Cap-2

NEUROTICISM AND THE EFFECT OF STRESS UPON THE PUPILLARY LIGHT REFLEX

by Louise M. A. Plouffe

Thesis presented to the School of Graduate Studies of the University of Ottawa as partial fulfilment of the requirements for the degree of Master of Arts

Ottawa, Canada, 1977

ABSTRACT

Neuroticism and the Effect of Stress upon the Pupillary Light Reflex[1]

The pupillary light reflex was used as a measure of autonomic reactivity in the investigation of Eysenckian Neuroticism and stress response. Thirty subjects were classified according to EPI scores into low, moderate, and high N groups. A series of 12 light stimulations of 2-second duration were presented in control, stress (cold pressor), and subsequent post-stress conditions while the light reflex was recorded pupillographically. Subjects then completed a pain rating scale. Latency to maximum constriction, extent and rate of constriction, and the magnitude and mean rate of redilation were measured.

Neuroticism was not related to any of the five aspects of the light reflex under control and stress conditions. In the post-stress period, N was associated with slower, less extensive constriction and redilation at $\underline{p} < .10$. The longest constriction latencies and largest extent of constriction were observed in the control condition, while converse trends were noted during post-stress. Neuroticism was not related to subjective pain ratings.

The Eysenckian hypothesis that high N scorers manifest more immediate, more intense, and more prolonged autonomic

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1 Louise M. A. Plouffe, Master's thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario, 1977, xi-92 p.

response to stress was not confirmed. These results are discussed in terms of the nature of the stressor, the possible over-generality of N, individual response specificity, and the appropriateness of the light reflex as an index of individual differences in autonomic reactivity. The effects of stress upon the light reflex were considered in terms of their congruence with the observations of Lowenstein and Loewenfeld (1961, 1969).

ACKNOWLEDGEMENTS

This thesis was prepared under the supervision of Dr. Robert Stelmack, of the Faculty of Psychology, University of Ottawa. I gratefully acknowledge his interest, guidance and support throughout all phases of the research.

I am further indebted to Mr. Edwin Achorn, of the Department of General-Experimental Psychology, and to Mrs. Ann Hurd, of the Department of Computer Science, for their assistance in preparing computer programs required for implementation of this project.

Gratitude is also extended to Dr. Lawrence T. Dayhaw, of the Faculty of Psychology, for his generous help in solving a statistical problem. Finally, I thank Dr. Yvonne L. Perrault, of the Department of Psychology, Concordia University, for proofreading the manuscript and for providing advice concerning thesis format and presentation.

CURRICULUM STUDIORUM

Louise Marie-Aline Plouffe was born December 16, 1952, in Noranda, Quebec. She obtained a Bachelor of Arts from the University of Ottawa in 1974.

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INTRODUCTION

Within the last quarter century, advances have been made in elaborating the biological basis of neurotic behaviour. Eysenck (1967) has proposed the theory that neurotics have a constitutionally lower threshold of hypothalamo-limbic arousal, manifested by a more immediate, more intense, and more prolonged sympathetic response to stress. Using psychiatrically diagnosed neurotic subjects, Rubin (1964, 1965a) examined pupillary adaptation to light and darkness as an index of autonomic reactivity under conditions of cold pressor stimulation. He observed differences between neurotics and normals in post-stress conditions only. The main purpose of the present study is to extend Rubin's research within an Eysenckian framework. The rationale for the use of the pupillary light reflex as a measure of autonomic responsiveness is based upon the description of pupillary mechanisms provided by Lowenstein and Loewenfeld (1969). The reflex action of the pupil to a sudden, brief increase in light intensity is a bi-directional response: parasympathetic activity is involved in the constriction movement and sympathetic activity in the subsequent redilatory movement. Of particular significance is the observation that heightened sympathetic activation produces an inhibition of the light reflex, characterized by slower, less extensive constriction and redilation. This thesis attempts to specify the components of the pupillary light reflex which differentiate neurotic groups in control, stress, and post-stress conditions.

In the first section of the thesis, the literature concerning differences in autonomic reactivity between neurotics and normals is reviewed. Attention is paid to Eysenck's bi-dimensional theory of personality and to research using the Neuroticism scale of the Eysenck Personality Inventory (EPI). The anatomy and dynamics of the pupillary response are described, and the pertinent psychological research is discussed. The statement of the hypothesis of the present study concludes the first chapter.

The experimental method and statistical design are presented in Chapter II. The subjects, psychological instruments, apparatus, and experimental procedure are described. The pupillary light reflex is scored along five dimensions: latency to maximum constriction, extent and rate of constriction, magnitude of redilation, and mean rate of redilation.

In the Results and Discussion chapters, the findings are presented and interpreted. The relationship between Neuroticism and the physiological and psychological measures is discussed. Finally, the observations of pupillary behaviour under stress conditions are compared with previous findings.

CHAPTER I

REVIEW OF THE LITERATURE

Autonomic Reactivity in Normal and in Neurotic Emotional Response

The psychophysiological research literature is replete with attempts to establish a biological basis for individual differences in normal and pathological personality functioning. These efforts are in accordance with the principle that an adequate explanation of human behaviour ought to account both for psychic and physical events. A particular focus of research in this area involves the relationship of differences in emotional behaviour with differential autonomic reactivity.

The initiation and coordination of the various responses associated with emotion are central nervous events in which an important role is played by the hypothalamus (Gellhorn & Loofbourrow, 1963). Cortical impulses arising, for example, from the perception of an external stimulus, trigger hypothalamic discharges which travel through the limbic circuit, activating specific subcortical nuclei as well as endocrine, visceral and muscular systems. Neural feedback from these systems passes through the reticular pathways and thalamus, and is integrated in the limbic circuit. Excitatory connections between the hypothalamus and neocortex permit the integration of somato-visceral activity with the cortical concept into the subjective interpretation of an internal state, that is, a felt emotion.

Generally, the hypothalamically stimulated autonomic discharges are sympathetic in origin, and are intended to mobilize the organism to vigorous, goal-directed activity (Lang, Rice & Sternbach, 1972). Increased adrenaline secretion produces faster, deeper breathing, dilation of the pupils, profuse perspiration, faster and harder pumping of the heart, and dilation of the blood vessels reaching the striated musculature. Blood vessels feeding the gastrointestinal tract constrict, resulting in increased vascular pressure, and the blood supply is reduced. Salivary secretion and visceral motility are inhibited.

While sympathetic discharge is common, the above pattern of ANS functioning is not invariable. The precise nature of autonomic activity depends upon the type of emotion as well as individual differences and situational factors. Gellhorn and Loofbourrow (1963) noted that sympathetic activity predominates in fear and parasympathetic activity in joy, while in other emotions, such as sex and aggression, both systems are mobilized. Averill and Opton (1968) have also stressed the importance of the quality of an emotion in the patterning of autonomic response. Lacey, Bateman and Van Lehn (1953) observed individual differences in the hierarchy of autonomic responses in stimulation; they found, moreover, that the consistency of hierarchical autonomic activation varied between individuals. Lacey (1967) demonstrated that varying physical parameters or other objective criteria of a stimulus situation, i.e., stimulus specificity, also exerts an influence on the pattern of autonomic activation.

From the evidence that autonomic correlates of emotion vary in accordance with the nature of the emotion, the responding individual, and the stimulus situation, it is clear that differences in personality are related to autonomic functioning. In particular, the clinical research relating neurotic disorder with physiological activity rests on the assumption that some form of physiological aberration underlies neurotic behaviour (cf. Alexander, 1972; Altschule, 1953; Gellhorn & Loofbourrow, 1963; Martin, 1971).

In many of the earlier studies, omnibus measures of physiological activity were used to locate differences in autonomic functioning between neurotics and normals. In an important, large-scale study, Wenger (1948) measured the physiological responses of over 800 subjects, among whom were army personnel suffering from operational fatigue, hospitalized psychoneurotics, and normal controls. It was found that, in contrast to normals, the neurotics and operational fatigue patients manifested higher levels of sympathetic activity on measures of salivary secretion, palmar conductance, blood pressure, sinus arrhythmia, heart period, cutaneous temperature, respiration period and tidal air mean.

Jost (1941) and, later, Sherman and Jost (1942) examined the overt motor behaviour and physiological reactions of 18 neurotic and 18 normal children during rest and during experimentally induced frustration. No differences between groups were observed with respect to motor and verbal behaviours. The measures which revealed the greatest differences between neurotics and normals were GSR, hand tremor, respiratory rate, and EEG activity. The authors concluded that the neurotic children were frustrated more easily and for a longer period of time than the normals.

A subsequent experiment conducted by Jurko, Jost and Hill (1952) investigated the mobilization, discharge, and recovery of the "energy system" in adult neurotics and normals. Measures of respiration, blood pressure, heart rate, skin conductance and overt muscle response were taken during a rest period, stress (presentation of the Rosenzweig Picture Frustration Study), and again following the termination of stress. The results for the neurotic group indicated a delayed but excessive energy mobilization during stress and a delayed post-stress recovery.

More recently, Muller, Presslich, Schuster and Zopotoczky (1974) examined the EEG, heart rate, respiratory rate, skin resistance, and blink rate of 32 mixed neurotic patients at rest and during exposure to verbal stimulation. The authors reported that some patterns of physiological response seemed to be linked to emotional disorder, although the conventional diagnostic categories were not associated with any typical pattern of physiological functioning.

Experimentation using single physiological indices has yielded results similar to those of multi-measure studies, despite the response-specificity factor. Using cardiographic indices, White and Gildea (1937) reported that anxiety patients manifested greater increases in heart rate than normals to cold pressor stimulation. Aitken, Zealley and Rosenthal (1969) found higher resting heart rates in neurotics. Freeman and Katzoff (1942) observed in neurotics a greater skin conductance increment during a mildly arousing performance task, and a slower recovery to homeostasis. Van der Merwe (1948) found neurotics to be more labile than normals in peripheral vasomotor response. The palmar skin resistance of anxiety-state patients and normals was recorded by Lader and Wing (1964). A greater occurrence of spontaneous fluctuation and a much slower habituation to auditory stimulation were demonstrated in the anxiety-state group. The authors also reported a high positive correlation between the degree of overt anxiety and physiological activity.

Of special relevance in the area of differential autonomic reactivity is the work of Malmo and Shagass. Using electromyographic indices, Malmo, Shagass, Belanger and Smith (1951) and Malmo, Shagass and Davis (1951) observed that neurotics tended to exhibit greater covert muscle tension and less adaptation during stress than normals. An investigation of the blood pressure response, conducted by Malmo, Shagass and Heslam (1951), revealed that under cold pressor conditions, the initial blood pressure of both neurotics and normals rose; however, with continued stimulation, the response of the normal subjects decreased while the response of the neurotics persisted at the initial level. These results were confirmed in a subsequent study performed by Malmo and Shagass (1952).

Kelly (1966) examined the heart rate, forearm blood flow and blood pressure of 40 mixed neurotics, 20 anxiety neurotics, and 40 normal controls during basal and stress conditions. The anxiety neurotics manifested the highest basal forearm blood flow and heart rate. The greatest increases on all measures during stress were shown for the normal group; the anxiety group exhibited the least change in autonomic response during stress. Kelly concluded that the extent of autonomic reactivity was in part determined by the basal levels, and that further research should focus on basal autonomic functioning rather than on differences in reactivity.

