil is controlled by two muscles which are located in the iris: the iris sphincter muscle, which is innervated by the parasympathetic nervous system and causes the pupil to constrict; and the iris dilator muscle, which is innervated by the sympathetic nervous system and causes the pupil to dilate [7]. The iris sphincter muscle encircles the pupil, whereas the iris dilator muscle is oriented radially and connects the exterior of the iris with the interior.

The parasympathetic nervous system is the part of the autonomic nervous system that is responsible for keeping the body in a stable condition. When we are at rest, the parasympathetic nervous system dominates and causes the pupil to constrict by activating the iris sphincter muscle. The sympathetic nervous system is the part of the autonomic nervous system that is involved in arousal, wakefulness, and the fight-or-flight response. When we are aroused, the sympathetic nervous system dominates, and it causes the pupil to dilate by activating the iris dilator muscle. Some people can recover themselves from stress more easily whereas some people need more time for that. The people who need more time for stress recovery may stay in a negative high arousal for a long time which may result in mental and/or physiological illnesses. Activation in parasympathetic nervous system helps us to recover from stress [8].

Pupillary responses are triggered by three different types of stimuli, namely light, focus shifts, and arousal [9]. The responses to these stimuli are as follows:

- Pupillary light reflex: Changes in the intensity of light in

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the environment causes pupil to dilate or constrict [10].
- Pupillary near reflex: It is a constriction of the pupil that occurs when gaze shifts from a far-away to a nearby object [11].
- Psychosensory pupillary reflex: It is a dilation of the pupil in response to increased arousal [12].

The adaptive-gain theory links the psychosensory pupil response to different modes of behavior [13]: A small pupil size would indicate drowsiness; an intermediate pupil size would indicate exploitation, a state in which attention is narrowly focused on a single task; and a large pupil would indicate exploration, a distracted state that is characterized by switching between tasks. Exploitation and exploration are two extreme strategies of humans.

Due to the connection between the pupillary responses and the autonomic nervous system activities, studying the pupillary responses could reveal clues about interpersonal and intrapersonal differences in the response to arousal stimuli. The pupillary response during the stimuli might be able to reveal how fast or how slow a person recover from the stimuli. This paper is an initial effort in investigating the relationship between pupillary response, stress recovery ability, and personality type.

II. Research Questions

The long-term goal is to find answers to two research questions:

- Can we get clues about the personality of a person through his/her psychosensory pupillary response?
- Can we estimate the stress recovery ability of a person through his/her psychosensory pupillary response?

This paper reports the preliminary results towards finding answers to these questions.

III. Method

Thirteen adults (6 women and 7 men) in the age of 40 ± 10 years[1] were recruited for the study. All the participants had normal or corrected-to-normal vision. Fig. 1 shows the experiment setup. The experiment consisted of two stages– data collection and data analysis.

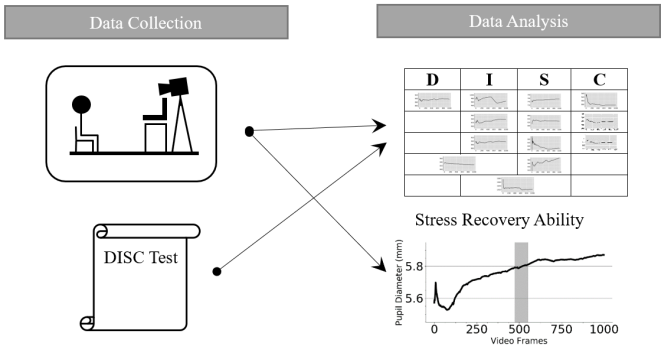


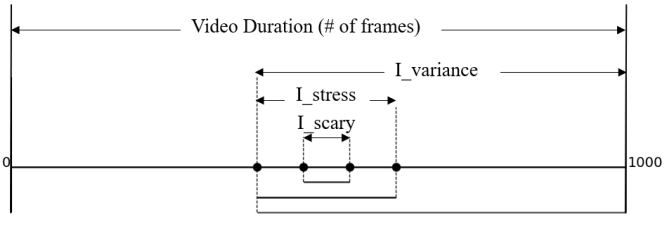
Fig. 1. Main stages of the experiment.