The pupillometric research conducted by Rubin (1964, 1965a) ought to be highlighted, partly because the procedures have been adopted by others, but primarily because Rubin's method and conclusions have influenced the rationale and design of the present study. Rubin observed the homeostatic recovery patterns of neurotics and normals by measuring pupillary adaptation to light and to darkness. Pupil dilation in darkness was conceived as an index of adrenergic (sympathetic) activity, and pupillary constriction in response to light was used as a measure of opposite cholinergic (parasympathetic) functioning.

In the 1964 study, Rubin took successive photographic measurements of pupil constriction and dilation for 11 neurotic patients and 11 normals during rest, cold pressor stimulation, and then immediately after stress. The stress period lasted two minutes, and the post-stress period, 20 minutes. The results of analysis of variance indicated no differences between neurotics and normals in the rate of dilation to darkness or the rate of constriction to light during the pre-stress period; during stress, both groups reacted with a similar increase in adrenergic outflow (i.e., faster dilation in darkness) and diminished cholinergic outflow (i.e., inhibited constriction response to light). Following the cessation of stress, however, the dilation rate of normals returned almost immediately to pre-stress levels. The neurotic group manifested a dilation rate characteristic of stress for 7 minutes after the termination of the cold pressor stimulation; the dilation rate then briefly declined to pre-stress levels, and rose again to stress levels. Conversely, the constriction rate of normals gradually increased during the post-stress period while the constriction rate of neurotics showed an erratic pattern of sharp increase, then rapid reduction of rate. Rubin concluded from this experiment that:

> in contrast to normals, the neurotic individuals following the termination of painful stimulation, continued to manifest a sustained pattern of increased adrenergic outflow and decreased cholinergic outflow which was characteristic of their response to noxious stimulation (p. 573).

In a subsequent study, Rubin (1965a) measured the pupillary adaptation to light and darkness while subjecting neurotics and normal controls to prolonged food deprivation. Both groups showed increased hunger drive (dominant adrenergic outflow) during the first 15 hours of fasting. The hunger drive decreased thereafter in the normals, but the neurotics continued to manifest increasing drive after 15 and 23 hours. Again, it was concluded that neurotics were characterized by abnormally long stress responses.

The findings obtained by Rubin (1964, 1965a) have not been conclusively supported by later studies in which his procedures were utilized. McCawley, Stroebel and Glueck (1966) found that the variability of both dilation and constriction responses increased with age; the study therefore failed to confirm any relationship between pupillary response and neurotic disorder. Apley, Haslam, and Tulloh (1971) tested the autonomic reactivity of 16 children with recurrent psychosomatic pain, 14 children with various behaviour problems, and 20 normal children. No significant differences between groups were found under stress conditions; however, the behaviour problem group tended to exhibit the smallest dark-adapted pupil size (i.e., in Rubin's terms, the least adrenergic outflow), and the least change from pre-stress measures of dilation. The post-stress results were similar to Rubin (1964) in that the normal children showed rapid recovery to pre-stress pupillary dilation rate, and the behaviour problem children manifested an unstable pattern of recovery. The psychosomatic group showed delayed recovery of pupillary dilation.

From the studies cited, general conclusions may be drawn concerning the nature of the autonomic response observed in neurotic individuals. Neurotics have been shown to have higher or more labile baselines of autonomic activity (Kelly, 1966; Lader & Wing, 1964; Theron, 1948; Van der Merwe, 1948; Wenger, 1948). They also have been found to manifest more immediate autonomic arousal to stimulation (Sherman & Jost, 1942), as well as more extensive arousal and/or delayed reduction of sympathetic activity (Apley et al., 1971; Altschule, 1953; Freeman & Katzoff, 1942; Jurko, Jost & Hill, 1952; Lader & Wing, 1964; Malmo & Shagass, 1952; Malmo, Shagass & Davis, 1951; Malmo, Shagass & Heslam, 1951; Rubin, 1964, 1965a; Shagass, Belanger & Smith, 1951; Sherman & Jost, 1942; White & Gildea, 1937).

A major hypothesis which has arisen from many of these studies proposes the existence of a deficient regulatory mechanism as the underlying cause of the excessive autonomic arousal to stress and delayed homeostatic recovery exhibited by neurotics. An early formulation of this notion was that of Freeman and Katzoff (1942), who contended that neurotics were characterized by a slower recovery quotient, that is, an impaired ability to regain homeostasis after emotional stress. Similarly, Rubin (1965b) advanced the concept of an inefficient drive reduction mechanism operative in neurotic disorder. Malmo and Shagass (1952) have suggested that "deficient regulation in psychoneurosis may occur in both autonomic and central nervous systems" (p. 9). Gellhorn and Loofbourrow (1963) have specified the hypothalamus as the locus of differential autonomic excitability. The most recent development of this hypothesis is Kraines' (1969) description of hypothalamic functioning in the neurotic emotional response:

> The imprinted patterns of the hypothalamus and emotional circuit are not only easily triggered, but they continue to respond--indeed to over-respond. Long after the stimulus has disappeared the patterns continue to operate, to reverberate, and to generate the excessive flow of biologic emotion (p. 286).

The concept of a deficient central regulation may be related to Selye's (1956) theory of the General Adaptation Syndrome. The initial sympathetic alarm reaction to a stressor is normally followed by specific local adaptation, whereby the stress is delimited to the smallest area capable of meeting the demands of a situation. The deficient regulation posited to underlie neurotic over-responsiveness could thus be understood as an inefficient transition from general alarm to specific local adaptation.

Eysenck's Bi-dimensional Theory of Personality

By means of factor analysis, Eysenck (1967) has identified the two orthogonal personality dimensions of extraversion-introversion (E) and neuroticism-stability (N), and has constructed the Eysenck Personality Inventory (EPI) to measure individual differences on each dimension (Eysenck & Eysenck, 1968). A distinction in neurological functioning is postulated to be the basis of the behaviours and psychophysiological response patterns subsumed under each type-level concept. The excitation-inhibition balance of the cortico-reticular network is hypothesized to underlie extraversion-introversion, while differential thresholds of excitation in the hypothalamo-limbic structures are thought to mediate neuroticism-stability. A high EPI N score implies a low tolerance for stress, both physical and psychological. Neurotic individuals thus tend to over-react emotionally and to have difficulty in recovering equilibrium following an emotional experience. Eysenck (1967) concedes the existence of a partial dependence between the two neurological systems: emotional activation is dependent upon cortical arousal, but cortical arousal need not involve emotional activation.

The distinction between cortical and subcortical arousability applies to a normal population for whom extraversion and neuroticism scores are statistically independent. However, Eysenck's (1967) observation that among high neuroticism scorers, extraversion scores tend to be quite low has led to the conclusion that for very emotionally labile individuals, mild stimuli trigger emotional activation as well as general cortical arousal. The confluence of high-neuroticism low-extraversion is thought to constitute the anxiety dimension of dysthymia. Eysenck (1967) has noted that the frequent use of hospitalized dysthymics in whom anxiety is a prominent feature likely results in a confounding of the contributions of extraversion and neuroticism in the experimental findings. This criticism would be particularly applicable to Rubin's (1964, 1965a) work, since the neurotic sample used in these studies consisted of a majority of dysthymics (e.g., anxiety neurotics, depressives, obsessive-compulsives, and phobics). Within an Eysenckian framework, therefore, it might be necessary to differentiate the extraversion and neuroticism dimensions when examining the physiological correlates of neurotic behaviour.

In contrast to psychiatric diagnosis, psychometric classification provides a standardized assessment of behaviour. Eysenck (1968) reported significantly higher mean neuroticism scores for 120 psychiatrically diagnosed neurotics than for a population of 200 normals. Significant agreement between psychiatric diagnosis and EPI neuroticism scores was obtained by Hosek (1974) who administered the EPI to 185 hospitalized psychoneurotics. Thus, there seems to be sufficient justification for using the Eysenckian dimensions to examine the autonomic correlates of neurotic emotional response.

An important study relating Eysenckian dimensions to psychiatric classification and to autonomic functioning was undertaken by Kelly and Martin (1969). The subject population consisted of three equal groups of 20 persons categorized as anxiety neurotics, mixed neurotics, and normal controls. The Maudsley Personality Inventory (MPI) was administered; subjects were then required to solve a difficult arithmetic problem while being harassed and criticized. During this stressful period, forearm blood flow, heart rate, and blood pressure were measured. The MPI results indicated that anxiety neurotics had the highest neuroticism (N) scores; the mixed neurotic group obtained the next highest N scores; and the normals obtained the lowest scores. Moreover, anxiety neurotics also scored lowest on extraversion, thus confirming the dysthymic dimension postulated by Eysenck (1967). On physiological indices, the anxiety neurotics manifested the highest basal levels of autonomic activity and the least reactivity to stress, even when the initial levels were partialled out. Normals were observed to have the greatest autonomic reactivity to stress. The mixed neurotic group exhibited basal activity comparable to that of normals, and moderate reactivity under stress conditions. A low correspondence was found between self-ratings of anxiety obtained before and after stress and physiological responsiveness. The authors drew conclusions similar to those of Kelly (1966); that is, persistent overarousal among anxiety neurotics may inhibit maximal autonomic activity during stress. It was also concluded that basal autonomic activity, not autonomic reactivity to stimulation, is related to MPI questionnaire measures in a Neuroticism/Anxiety factor.

Burdick (1966) investigated the basal galvanic skin response (GSR) activity of 27 normals classified as emotionally labile or stabile along the N dimension of the MPI. The results failed to confirm any relationship between neuroticism and basal autonomic functioning. Martin (1960) also previously observed no relationship between neuroticism and resting GSR activity, but questioned the reliability of the GSR as a measure of autonomic activity.

Habituation of the orienting reflex (OR) to repeated stimulation has been used as a measure of physiological responsivity in relation to neuroticism and extraversion. Coles, Gale and Kline (1971) failed to find a relationship between either neuroticism or extraversion and tonic skin conductance; however, high N scorers were found to habituate more slowly and to give more phasic responses to stimulation than low scorers. Somewhat contradictory results were obtained by Sadler, Mefferd and Houck (1971) who observed that low N subjects responded more frequently to stimuli and showed slower habituation than high N subjects. These results supported the earlier findings of Fried, Friedman and Welch (1967).

Interaction between neuroticism and extraversion in GSR was demonstrated by Mangan and O'Gorman (1969), who concluded that initial GSR amplitude is primarily related to neuroticism, and habituation to extraversion. However, Crider and Lunn (1971) reported that habituation of the OR was unrelated to neuroticism and negatively related to extraversion when the spontaneous fluctuation rate and speed of habituation were measured for 22 subjects. Finally, Koriat, Averill and Malmstrom (1973) failed to observe any relationship between individual differences in habituation rate and either neuroticism or extraversion.

Interactive patterns between extraversion and neuroticism have been shown on measures of neocortical activity unrelated to autonomic functioning. In the experiment conducted by Winter, Broadhurst and Glass (1972), extraversion influenced the relation between neuroticism, EEG amplitude, and alpha rhythm. Savage (1964) showed, on the contrary, that neuroticism had a moderating effect on the relation between extraversion and EEG activity. The influence of neuroticism also has been reported in research relating extraversion with perceptual sensitivity as measured by the spiral after-effect (Feij & Orlebeke, 1974; Kroncks & Krasner, 1965; Levy & Lang, 1966).

Observation of drug effects is another means by which the relationship between Eysenckian dimensions and physiological responsiveness has been studied. A series of studies conducted by Claridge, Wawman and Davies (1963) examined the physiological measures associated with extraversion (i.e., sedation threshold and spiral after-effect) and those related to neuroticism (i.e., blood pressure). Under the effects of parasympathetico- and sympatheticomimetic drugs, and cold pressor stimulation, sedation threshold and blood pressure were found to be positively related. The authors concluded that extraversion and neuroticism may not, in fact, be independent neurological dimensions.