[1]This age group belongs to the age-group with the highest employment rate [14] and shows highest incidence of work-related stress [15].

In the data collection stage, the participants watched a relaxing video embedded with a scary pop-up. This video showed the sea with sounds of waves and a calming music in the background. The scary pop-up was novel to the participants and was intended to increase their arousal. The video lasted 40 seconds (1000 frames). The intervals of the video which are used in variance analysis and stress recovery analysis parts are shown in Fig. 2. These interval names will be used in the rest of the paper. The scary pop-up was embedded between the 19^{th} and 22^{nd} second of the video that is denoted as I-scary. A larger interval was chosen around the I_scary interval to study the response to the stimulus more clearly. This interval is denoted as I_stress. The variance of the pupil diameter was investigated in the interval denoted as I_variance. This interval starts immediately before the scary pop-up and continues up to the end of the video. This interval was chosen to study the recovery from the impact of the stimulus. The initial part of the video till immediately before the scary pop-up could be analyzed to investigate the effects of anticipation. This interval was excluded in this preliminary study.

The faces of the participants were recorded while watching this video. A Nikon D5300 digital camera is used to record the videos at 25 frames per second. The sensor size of the camera was 23.5 mm x 15.6 mm. The focal length was F=50 mm and each frame had the resolution of 640x424 pixels. These parameters were later configured in OpenFace [16]. OpenFace takes the video as an input and gives the facial landmark detection, head pose estimation, facial action unit recognition, and eye-gaze estimation as an output.

After watching the video, the participants filled the DiSC profile test. DiSC is a personality test which classifies the tested person in one (or more) of these personality groups: Dominant (D), Inspiring (I), Supporter (S), and Cautious (C) [17]. Every participant answered a forced-choice questionnaire about his/her own behaviour. Answers to each question were given scores on a scale from 1 to 4. Overall scores were computed for questions relating to each personality type. The personality type with the highest score was chosen as the personality of the participant.



I_scary	Scary Pop-up Interval	Frames: 475 - 550
I_stress	Stress Analysis Interval	Frames: 400 - 625
I_variance	Pupil Diameter Variance Analysis Interval	Frames: 400 - 1000

Fig. 2. Description of the intervals in the video which are used to investigate the variance and the stress recovery ability behaviours.

In the first part of the data analysis stage, from each pupil, x,y,z coordinates of 8 points are detected by using OpenFace. We calculated the diameter of the pupil by fitting a circle to these 8 points in each frame. In the method of fitting a circle, we used the singular value decomposition (SVD) for the best fitting plane. After projecting the points onto this plane, we used the method of least-squares to fit a circle to the projected points.

Fig. 3 shows the 8 points from the pupil of a participant in different views. In the above figure, the 8 points are projected onto a plane, and a circle is fitted to these projected points. In the below figures, the 8 points are shown on three orthogonal views. In order to validate the pupil diameters, the shortest distances to the fitted planes of all the points are calculated. The maximum shortest distance was calculated as 0.078 mm which shows the error in the calculation of the pupil diameters is negligible. We then plotted the pupil diameter vs. frame graphs and labelled them with the corresponding DiSC personality. Only one of the pupils (right) is taken into consideration.

In the second part of the data analysis, we looked at the pupillary response graphs closer to study the responses in the interval I-stress. We observed three different pupillary behaviors. In order to simplify the representation in the further work, these behaviors are generalized as increasing, constant and decreasing pupil size as shown in Fig. 4. The three pupillary response graphs shown in the Figure are randomly selected among the participants to illustrate the three behaviors. They don't represent any personality groups.

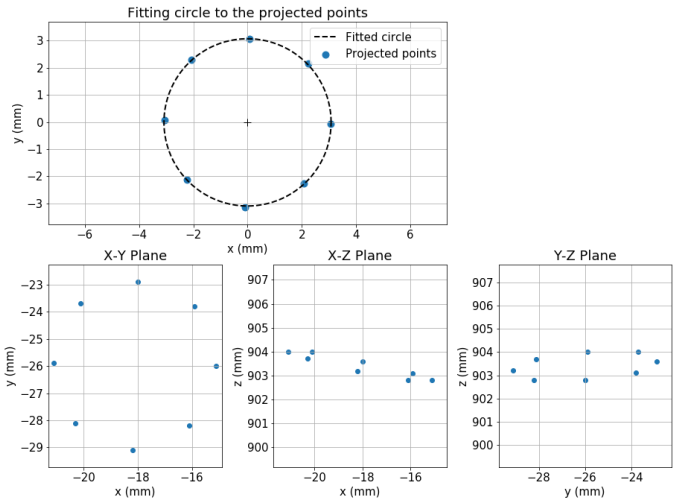


Fig. 3. Above graph shows fitting a circle to projected 8 points. Below graphs are showing the 8 points viewed from the three orthogonal views.

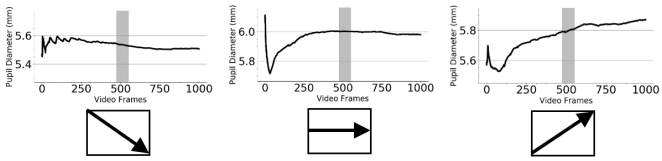


Fig. 4. Examples of the three different pupillary behaviors observed in the interval I-stress. The horizontal axis represents the frame sequence, and the vertical axis represents the pupil diameter (in mm).

IV. Results

This study is an initial effort towards studying the relationship between pupillary response, personality type, and stress recovery ability. In this Section, the results of the preliminary analysis of the pupillary response vs. frame graphs is presented.

Fig. 7 (on the last page) shows the pupillary response vs. frame graphs for all 13 participants, grouped based on the personality types determined by the DiSC profile test. Next to each pupillary response graph, the DiSC test results of the participant is shown. The interval where the scary pop-up took place is marked as a white window between the frames 475 and 550. For a better observation of the stress recovery ability, we investigated pupillary response between the frames 400 and 625 which includes the scary pop-up. According to the DiSC test results, there were one dominant, three inspiring, four supporter, and three cautious participants. Additionally, there were also two participants who belong to two groups: dominant-inspiring (DI) group and inspiring-supporter (IS) group.

The variances of the pupillary responses in the interval I-variance are shown in Fig. 5 for the six observed DiSC personality groups (including the two mixed groups; DI, IS). They are categorized into three intervals: $\sigma^2 < 1 \times 10^{-4}\text{mm}^2$ (small variance), $1{\times}10^{-4}\text{mm}^2 < \sigma^2 < 6{\times}10^{-4}\text{mm}^2$ (medium variance), and $\sigma^2 > 6 \times 10^{-4}\text{mm}^2$ (high variance). The inspiring and cautious groups had mostly the high variance domain, whereas the dominant and supporter groups had the small and middle variance domains. In the mixed groups (DI, IS), the pupillary responses of the participants were in the small variance domain.

In Fig. 6, the three different pupillary behaviors–increasing, constant, decreasing–are presented for the six observed DiSC personality groups (including the two mixed groups; DI, IS). The participant in the dominant group showed constant behavior in pupillary response in the interval I-stress. In the inspiring and cautious groups, both constant and decreasing behaviors were observed. In supporter group, all the three behaviours were observed. In DI group constant, and IS group increasing behaviours were observed. These results cannot be generalized because of the low number of participants. In the further experiments, stress recovery ability will be investigated independent from the personality groups.