Rodnight and Gooch (1963) demonstrated an interaction between MPI neuroticism and extraversion in the determination of susceptibility to a central nervous depressant (nitrous oxide). The results indicated that the value of neuroticism as a predictor of drug susceptibility increased as the extraversion score increased.

Meikle (1970) tested the hypothesis advanced by Eysenck (1960) that injection of a sympatheticomimetic drug would result in an increase in the EPI neuroticism score. Despite the increase in sympathetic activity observed after drug administration, no significant increases in neuroticism scores were reported.

Of particular relevance to the present study is the research relating neuroticism and extraversion to measures of pain response and frequency of blinking as an index of muscle tension. With respect to pain response, Lynn and Eysenck (1961) tested the hypothesis that the strength of the autonomic reaction to painful stimulation was related to neuroticism by applying radiant heat to subjects classified according to N and E scores. They reported that non-neurotics and extraverts exhibited greater pain tolerance than neurotics and introverts. In contrast to these findings, Davidson and McDougall (1969) failed to show any relationship between N or E and tolerance for pain demonstrated in a variety of stimulus conditions, including the cold pressor, radiant heat, skin pressure and electric shock. These results were replicated by Brown, Fader and Barber (1973).

Ocular muscle tension was measured by Franks (1963), who reported a positive correlation between extraversion, blink rate and spontaneous eye movements. Harris, Thackeray and Schoenberger (1966) found a significant positive relationship between neuroticism and blink rate during resting conditions and during induced muscular tension.

In summary, the research relating Eysenckian dimensions to physiological responsiveness has not, to date, yielded incontrovertible results. Relationships have been demonstrated between certain physiological responses and the Eysenckian dimensions, either singly, or in interaction. Nevertheless, there is also evidence which disconfirms any association between neuroticism and/or extraversion and physiological responsiveness.

The Pupillary Response

In recent years, pupillometry has proved to be an effective technique in the psychological study of psychosensory functions, cognition, and emotion (Goldwater, 1972; Hess, 1972; Janisse, 1973). Measurement of the pupillary response may therefore be useful for examining hypotheses related to differential neurological functions mediating Eysenckian neuroticism and extraversion.

The iris is reciprocally innervated by the autonomic nervous system. The smooth fibres of the pupillary sphincter surrounding the pupil are activated by parasympathetic impulses transmitted via the ciliary ganglion; the converging radial strands of the dilator pupillae are innervated by sympathetic nerve fibres originating in the superior cervical ganglion. Dilation of the pupil in darkness involves sympathetic activity, whereas the constriction response to light is mediated by parasympathetic impulses. The pupillary light reflex, that is, the response of the pupil to a sudden, brief increase in light intensity, is a bi-directional response: both branches of the ANS are operative in the constriction and redilation movements.

The neurological dynamics of the pupillary light reflex have been described in detail by Lowenstein and Loewenfeld (1969). Afferent light reflex impulses travel from the retina via the optic nerve, cross in the optic chiasm, then pass through the optic tract. The impulses emerge from the posterior third of the tract and course by way of the brachia of the anterior colliculi to the pre-tectal area where they synapse with cells of the pre-tectal nucleus. Pre-tectal fibres carry the light reflex impulses to the anterior portion of the oculomotor nucleus. Efferent sympathetic impulses arising in the neocortex, thalamus, and hypothalamus pass via the cervical cord and superior cervical ganglion to the peripheral sympathetic chain, and then are transmitted to the dilator pupillae. Efferent parasympathetic messages course from the oculomotor nucleus to the iris sphincter. Inhibition of constriction (i.e., parasympathetic activity) is a central nervous event, with the interfering impulses converging upon the oculomotor nucleus from higher brain centres and from afferent connections in the reticular formation. These impulses prevent the oculomotor nucleus from sending constrictor impulses to the pupillary sphincter. In other words, inhibition of the pupillary light reflex is not due to sympathetic excitation of the pupillary sphincter, but rather to central parasympathetic inhibition.

Lowenstein and Loewenfeld (1950) have found that in all species, pupillographs of the light reflex manifest the same characteristics. From the onset of light stimulation to the initial moment of constriction, there is a latency period of about 0.2 seconds. Constriction consists of two phases: a fast, ascending primary, and a slower, descending secondary phase. Similarly, redilation consists of a rapid initial movement followed by a second, negatively accelerating movement. The brief ascending period of constriction is due primarily to parasympathetic activity; the descending motion is caused by parasympathetic reflex activity moderated by increasing sympathetic opposition. The rapid redilatory phase reflects parasympathetic relaxation; the slower redilation motion is due to peripheral sympathetic activity.

Optimal light reflex response is contingent upon the balanced functioning of both autonomic branches. Lowenstein and Loewenfeld (1950) have concluded from their research that the parasympathetic element is essential for the appearance of the light reflex, and the sympathetic factor determines its shape. Weakening of the PNS tonus produces inhibition of the light reflex, characterized by sluggish and inextensive constriction and redilation. A decrement in SNS influence results in a disinhibition of the light reflex, manifested by a shortened latency and possible increase in the extent of constriction. Conversely, strengthening of either PNS or SNS tonus produces an inhibition of the light reflex. It is noteworthy that reflex inhibition results from experimentally induced weakening and strengthening of PNS tonus. As yet, no explanation has been offered for this paradox.

Environmental conditions and internal states have been found to affect the light reflex. Under conditions of high intensity light stimulation, constriction and redilation are more extensive and sustained; low intensity stimulation results in an increased latency period, slower constriction and premature redilation (Lowenstein & Loewenfeld, 1952). Repeated exposure to light stimulation brings about pupillary fatigue, shown in an inhibition of the light reflex; however, the exhausted reflex can be quickly reintegrated through psychosensory stimulation (Lowenstein & Loewenfeld, 1952). Subjection of alert individuals to sensory or emotional stress results in an enlargement of the pupil diameter and inhibition of the light reflex; complete suppression may occur if the interfering stimulus is sufficiently strong (Lowenstein, Feinberg, & Loewenfeld, 1963).

Pupillary reactivity to light has been found to vary with age: in persons under 35 years the resting pupil measures more than 7 mm and spontaneous fluctuations do not exceed 0.5 mm. With increasing age, the pupil decreases in diameter, and shows greater spontaneous variability (Lowenstein et al., 1963). Of special relevance to the present research is the observation that hyperexcitable subjects tend to have larger dark-adapted pupils and less extensive light reflexes than calm subjects even in resting conditions (Lowenstein & Loewenfeld, 1961).

Research Relating Pupillary Response to Extraversion and Neuroticism

Within the last decade, the pupillary response has been used as a dependent variable in testing hypotheses related to extraversion and neuroticism. With respect to extraversion, Hess (1972) reported that introverts demonstrate more definite pupil responses than extraverts. Holmes (1967), using procedures similar to Rubin (1964), observed that introverts manifest a significantly faster rate of pupillary constriction to light. Somewhat contradictory results were obtained by Stelmack and Mandelzys (1975), who found that introverts show a greater magnitude of dilation in response to neutral, affective, and taboo words.

Studies relating various measures of anxiety to pupillary responsiveness are worth mentioning, although the lack of clear distinction in the contribution of neuroticism and extraversion to anxiety invites a cautious interpretation of the results. Arima and Wilson (1972) investigated the effects on pupillary response of situational stress (Stroop test) and MAT measures of 30 males. It was observed that dilation occurred concomitantly with stress, and continued during a subsequent post-stress period, particularly for low-anxiety subjects. High anxiety subjects initially responded to stress in a similar way, but adapted quickly and became minimally responsive. The authors concluded that the reactions of the low anxiety group were manifestations of normal arousal, while the inhibition shown by the high-anxiety group was a defensive reaction to threat. Adams (1968) classified subjects according to the IPAT Anxiety Scale in examining the relation between anxiety and pupil response under conditions of noxious auditory stimulation. No significant differences were observed in the pupil responses of high and low anxious persons.

Specific use of EPI dimensions has not yielded a definite relation between neuroticism and pupillary responsivity. Holmes (1967) failed to observe any differences in pupil size between high and low neuroticism scorers under non-stress conditions. However, Francis (1969) and Francis and Kelly (1969) found a statistically significant relationship between extent of pupil dilation to auditory word stimuli and N scores.

Both extraversion and neuroticism were related to pupillary activity in the research conducted by Boddicker (1972). Neither dimension was found to be reflected in the pupil response to neutral, positive, and negative affect word stimuli, although there was a tendency for low neuroticism and low extraversion to be associated with high pupillary activity. In his conclusions, Boddicker questioned the adequacy of the EPI in identifying individual differences in autonomic reactivity, and emphasized the need for concurrent use of other physiological indices.

Studies linking neuroticism and pupillary response have, to date, observed changes in pupil size independent of changes in illumination, or the adaptation response to light and darkness. There is no precedent for the use of the pupillary light reflex as a dependent measure in examining the association between EPI neuroticism and autonomic lability.

Summary and Statement of Hypothesis

The autonomic components of emotional response have been found to depend upon individual and situational factors, and are hypothesized to underlie individual differences in personality. Differential autonomic responsivity between neurotic and normal persons has been demonstrated on a variety of physiological indices. In general, the research results indicate that neurotics possess greater autonomic lability, which is manifested in higher levels of basal activity, more immediate, more intense and/or more prolonged autonomic responses to stressful stimulation. In addition, neurotics have been shown to differ from normals on electromyographic and blink rate measures. Interestingly, despite differences in physiological responsiveness, neurotics and normals have not been found to differ on subjective measures of stress.

Eysenck (1967) has advanced a bi-dimensional theory of personality according to which individual differences in extraversion and neuroticism as measured by the EPI are biologically based. However, experimental investigation of the theory has not conclusively shown functional distinctions in physiological responsivity in relation to neuroticism and extraversion.

Pupillometry may be a valuable technique for investigating individual differences in physiological responsiveness in relation to extraversion and neuroticism, since the pupil reflects psychosensory, cognitive, and emotional activity. Research in which changes in pupil size independent of illumination or pupillary adaptation to light and darkness have been used as dependent variables has not yielded definitive results with respect to Eysenckian personality dimensions. The pupillary light reflex has not yet been applied to this problem. The rationale for its use rests on evidence that sympathetic disruptions resulting from stressful stimulation produce an inhibition of the light reflex, seen in slowed and inextensive constriction.

The principal aim of the present study is to examine differences in autonomic reactivity reflected in the pupillary reflex to light within the context of Eysenckian theory. The following hypothesis is therefore advanced.

If, as Eysenck contends, individuals high on neuroticism are characterized by a lower threshold of limbic activation, under stress conditions where impulses from the limbic system are intensified, these individuals will exhibit a faster and more extensive inhibition of the pupillary light reflex than will moderate and low neuroticism scorers. Inhibition will be evident in longer latencies to constriction, as well as slower and less extensive constriction. Inhibition will also persist for a longer time after the cessation of stress for the high neuroticism individuals. Moreover, the high neuroticism group will exhibit a larger resting pupil size and a greater frequency of eyeblinks than moderate and low neuroticism groups. It is also expected that on a subjective measure of stress response, individuals who report themselves to be more neurotic on the EPI will report a greater experience of stress than persons who report themselves to be moderately emotional or unemotional on the EPI.

CHAPTER II

METHOD

Subjects

The subject population consisted of male undergraduate and graduate students of the University of Ottawa who had obtained moderate extraversion scores (8 - 15) on Form A of the Eysenck Personality Inventory (EPI). Selection of 30 subjects from this pool was made with the aim of ensuring a broad range of neuroticism scores (0 - 21). Subjects ranged in age from 18 to 29 (mean age 21.8; standard deviation 2.7). All were screened by verbal inquiry for intake of stimulant or tranquilizing drugs. Participation was voluntary and was solicited by telephone or by personal contact.

Psychological Instruments and Apparatus

Eysenck Personality Inventory (EPI). The EPI is a self-report questionnaire, comprised of 57 "yes" or "no" items requiring approximately 15 minutes to complete. The personality dimensions of extraversion-introversion (E) and neuroticism-stability (N) are each measured by 24 questions, with the remaining 9 items constituting a "Lie Scale." Form A of the test was used for initial selection of subjects and Form B was administered after the experiment in order to assess the reliability of N and E scores and also to allow for regression of extreme N scores in dividing subjects into low, moderate, and high N groups.

The test norms used in this study have been established on a normal English population (Eysenck & Eysenck, 1968). For Form A, the mean E score is 12.1, with a standard deviation of 4.4; the mean N score is 9.0, with a standard deviation of 4.8. For Form B, the mean E is 14.2, the mean N is 10.5, and the corresponding standard deviations are 3.9 and 4.7, respectively.

On the basis of the combined Form A and Form B neuroticism scores, subjects were placed into three equal groups of 10. The range of scores in the Low N group was 2 to 11 (mean, 7.5; standard deviation, 3.14); Middle N scores ranged from 17 to 26 (mean, 20.3; standard deviation, 2.75); the High N range was 27 to 43 (mean, 34.6; standard deviation, 5.17). Reliability was found between EPI Form A and Form B neuroticism and extraversion scores, respectively. The reliability coefficient for N was +.84; for E, a coefficient of +.51 was found. This lower correlation likely reflects the restriction of E scores to the ambivert range. Neuroticism and extraversion were not related on Form A (r = -.03, NS) or on Form B (r = -.14, NS).

Cold Pressor Questionnaire. Designed by Wood (1975), this questionnaire consists of four subjective measures of pain intensity rated along an 11-point scale and was used to determine the subjects' experience of the cold pressor pain. Of the four measures, only two were used in this research: the rating of the most intense pain felt (question 2) and the rating of the average intensity of pain felt (question 4).

Pupillometer System. The dependent measures of the pupillary light reflex, the resting pupil size, and the frequency of eyeblinks were recorded on a pupillometer system, Model V-1165, manufactured by the Polymetric Company. The system components include a stage on which are mounted a rear-projection screen, a head and chin rest, an eyelamp covered by an infra-red filter, and an image transducer. A video monitor equipped with an electronic overlay displayed the image of the pupil. Monitoring and recording of the pupil diameter was controlled by an analyzer unit. Pupil diameter was recorded on a Watanabe Multicorder, MC611, with a pen sweep of 10 inches, run at a speed of 600 mm per minute. A metal testplate with a bored hole of 5 mm was used for calibration.

Three-Channel Tachistoscope. A three-channel tachistoscope, Model GB, manufactured by the Scientific Prototype Corporation, was employed to present light stimuli. The pupillary light reflex was elicited by repeated exposures of a white illuminated surface 6 inches in diameter having a luminance of 2.5 ft. candles, presented for a 2-second duration with a 10-second interstimulus interval. The stimulus duration was sufficiently brief to prevent retinal adaptation to light (Lowenstein, 1961), and the 10-second interval permitted full redilation of the pupil to pre-exposure size.

Cold Pressor Apparatus. Physiological stress was induced by means of a cold pressor apparatus consisting of a 24" long X 14" wide X 11" deep Staycola styrofoam cooler, inside which was taped a standard outdoor thermometer and an aquarium air pump. The cooler was filled with ice water maintained at a temperature of 0° to 6° C. A towel was provided to dry the subject's hand after immersion.

Procedures

Experimental Procedure

Experimentation was conducted between 9:00 a.m. and 12:00 a.m. in order that the subjects be rested and alert to avoid the effects of fatigue on pupillary measurements (Lowenstein & Loewenfeld, 1969). The operation of the pupillometer was described briefly to each subject, after which he was instructed to seat himself in a small, darkened, and sound attenuated room with his head comfortably positioned on the chin rest and his gaze fixed upon the screen directly in front of him. Once a satisfactory image of the pupil was obtained on the video monitor, the test plate was inserted for calibration. The subject then resumed his position. He was instructed to fix an imaginary spot on the screen and to inhibit his blinking as much as possible. Pupil size was recorded at a chart speed of 300 mm per minute for a period of 5 minutes, during which the pupil reached a stable, dark-adapted size.

Control Condition. Subjects underwent a non-stress, control condition in order to obtain baseline measures of individual pupillary responsiveness to light. Following the 5-minute stabilizing period, the light stimulus was presented for 12 trials. In instances where the light reflex recordings were spoiled either by intrasystem disruptions or by blinking, additional stimuli were presented in order to obtain 12 scorable trials.

Stress and Post-Stress Conditions. On a second morning within the same week, the subject returned for the experimental session. Once calibration procedures were completed, the subject was told that after the initial 5-minute adaptation period, the box window of the experimental chamber would be moved slightly as a signal for him to immerse his left hand up to the wrist in the ice-water. The light stimuli would then be presented. After approximately 2 minutes (or 12 scorable trials), the window would be moved again to signal him to remove his hand from the water, dry it with the towel, and to resume his position for the presentation of additional light stimuli. The subject was reassured that the water, though cold, would not harm his hand.

Experimentation was begun when the subject clearly understood the procedure. The dark-adaptation period was followed by 12 stress trials, during which the hand was immersed in the ice-water. After the subject had dried his hand and readjusted his position (a delay of about 1 minute or less), 12 post-stress trials were presented in the same manner. When the pupillary measurements were terminated, each subject completed the EPI Form B and the Cold Pressor Questionnaire.

Scoring Procedure and Statistical Analysis

The pupillary light reflex was subdivided into five measures. A diagrammatic illustration of these measures is presented in Figure 1. (1) The latency to maximum constriction was measured in seconds from the moment of the onset of stimulation to the minimum constricted pupil diameter. (2) The extent of constriction was defined in terms of the difference, in millimeters, between the pre-stimulus pupil diameter and the minimum constricted diameter. (3) The ratio between extent and latency, expressed in millimeters per second, constituted the measure of constriction rate. (4) The largest pupil diameter reached during the interval following the offset of stimulation was recorded as the

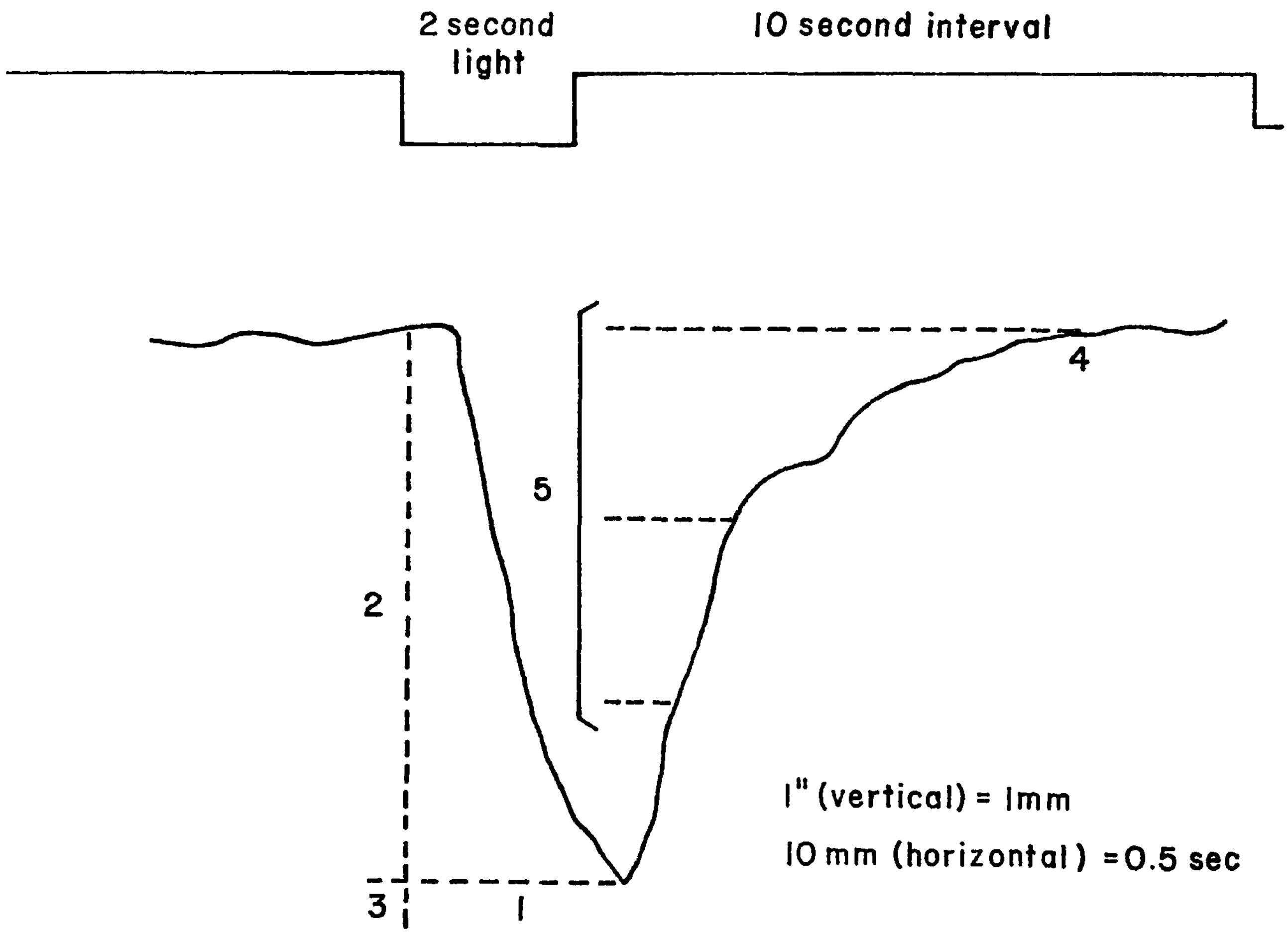

Figure 1. Pupillograph of the light reflex.

1. latency to maximum constriction
2. extent of constriction
3. rate of constriction
4. magnitude of redilation
5. mean rate of redilation

measure of maximum redilation. (5) Since redilation occurred along a negatively accelerating curve, the rate of redilation was calculated per millimeter of increase in pupil size up to the maximum redilated diameter; these values were averaged to obtain the mean rate of redilation.

In addition to these five measures of the light reflex, the magnitude of the resting pupil obtained during the two 5-minute adaptation periods was measured, and a frequency count of eyeblinks (spiked deflections of the pen to zero or near zero level) was recorded during the control, stress, and post-stress periods.

A three-factor analysis of variance with repeated measures on the last two factors (Winer, 1962) was applied to each of the five dependent measures of the pupillary light reflex. The first factor, Neuroticism (A), was subdivided into low, middle, and high levels. The experimental conditions, i.e., control, stress, and post-stress, constituted the three levels of the Stress factor (B). The presentation of the light stimulus in 12 trial blocks was the Trials factor (C). Analysis of variance was also employed for measures of the resting pupil size, eyeblink frequency, and the Cold Pressor Questionnaire. Where the F ratio was found to be statistically significant at the .05 level, the Newman-Keuls post hoc procedure (Kirk, 1968) was used to test for significant differences between means. The .05 level was also adopted for post hoc tests. Pearson correlation coefficients were also computed to provide an additional description of the magnitude and direction of relationships between neuroticism and the components of the pupillary light reflex.