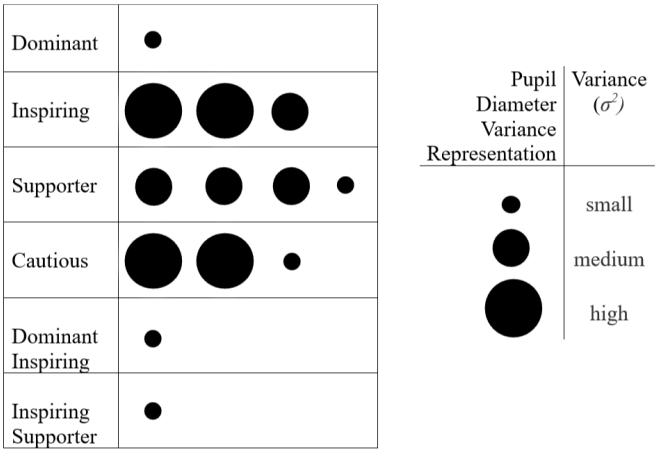


Fig. 5. Comparison of the variances in the interval I-variance for four personality groups. In the two mixed groups (DI, IS), the variances are shown on the white spaces between the four personality groups.

V. Conclusion

The overall results can be summarized as follows:

- The variance of pupillary response in the interval I-variance, the highest values were detected in cautious and inspiring groups. It had the smallest and middle values in the dominant and supporter groups.
- Three types of pupillary response behaviors are generalized from the pupillary response graphs in the interval I-stress: increasing, constant and decreasing.

Based on these results, a hypothesis regarding the relationship between the stress recovery ability and pupillary behavior is postulated: *A pupil constriction in the interval I-stress indicates a fast stress recovery ability through parasympathetic dominance, and a pupil dilation in the interval I-stress indicates a relatively slow stress recovery ability due to sympathetic dominance.*

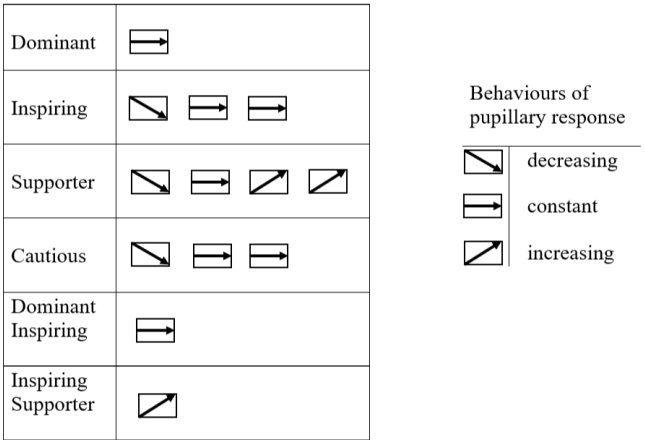


Fig. 6. Comparison of the pupillary behaviors in the interval I-stress. In the two mixed groups (DI, IS), the pupillary behaviours are shown on the white spaces between the four personality groups.

The study presented in this paper has an important limitation: Since this is a preliminary study, the number of participants is limited to 13. Further work will be required with high number of participants, to deduce a relationship between the pupillary response, the personality type and stress recovery ability, and to validate the above hypothesis. A more effective stimulus, additional personality tests, and self-report measures for stress and stress recovery levels will be used in the future experiment.

In the future work, more features will be extracted from the pupillary response vs frame graphs, and machine learning methods will be used to find the best feature set for the predicting stress recovery ability. These features will be extracted from both time and frequency domain of segmented graphs. Also, the exploitation and the exploration trade-off will be investigated in the pupillary responses of the participants.