CHAPTER III

RESULTS

Analysis of Pupillary Light Reflex Measures

Extent of Constriction. As shown in Table 1, analysis of variance on extent of constriction measures failed to demonstrate statistical significance on the Neuroticism and Stress factors. Significant main effects on the Trials factor, and a significant Stress X Trials interaction were observed. The Neuroticism X Stress and Neuroticism X Trials interactions were nonsignificant. The mean extent of constriction values obtained over the 12 trials in each stress condition are graphically presented in Figure 2. During the control period, the extent of pupillary constriction to light was found to be consistently greater than during the stress and post-stress periods. Moderate constriction was observed during stress; the least amount of constriction was noted during the post-stress period. The Newman-Keuls test demonstrated a significantly ($p < .05$) larger control than stress constriction on trial 2, and a significantly greater control than post-stress constriction on trials 1 and 2.

A decrease in the extent of constriction over trials was evident during the control and stress periods. In the control condition, each mean value for trials 1 and 2 was

Table 1

Summary of Analysis of Variance for Extent of Constriction

Source	df	MS	F
Neuroticism			
Between groups	2	13.67	1.94
Subjects within groups	27	7.05	
Stress			
Between conditions	2	3.74	2.74
Neuroticism X Stress	4	0.64	0.47
Stress X Subjects within groups	54	1.37	
Trials			
Between trials	11	0.64	4.92*
Neuroticism X Trials	22	0.09	0.72
Trials X Subjects within groups	297	0.13	
Stress X Trials	22	0.20	1.91*
Neuroticism X Stress X Trials	44	0.08	0.77
Stress X Trials X Subjects within groups	594	0.11	

*$p < .05$

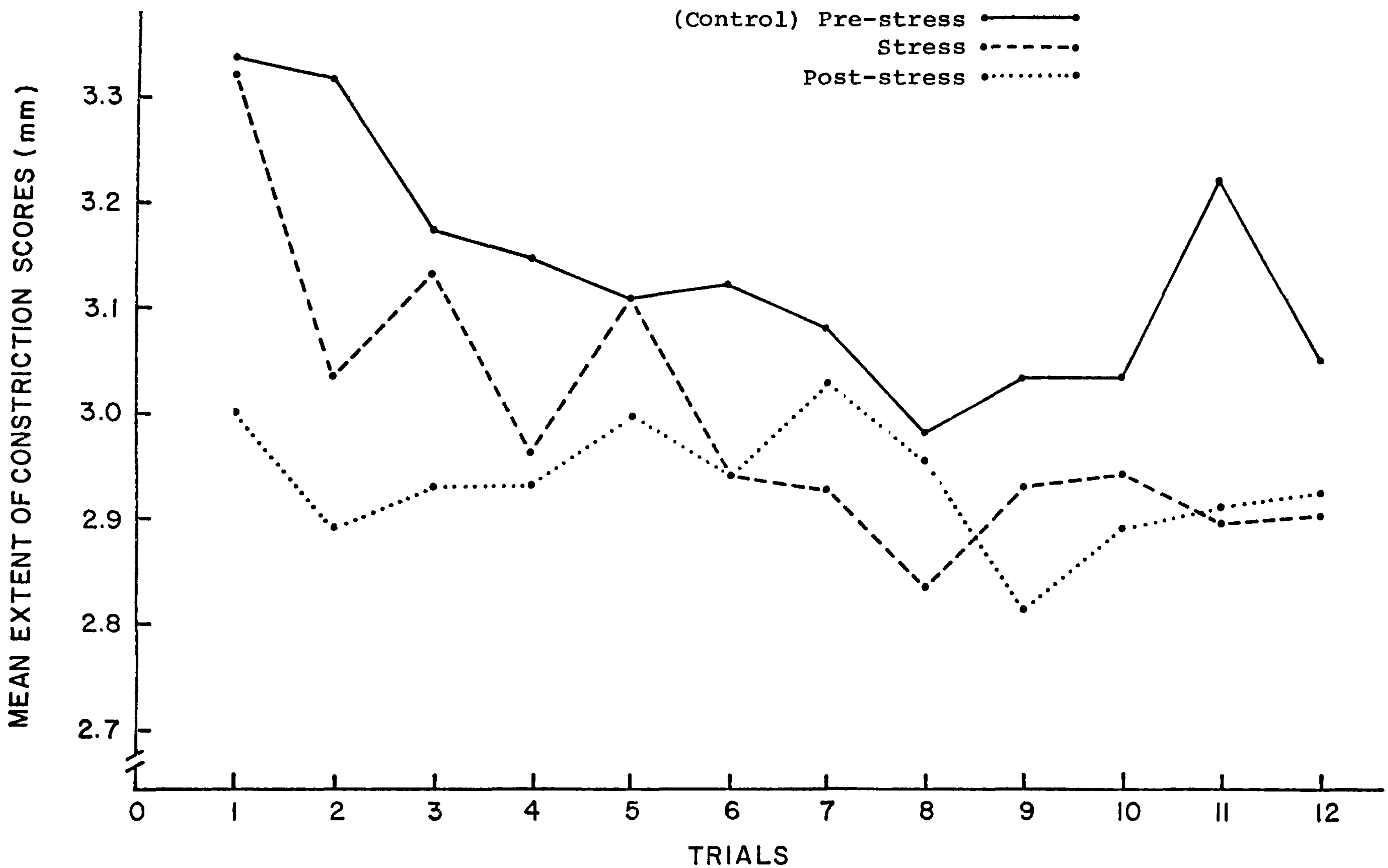

Figure 2. Mean values of extent of constriction in the Stress x Trials interaction

significantly larger than the individual means for trials 7 to 12, with the exception of trial 11 which, in view of the downward trend noted from trial 2 onwards, was possibly due to chance fluctuation. A somewhat greater variability was shown in the extent of constriction during stress, particularly from trials 1 to 5; however, the initial constriction of the pupil elicited immediately after immersion of the hand was found to be significantly greater than all subsequent constrictions elicited during stress. No significant change in the extent of constriction over trials was demonstrated in the post-stress period.

Latency to Maximum Constriction. The analysis of variance data on latency to maximum constriction measures are summarized in Table 2. Again, the F ratio for the Neuroticism factor was nonsignificant; the Stress and Trials factors yielded significant results. Of the three two-factor interactions, the Stress X Trials interaction exceeded chance expectancy.

Observation of individual mean latencies, which are graphically plotted in Figure 3, reveals the occurrence of the longest latencies to maximum constriction during the control period, the shortest during post-stress, and moderate latencies during stress. The greatest variation in latency between the stress conditions was observed during the first six trials; the latencies recorded during the latter trials

Table 2

Summary of Analysis of Variance for
Latency to Maximum Constriction

Source	df	MS	F
Neuroticism			
Between groups	2	0.17	0.23
Subjects within groups	27	0.73	
Stress			
Between conditions	2	0.61	4.10*
Neuroticism X Stress	4	0.08	0.56
Stress X Subjects within groups	54	0.15	
Trials			
Between trials	11	0.08	1.77*
Neuroticism X Trials	22	0.05	1.13
Trials X Subjects within groups	297	0.04	
Stress X Trials	22	0.09	1.88*
Neuroticism X Stress X Trials	44	0.04	0.86
Stress X Trials X Subjects within groups	594	0.05	

*$p < .05$

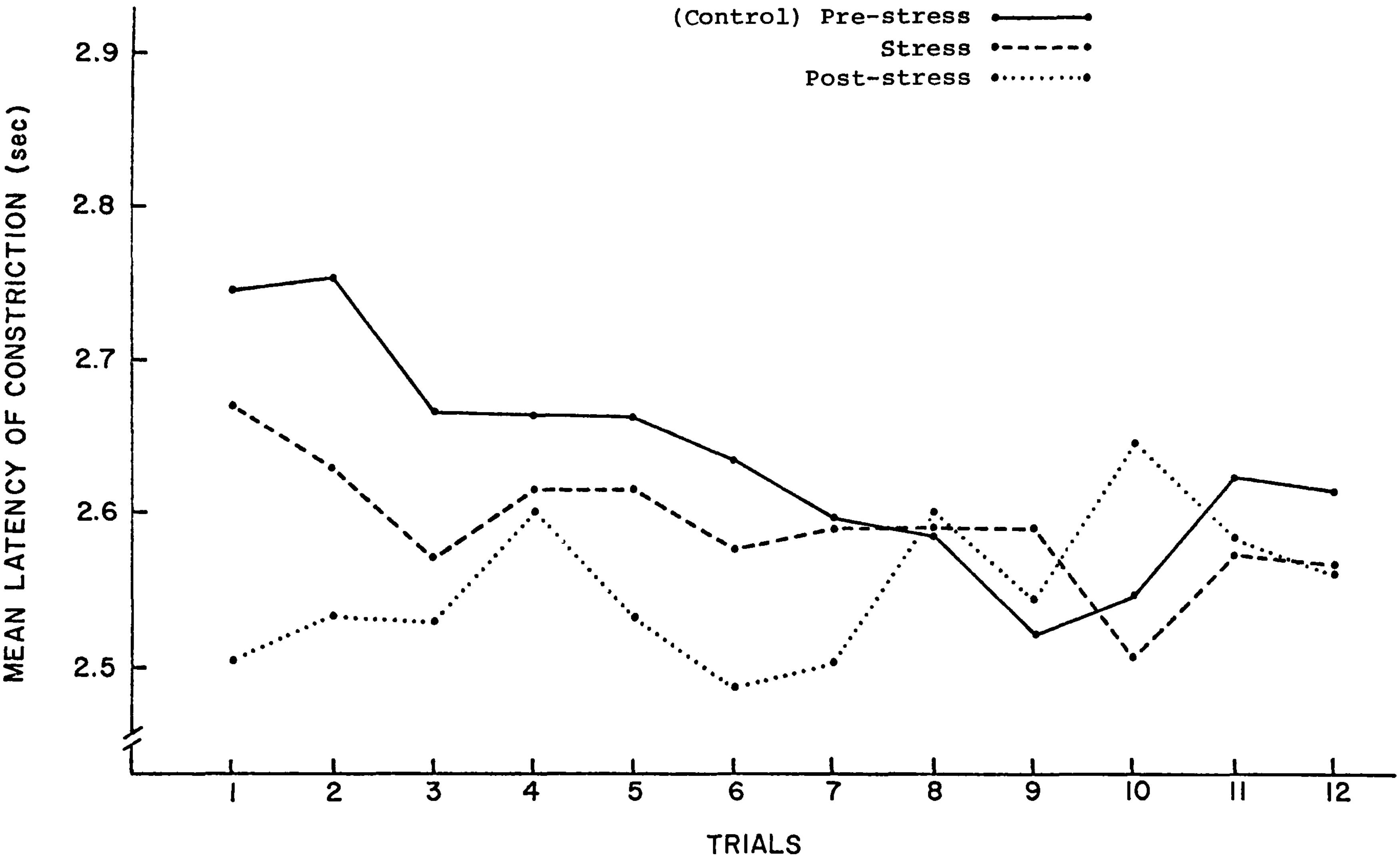

Figure 3. Mean latency to maximum constriction in the Stress x Trials interaction

in all conditions tended to coverge. Significant differences between control and stress latencies were noted on trial 2, and between control and post-stress latencies on trials 1 and 2. A decreasing tendency in constriction latency over trials was observed during the control period, with significant differences found between each of the initial two trials and trials 9 and 10, respectively.

Rate of Constriction. No significant main effects due to Neuroticism, Stress, or Trials were demonstrated with respect to rate of constriction measures, nor were any significant interactions observed. The results of the analysis of variance are shown in Table 3. It is curious that significant results were noted with both extent and latency, but not with rate, since rate is a composite of these components. This suggests that extent and latency are not additive and that their contributions to rate negate each other. There is thus a possible indication that independent processes contribute to rate of constriction.

Magnitude of Redilation. As shown in Table 4, the Stress factor yielded a significant F on measures of magnitude of redilation. No significant differences were found between Neurotic groups or Trials, and none of the two-factor interactions was significant. With respect to the Stress factor, the Newman-Keuls test revealed a significantly greater extent of pupil redilation during stress than during

Table 3

Summary of Analysis of Variance for
Rate of Constriction

Source	df	MS	F
Neuroticism			
Between groups	2	2.44	2.37
Subjects within groups	27	1.03	
Stress			
Between conditions	2	0.05	0.29
Neuroticism X Stress	4	0.11	0.61
Stress X Subjects within groups	54	0.19	
Trials			
Between Trials	11	0.06	1.10
Neuroticism X Trials	22	0.04	0.81
Trials X Subjects within groups	297	0.05	
Stress X Trials	22	0.05	0.98
Neuroticism X Stress X Trials	44	0.05	1.05
Stress X Trials X Subjects within groups	594	0.05	

Table 4

Summary of Analysis of Variance for
Magnitude of Redilation

Source	*df*	*MS*	*F*
Neuroticism			
Between groups	2	23.13	0.84
Subjects within groups	27	27.54	
Stress			
Between conditions	2	29.42	4.12*
Neuroticism X Stress	4	5.03	0.71
Stress X Subjects within groups	54	7.14	
Trials			
Between trials	11	4.49	1.52
Neuroticism X Trials	22	2.85	0.96
Trials X Subjects within groups	297	2.96	
Stress X Trials	22	3.13	1.04
Neuroticism X Stress X Trials	44	3.21	1.06
Stress X Trials X Subjects within groups	594	3.02	

*$p < .05$

the control or post-stress conditions. No differences at the .05 level were observed between the control and post-stress measures of maximum redilation.

Mean Rate of Redilation. On measures of the mean rate of redilation, no main or interaction effects due to Neuroticism, Stress, or Trials were indicated. The results of the analysis of variance are presented in Table 5. The frequent occurrence of blinking and other ocular movements during the 10-second redilation period may have accounted for the variability of the redilation rate.

To summarize at this point, the major findings emerging from the analysis of the pupillary light reflex measures may be listed.

(1) Neuroticism was not shown to have a significant relationship with any of the five dependent measures, either in isolation or in any interactive combination with Stress or Trials.

(2) Significant Stress X Trials interactions were observed on measures of constriction extent and latency. The largest extent of constriction and the longest latencies were found during the control period; conversely, the least amount of constriction and the shortest latencies were noted in the post-stress period. For both constriction and latency measures, the mean of the control condition on trial 2 was significantly greater than the respective mean of the

Table 5

Summary of Analysis of Variance for
Mean Rate of Redilation

Source	*df*	*MS*	*F*
Neuroticism			
Between groups	2	0.15	0.77
Subjects within groups	27	0.19	
Stress			
Between conditions	2	0.10	1.66
Neuroticism X Stress	4	0.04	0.71
Stress X Subjects within groups	54	0.06	
Trials			
Between trials	11	0.01	0.65
Neuroticism X Trials	22	0.01	0.78
Trials X Subjects within groups	297	0.02	
Stress X Trials	22	0.02	0.94
Neuroticism X Stress X Trials	44	0.02	0.99
Stress X Trials X Subjects within groups	594	0.02	

stress condition; on trials 1 and 2, the control period means were significantly larger than the corresponding means of the post-stress period.

(3) On rate of constriction measures, no significant results due to any main factor or interaction of factors were demonstrated.

(4) The magnitude of redilation observed during stress was significantly greater than during the control and post-stress periods.

(5) No significant differences were noted in the mean rate of redilation.

Resting Pupil Size and Eyeblink Frequency

One-way analysis of variance of the dark-adapted pupil size failed to yield statistically significant differences between neurotic groups, F (2/27) = .859, MSe = 1.064, NS. A correlation of +.62 ($p < .05$) was found for the whole sample between the resting pupil diameter measured at the beginning of the control condition and the resting diameter recorded during the stress period.

Results of a Neuroticism X Stress analysis of variance on eyeblink frequency showed no significant main effects due to Neuroticism, F (2/27) = 2.51, MSe = 79.46, NS, or due to Stress, F (2/27) = 2.52, MSe = 27.40, NS. The Neuroticism X Stress interaction was also nonsignificant, F (4/54) = .303, MSe = 27.40, NS.

A moderate positive relationship (r = +.42, $p < .05$) was found between the number of eyeblinks produced during control and stress conditions. Between the stress and post-stress periods, a correlation of +.60 ($p < .05$) was noted, and between control and post-stress, the relationship was shown to be slight and nonsignificant (r = +.30, NS).

Thus, on pupillographic measures of resting pupil size and eyeblink frequency, there was no evidence of differentiation between subjects with low, moderate, or high neuroticism scores. For the sample as a whole, positive correlations were found between stress conditions for both resting pupil size and frequency of eyeblinks.

Subjective Rating of Cold Pressor Pain

The possibility that individuals with low, moderate, or high neuroticism scores on the EPI might differ in their subjective experience of pain, if not on physiological indices of stress response, was investigated via measures of the greatest intensity of pain felt (question 2 on the Cold Pressor Questionnaire) and the average intensity felt (question 4). A Neuroticism X Subjective Measures analysis of variance failed to demonstrate significant differences with respect to Neuroticism, F (2/27) = 1.17, MSe = 9.82, NS. No interactive pattern between Neuroticism and Subjective Measures was observed, F (2/27) = .20, MSe = .665, NS.

Correlations between Neuroticism and Pupillary Light Reflex Measures

The degree and directionality of relationship between neuroticism scores and each of the pupillary light reflex measures within stress conditions was investigated. The Pearson correlation coefficients obtained appear in Table 6. In general, neuroticism was shown to be nonsignificantly related to the latency, extent and rate of constriction as well as to the magnitude and rate of redilation under all stress conditions. The highest correlations were found between neuroticism and the pupillary reflex measures during the post-stress period; although these negative *r*'s failed to reach the .05 level of significance, they provided the only indication of a relationship between high neuroticism and slower, less extensive pupillary constriction and redilation immediately following the cessation of stress.

Intercorrelations between Pupillary Light Reflex Measures

For the purposes of this study, the component features of the pupillary light reflex were analyzed separately. This distinction of features is more categorical than functional, since all are part of a unitary autonomic reflex act. Therefore, a decision was made to examine the intercorrelations between the separate measures within each stress condition. The results of this analysis are presented in Tables 7, 8, and 9. Low, nonsignificant correlations were found between

Table 6

Pearson Correlations between Neuroticism Scores and Pupillary Measures within Stress Conditions

Stress Condition	Extent of Constriction	Latency of Constriction	Rate of Constriction	Magnitude of Redilation	Mean Rate of Redilation
Pre-stress	-0.13	-0.12	-0.07	-0.05	-0.14
Stress	+0.10	-0.16	0.19	-0.06	-0.003
Post-stress	-0.22*	-0.24*	-0.12	-0.27*	-0.28*

*$p < .10$

Table 7

Intercorrelations between Pupillary Light Reflex Measures within the Control Condition

	Latency to Maximum Constriction	Extent of Constriction	Rate of Constriction	Magnitude of Redilation	Mean Rate of Redilation
Latency to Maximum Constriction	-	-.01	-.34*	.10	-.10
Extent of Constriction		-	.86*	.32*	.70*
Rate of Constriction			-	.48*	.79*
Magnitude of Redilation				-	.57*
Mean Rate of Redilation					-

*$p < .05$

Table 8

Intercorrelations between Pupillary Light Reflex Measures within the Stress Condition

	Latency to Maximum Constriction	Extent of Constriction	Rate of Constriction	Magnitude of Redilation	Mean Rate of Redilation
Latency to Maximum Constriction	-	-.10	-.17	.09	-.17
Extent of Constriction		-	.96*	.40*	.75*
Rate of Constriction			-	.34*	.73*
Magnitude of Redilation				-	.37*
Mean Rate of Redilation					-

*$p < .05$

Table 9

Intercorrelations between Pupillary Light Reflex Measures within the Post-stress Condition

	Latency to Maximum Constriction	Extent of Constriction	Rate of Constriction	Magnitude of Redilation	Mean Rate of Redilation
Latency to Maximum Constriction	-	.68*	.35*	.20	.35*
Extent of Constriction		-	.92*	.40*	.69*
Rate of Constriction			-	.38*	.69*
Magnitude of Redilation				-	.59*
Mean Rate of Redilation					-

*$p < .05$

latency and extent of constriction during the control and stress periods; the variability demonstrated between these measures likely resulted in the lack of consistent differences in their ratios (i.e., rate of constriction). In the post-stress condition, however, a positive relationship was found between constriction latency and extent.

Latency to maximum constriction was negatively related to the rate of constriction in the control condition, unrelated during stress, and positively related during post-stress. Thus, longer latencies were associated with slower rates of constriction in the control condition, and with faster rates during post-stress. A moderate positive relationship was also shown between constriction latency and the mean rate of redilation during post-stress.

Between the extent and rate of constriction, high positive correlations were observed in all stress conditions. Given the close association of these measures, both were also shown to correlate positively in a moderate to high degree with the magnitude and mean rate of redilation in all stress periods. A moderate inverse relation was noted between the magnitude and the mean rate of redilation.

In summary, the rate of constriction was found to be more closely associated with extent than with latency of constriction. Both constriction extent and rate were positively related to the magnitude and mean rate of redilation. Finally, the magnitude of redilation was shown to vary consistently with the mean rate of redilation.

CHAPTER IV

DISCUSSION

The main purpose of the present study was to examine differences in physiological reactivity manifested in various aspects of pupillary response, including the reflex to light, resting pupil diameter, and eyeblink frequency, under stress and non-stress conditions for individuals differing in degree of neuroticism. Subjective ratings of the cold pressor pain were also compared between neurotic groups.

Pupillary Response Measures

This study failed to demonstrate a significant relationship between neuroticism and any of the pupillary light reflex measures under control, stress, and post-stress conditions. The results are similar to previous attempts in their lack of confirmation of the Eysenckian hypothesis (1967) that neurotic individuals manifest greater autonomic lability, characterized by more immediate, more intense and/or more prolonged reactions to stress. On the contrary, neurotics have been found to produce less intense autonomic reactions than non-neurotics in the studies conducted by Othmer, Netter-Munkelt, Golte and Meyer (1969) and by Kelly and Martin (1969).

A slight congruence with the observations of Rubin (1964, 1965a) was shown in the correlational analysis of post-stress reflex measures, although these results failed to meet the .05 criterion of significance ($p < .10$). High neuroticism scores were associated with a longer latency to maximum constriction, smaller extent of constriction and redilation, and a slower rate of redilation; these observations are consistent with the pattern of light reflex inhibition resulting from heightened sympathetic mobilization described by Lowenstein and Loewenfeld (1950, 1969). There was thus modest evidence that high neuroticism individuals manifest a more prolonged stress response than low and moderate neuroticism scorers. This interpretation of congruence with Rubin's work is nevertheless restricted, not only because of the failure of the results to reach the .05 criterion, but also because of important procedural differences. In the present study, light reflex activity was recorded for about 2 minutes (12 trials) after stress, while in Rubin's (1964) study, pupillary adaptation was observed during a 20-minute recovery period.