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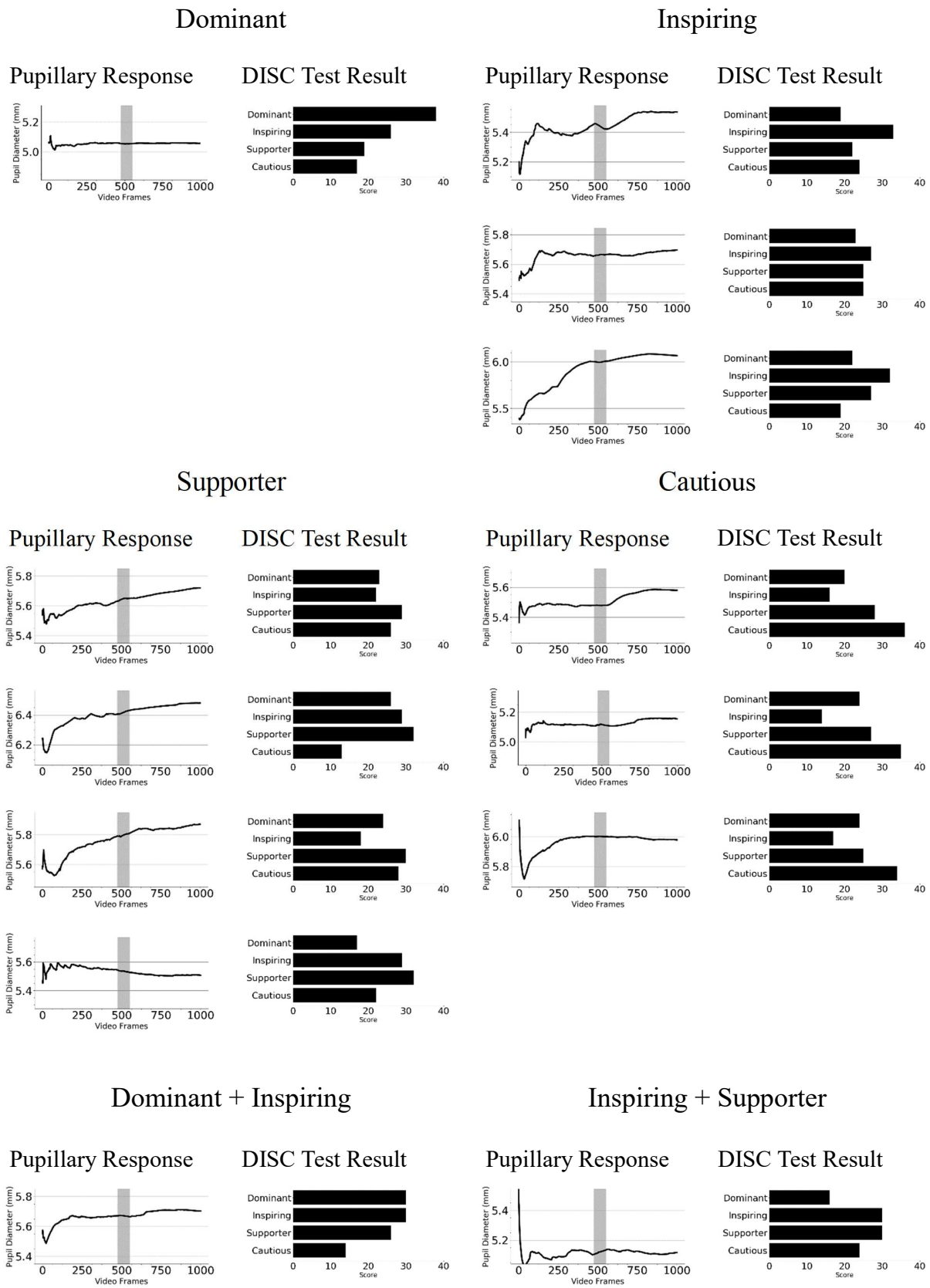

Fig. 7. Pupillary Response Graphs and DiSC Test Results for each of the 13 participants. In a pupillary response graph, the horizontal axis represents the frame sequence, and the vertical axis represents the pupil diameter (in mm). Scary pop-up occurs between the frames 475 and 550. In the DiSC Test Results, horizontal axis represents the scores of personality types.