No significant differences were found in basal autonomic activity, as reflected in the resting dark-adapted pupil size of low, moderate, and high neuroticism groups. Lowenstein and Loewenfeld's (1961) observation of larger resting pupil diameters among "hyperexcitable" subjects was therefore not replicated. Rather, the results of this study can be aligned with those obtained by Burdick (1966) and by Crider and Lunn (1971); these researchers found no relationship between basal GSR activity and neuroticism scores. Kelly and Martin (1969) also reported no differences in the basal forearm blood flow, blood pressure, and heart rate of normals and a mixed neurotic population.

The expectation that high neuroticism individuals would manifest greater baseline ocular muscle tension or a greater increase in tension during stress was not substantiated: no significant differences were found between neurotic groups in eyeblink frequency under any condition. The significant positive relation between neuroticism and blink rate reported by Harris, Thackray and Schoenberger (1966) was therefore not supported.

The main hypothesis of the present research is thus not supported. EPI neuroticism scores have not been shown to be significantly related to basal pupil response or to pupillary reactivity during or after stressful stimulation.

Subjective Pain Rating Scale

The findings of this study also have failed to confirm the expectation that individuals who score high on the neuroticism scale would evaluate a physical stressor as more painful than low or moderate neuroticism scorers. No significant differences were demonstrated between groups on either ratings of the most intense moment of cold pressor pain, or the average intensity of pain. These results are congruent with those of Davidson and McDougall (1969) who failed to show a relationship between neuroticism and pain tolerance and, more recently, with the findings of Brown, Fader and Barber (1973) who reported no effect of neuroticism on several measures of pain responsiveness. It may be concluded that EPI neuroticism may not be related to the physiological or psychological measures of stress response used in the present study.

Several tentative explanations may be offered to account for the lack of statistically significant results. One possibility is that emotionally labile individuals possess heightened physiological responsiveness to stress of a psychological nature; when subjected to purely physical stress, their reactions might not differ from those of emotionally stable persons. The items comprising the EPI neuroticism scale deal, in fact, with internal feeling states and social-psychological sensitivity rather than sensitivity to physical stimulation. For instance, the EPI inquires about dizziness, palpitations, nervousness, irritability, easily hurt feelings, lack of self-confidence, and feelings of inferiority. However, this suggestion of a greater susceptibility to psychological stress among high neuroticism individuals is made with reservation, in light of the negative findings of Kelly and Martin (1969) and Boddicker (1972), who used psychological stress conditions in comparing the autonomic reactivity of neurotic groups.

The subjective evaluation of stimulus conditions may also have influenced autonomic reactivity in an unforeseen direction. Lazarus (1967) has postulated that "the nature of an autonomic response is determined by the nature of the coping process" (p. 160). In turn, coping is partly dependent upon the individual's cognitive appraisal of a situation. With respect to the present study, if the pain ratings were an accurate expression of the subjects' appraisal of the cold pressor stimulation, the lack of differences in the objective measure of autonomic reactivity could be attributable to the similarity of subjective stimulus evaluation in all groups. A 2-minute immersion of the hand in ice water may be physiologically stressful, but psychologically, it may be perceived as minimally threatening. Neurotic subjects might therefore have felt no more alarmed by the stressor than non-neurotics, and would not have over-responded autonomically.

Perhaps, as Averill and Opton (1968) have contended, the failure to find a significant relation between a psychological disposition and physiological reactivity is due to an over-generality of a trait, in this case, of neuroticism. According to this interpretation, a lower-order trait may influence the individual's reactivity to a stimulus, thereby masking the effects of the genotype. Prediction might be improved by analyzing the genotypic trait into subtraits, and examining each of these in relation to appropriate stimulus conditions.

Such an analysis has been performed with the Taylor Manifest Anxiety Scale. Katkin and McCubbin (1969) and Kirschman and Brumbaugh-Buehler (1975) reported little relationship between MAT anxiety and basal GSR activity when the total MAT score was used; however, Epstein and Fenz (1970) divided subjects according to subscales of the MAT (reports of muscle tension, autonomic arousal, and feelings of fear and insecurity), and found significant relationships between the MAT self-report measures and physiological activity.

The failure to demonstrate the relation of neuroticism to autonomic reactivity may also have been due to response specificity variables which, in the opinion of several authors, pose a major difficulty in psychophysiological research (Averill & Opton, 1968; Lang, Rice & Sternbach, 1972; Steinschneider & Lipton, 1965). Since the pupillary response was the only physiological measure used in the present study, autonomic reactivity manifested via other modes was not assessed. Concurrent use of several physiological indices would thus be recommended in future research to obviate the problem of individual response hierarchy.

Finally, it is possible that the pupillary light reflex is not an appropriate measure for testing individual differences in autonomic reactivity related to neuroticism. Although it has an advantage over other psychophysiological measures inasmuch as it is insensitive to extraneous influences (such as random thoughts or feelings), this insensitivity may also paradoxically be its major drawback for psychological research; in other words, as a uniform response to a stimulus, the pupillary light reflex may be influenced only minimally by psychological processes.

The Effects of Stress upon Pupillary Response Independent of Neuroticism Scores

The effects of stress on the pupillary light reflex were found to be consistent with the description of pupillary mechanisms given by Lowenstein and Loewenfeld (1969) for the extent of constriction and magnitude of redilation variables, but not for measures of constriction latency, rate of constriction, and mean rate of redilation.

During cold pressor stimulation, constriction to light was less extensive than during the control period, and constriction continued to decrease in extent following the cessation of stress. This response pattern can be explained in terms of the inhibition of parasympathetic oculomotor impulses consequent to an increased central sympathetic activation. The larger magnitude of pupil dilation observed following the constriction response during the stress condition could be interpreted as a manifestation of greater peripheral sympathetic activity. However, it was noted that redilation quickly regained a baseline level after the termination of stress. It may be inferred from this observation that homeostatic recovery of the pupillary light reflex occurs more rapidly at the peripheral than at the central level.

Contrary to the findings of Lowenstein and Loewenfeld (1969), the pupillary reflex activity was not shown to become more sluggish as a result of stress; latency to maximum constriction was observed to decrease rather than increase under stress and post-stress conditions. In general, however, less variability was manifested in latency measures than in extent of constriction.

Since Lowenstein and Loewenfeld (1969) have reported that inhibition of the light reflex is characterized by sluggish and inextensive constriction and redilation, it was expected that the rate of both movements would decrease as a result of stress and that constriction latency and extent would be negatively correlated. However, no differences were observed in the rate of constriction during and after stress, and the correlation between constriction latency and extent was nonsignificant. Correlational analysis also revealed that constriction rate was more a function of extent than of latency.

The mean rate of redilation was shown to be positively associated with the magnitude of redilation. During the stress and post-stress periods, redilation rate was not found to decrease. The failure to show a significant decrement in redilation rate may have been due to the extreme variability in measurement resulting from frequent eye movements and eye-blinking. Furthermore, the fast primary and slower secondary phases of redilation were not distinguished in the mean rate measure. A more accurate index of redilation rate might be obtained by means of curve analysis.

Finally, the results of the present study confirmed the findings of Lowenstein and Loewenfeld (1950) with respect to the balance of parasympathetic and sympathetic mechanisms in the dynamics of the light reflex. The aspects of pupil activity mediated principally by parasympathetic functioning, i.e., constriction extent and rate, were found to be positively related to the sympathetically controlled aspects, i.e., the magnitude and rate of redilation.

Conclusion

The results of the present study have not confirmed the Eysenckian (1967) hypothesis that neurotic individuals manifest greater autonomic reactivity than non-neurotics. Furthermore, the subjective appraisal of cold pressor pain was not found to be related to neuroticism. In interpreting the lack of significance obtained on both physiological and psychological measures of stress response, the nature of the stress condition, over-generality of the neuroticism dimension, and individual response patterning have been suggested as possible intervening factors. Also, the appropriateness of the pupillary light reflex as an index of individual differences in autonomic reactivity was questioned. The features of the pupillary light reflex which were observed to behave in a manner consistent with previous descriptions included the extent of constriction, the magnitude of redilation, and the balance between constriction and redilation movements.

In light of the results obtained in the present study, suggestions may be made to direct future research on the problem of determining the biological basis of neuroticism. Stress conditions in which an element of potential threat is presented to the individual's well-being may prove to be more effective than cold pressor stimulation in eliciting differential psychological and autonomic stress response. Furthermore, a variety of physiological indices could be used concurrently to circumvent the problem of measurement posed by individual response specificity. It is also recommended that both extraversion and neuroticism be included as variables in a future study, since there is the experimental evidence that these dimensions interact in determining physiological responsiveness.

The observations of pupillary dynamics under stress conditions independent of the Eysenckian personality dimensions also warrant further attention. Refinements in the measurement of the components of the pupillary light reflex may be required, and attempts may be made to discriminate the components or combination of components which are most sensitive to variations in autonomic balance.

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APPENDIX A

EYSENCK PERSONALITY INVENTORY (EPI)
FORMS A AND B

EYSENCK PERSONALITY INVENTORY

FORM A

By H. J. Eysenck
and Sybil B. G. Eysenck

Name ____________________ Age __________ Sex __________

Grade or Occupation ____________________ Date __________

School or Firm ____________________ Marital Status __________

INSTRUCTIONS

Here are some questions regarding the way you behave, feel and act. After each question is a space for answering "Yes," or "No."

Try and decide whether "Yes," or "No" represents your usual way of acting or feeling. Then blacken in the space under the column headed "Yes" or "No."

Section of Answer Column Correctly Marked

Yes	No
▮	⁞
Yes	**No**
⁞	▮

Work quickly, and don't spend too much time over any question; we want your first reaction, not a long drawn-out thought process. The whole questionnaire shouldn't take more than a few minutes. Be sure not to omit any questions. Now turn the page over and go ahead. Work quickly, and remember to answer every question. There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave.

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1. Do you often long for excitement? . . . . Yes No
2. Do you often need understanding friends to cheer you up? . . . . Yes No
3. Are you usually carefree? . . . . Yes No
4. Do you find it very hard to take no for an answer? . . . Yes No
5. Do you stop and think things over before doing anything? . . . . Yes No
6. If you say you will do something do you always keep your promise, no matter how inconvenient it might be to do so? . . . . Yes No
7. Does your mood often go up and down? . . . . Yes No
8. Do you generally do and say things quickly without stopping to think? . . . . Yes No
9. Do you ever feel "just miserable" for no good reason? Yes No
10. Would you do almost anything for a dare? . . . . Yes No
11. Do you suddenly feel shy when you want to talk to an attractive stranger? . . . . Yes No
12. Once in a while do you lose your temper and get angry? . . . . Yes No
13. Do you often do things on the spur of the moment? . . . Yes No
14. Do you often worry about things you should not have done or said? . . . . Yes No
15. Generally do you prefer reading to meeting people? . . Yes No
16. Are your feelings rather easily hurt? . . . . Yes No
17. Do you like going out a lot? . . . . Yes No
18. Do you occasionally have thoughts and ideas that you would not like other people to know about? . . Yes No
19. Are you sometimes bubbling over with energy and sometimes very sluggish? . . . . Yes No
20. Do you prefer to have few but special friends? . . . . Yes No
21. Do you daydream a lot? . . . . Yes No
22. When people shout at you, do you shout back? . . . . . . Yes No
23. Are you often troubled about feelings of guilt? . . . . . . Yes No
24. Are all your habits good and desirable ones? . . . . . . Yes No
25. Can you usually let yourself go and enjoy yourself a lot at a gay party? . . . . Yes No
26. Would you call yourself tense or "highly-strung"? . . . Yes No
27. Do other people think of you as being very lively? . . . Yes No
28. After you have done something important, do you often come away feeling you could have done better? . . . . . Yes No
29. Are you mostly quiet when you are with other people? Yes No
30. Do you sometimes gossip? . . . . Yes No
31. Do ideas run through your head so that you cannot sleep? . . . . Yes No
32. If there is something you want to know about, would you rather look it up in a book than talk to someone about it? . . . . Yes No
33. Do you get palpitations or thumping in your heart? . . . Yes No
34. Do you like the kind of work that you need to pay close attention to? . . . . Yes No
35. Do you get attacks of shaking or trembling? . . . . Yes No
36. Would you always declare everything at the customs, even if you knew that you could never be found out? . . Yes No
37 Do you hate being with a crowd who play jokes on one another? . . . . Yes No
38. Are you an irritable person? . . . . Yes No
39. Do you like doing things in which you have to act quickly? . . . . Yes No
40. Do you worry about awful things that might happen? . . Yes No
41. Are you slow and unhurried in the way you move? . . . Yes No
42. Have you ever been late for an appointment or work? . Yes No
43. Do you have many nightmares? . . . . Yes No
44. Do you like talking to people so much that you would never miss a chance of talking to a stranger? . . . . . . Yes No
45. Are you troubled by aches and pains? . . . . Yes No
46. Would you be very unhappy if you could not see lots of people most of the time? . . . . Yes No
47. Would you call yourself a nervous person? . . . . . Yes No
48. Of all the people you know are there some whom you definitely do not like? . . . . Yes No
49. Would you say you were fairly self-confident? . . . . . Yes No
50. Are you easily hurt when people find fault with you or your work? . . . . Yes No
51. Do you find it hard to really enjoy yourself at a lively party? . . . . Yes No
52. Are you troubled with feelings of inferiority? . . . . . Yes No
53. Can you easily get some life into a rather dull party? . Yes No
54. Do you sometimes talk about things you know nothing about? . . . . Yes No
55. Do you worry about your health? . . . . Yes No
56. Do you like playing pranks on others? . . . . Yes No
57. Do you suffer from sleeplessness? . . . . Yes No

PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS.

EYSENCK PERSONALITY INVENTORY

FORM B

By H. J. Eysenck
and Sybil B. G. Eysenck

Name____________________ Age________ Sex________

Grade or Occupation____________________ Date________

School or Firm____________________ Marital Status________

INSTRUCTIONS

Here are some questions regarding the way you behave, feel and act. After each question is a space for answering "Yes," or "No."

Try and decide whether "Yes," or "No" represents your usual way of acting or feeling. Then blacken in the space under the column headed "Yes" or "No."

Section of Answer Column Correctly Marked

Yes No

Yes No

Work quickly, and don't spend too much time over any question; we want your first reaction, not a long drawn-out thought process. The whole questionnaire shouldn't take more than a few minutes. Be sure not to omit any questions. Now turn the page over and go ahead. Work quickly, and remember to answer every question. There are no right or wrong answers, and this isn't a test of intelligence or ability, but simply a measure of the way you behave.

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EPI 002

1. Do you like plenty of excitement and bustle around you? Yes No
2. Have you often got a restless feeling that you want something but do not know what? Yes No
3. Do you nearly always have a "ready answer" when people talk to you? Yes No
4. Do you sometimes feel happy, sometimes sad without any real reason? Yes No
5. Do you usually stay in the background at parties and "get-togethers"? Yes No
6. As a child did you always do as you were told immediately and without grumbling? Yes No
7. Do you sometimes sulk? Yes No
8. When you are drawn into a quarrel, do you prefer to "have it out" to being silent hoping things will blow over? Yes No
9. Are you moody? Yes No
10. Do you like mixing with people? Yes No
11. Have you often lost sleep over your worries? Yes No
12. Do you sometimes get cross? Yes No
13. Would you call yourself happy-go-lucky? Yes No
14. Do you often make up your mind too late? Yes No
15. Do you like working alone? Yes No
16. Have you often felt listless and tired for no good reason? Yes No
17. Are you rather lively? Yes No
18. Do you sometimes laugh at a dirty joke? Yes No
19. Do you often feel "fed-up"? Yes No
20. Do you feel uncomfortable in anything but everyday clothes? Yes No
21. Does your mind often wander when you are trying to attend closely to something? Yes No
22. Can you put your thoughts into words quickly? Yes No
23. Are you often "lost in thought"? Yes No
24. Are you completely free from prejudices of any kind? Yes No
25. Do you like practical jokes? Yes No
26. Do you often think of your past? Yes No
27. Do you very much like good food? Yes No
28. When you get annoyed do you need someone friendly to talk to about it? Yes No
29. Do you mind selling things or asking people for money for some good cause? Yes No
30. Do you sometimes boast a little? Yes No
31. Are you touchy about some things? Yes No
32. Would you rather be at home on your own than go to a boring party? Yes No
33. Do you sometimes get so restless that you cannot sit long in a chair? Yes No
34. Do you like planning things carefully, well ahead of time? Yes No
35. Do you have dizzy spells? Yes No
36. Do you always answer a personal letter as soon as you can after you have read it? Yes No
37. Can you usually do things better by figuring them out alone than by talking to others about it? Yes No
38. Do you ever get short of breath without having done heavy work? Yes No
39. Are you an easy-going person, not generally bothered about having everything "just-so"? Yes No
40. Do you suffer from "nerves"? Yes No
41. Would you rather plan things than do things? Yes No
42. Do you sometimes put off until tomorrow what you ought to do today? Yes No
43. Do you get nervous in places like elevators, trains or tunnels? Yes No
44. When you make new friends, is it usually you who makes the first move, or does the inviting? Yes No
45. Do you get very bad headaches? Yes No
46. Do you generally feel that things will sort themselves out and come right in the end somehow? Yes No
47. Do you find it hard to fall asleep at bedtime? Yes No
48. Have you sometimes told lies in your life? Yes No
49. Do you sometimes say the first thing that comes into your head? Yes No
50. Do you worry too long after an embarrassing experience? Yes No
51. Do you usually keep "yourself to yourself" except with very close friends? Yes No
52. Do you often get into a jam because you do things without thinking? Yes No
53. Do you like cracking jokes and telling funny stories to your friends? Yes No
54. Would you rather win, than lose a game? Yes No
55. Do you often feel self-conscious when you are with superiors? Yes No
56. When the odds are against you, do you still usually think it worth taking a chance? Yes No
57. Do you often get "butterflies in your stomach" before an important occasion? Yes No

PLEASE CHECK TO SEE THAT YOU HAVE ANSWERED ALL THE QUESTIONS.

APPENDIX B

NEUROTICISM AND EXTRAVERSION SCORES ON EPI FORMS A AND B

APPENDIX B

NEUROTICISM AND EXTRAVERSION SCORES ON EPI FORMS A AND B

Subject	Form A		Form B	
	N	E	N	E
1	0	10	2	11
2	1	8	3	11
3	1	13	4	16
4	4	9	3	13
5	4	10	3	20
6	3	9	5	14
7	4	13	5	15
8	4	13	7	18
9	4	13	7	19
10	3	13	8	14
11	7	15	10	12
12	5	10	13	15
13	14	11	5	16
14	8	9	11	7
15	9	12	10	17
16	9	10	11	18
17	12	9	8	14
18	7	15	14	17
19	10	9	14	16
20	14	14	12	10
21	13	13	14	15
22	11	10	17	17
23	16	12	15	10
24	19	11	14	22
25	18	11	16	11
26	16	9	18	11
27	18	12	20	17
28	19	11	19	7
29	21	9	19	16
30	20	12	23	12

APPENDIX C

COLD PRESSOR QUESTIONNAIRE

APPENDIX C

COLD PRESSOR QUESTIONNAIRE

Name:________________

Rate the intensity of the pain by circling the number that best corresponds to how you felt.

1. When the pain was first felt.

0 . 1 . 2 . 3 . 4 . 5 . 6 . 7 . 8 . 9 . 10

no pain felt — worst pain ever felt

2. At the most intense point.

0 . 1 . 2 . 3 . 4 . 5 . 6 . 7 . 8 . 9 . 10

no pain felt — worst pain ever felt

3. Immediately before your hand was withdrawn.

0 . 1 . 2 . 3 . 4 . 5 . 6 . 7 . 8 . 9 . 10

no pain felt — worst pain ever felt

4. On the average, how painful did you find the ice water?

0 . 1 . 2 . 3 . 4 . 5 . 6 . 7 . 8 . 9 . 10

not painful — very painful

APPENDIX D

SUBJECTIVE RATINGS OF MOST INTENSE COLD PRESSOR PAIN AND AVERAGE PAIN FELT

APPENDIX D

SUBJECTIVE RATINGS OF MOST INTENSE COLD PRESSOR PAIN AND AVERAGE PAIN FELT

Subject	Most Intense Pain	Average Pain
1	8	7
2	9	9
3	2	1
4	8	7
5	5	4
6	1	1
7	8	5
8	5	4
9	8	7
10	7	5
11	6	7
12	10	8
13	8	7
14	8	6
15	7	7
16	6	5
17	10	9
18	6	6
19	3	2
20	10	8
21	10	8
22	10	7
23	7	5
24	8	7
25	6	5
26	8	5
27	8	6
28	3	2
29	8	8
30	6	8

APPENDIX E

FREQUENCY OF EYEBLINKS DURING CONTROL, STRESS AND POST-STRESS CONDITIONS, AND MEAN RESTING PUPIL DIAMETER

APPENDIX E

FREQUENCY OF EYEBLINKS DURING CONTROL, STRESS AND POST-STRESS CONDITIONS, AND MEAN RESTING PUPIL DIAMETER

Subject	Eyeblink Frequency			Pupil Diameter (mm)
	Pre-stress	Stress	Post-stress	
1	13	8	10	8.4
2	13	11	18	9.5
3	8	5	7	9.5
4	10	4	11	8.2
5	7	5	8	7.3
6	28	14	5	8.7
7	14	21	24	8.4
8	10	1	2	9.6
9	6	11	5	10.4
10	9	2	3	8.3
11	8	9	1	8.9
12	6	15	10	9.4
13	4	8	9	8.9
14	1	1	1	7.7
15	2	2	6	6.9
16	14	2	3	9.6
17	11	18	9	7.3
18	10	1	2	8.9
19	3	1	1	6.7
20	19	6	9	7.9
21	18	33	9	9.4
22	19	12	7	6.9
23	3	6	8	9.5
24	12	8	13	8.4
25	13	23	25	8.1
26	11	8	11	8.2
27	8	0	1	9.2
28	6	11	3	10.3
29	29	12	12	9.6
30	12	5	6	6.9

APPENDIX F

PUPILLARY LIGHT REFLEX MEASURES

APPENDIX F

EXTENT OF CONSTRICTION

MEAN		SUBSCRIPT SET A	B	C	D
0.36916662D	01	1	1	0	1
0.32583330D	01	1	1	0	2
0.25416663D	01	1	1	0	3
0.25749997D	01	1	1	0	4
0.29499996D	01	1	1	0	5
0.29083329D	01	1	1	0	6
0.28499997D	01	1	1	0	7
0.31166662D	01	1	1	0	8
0.41249996D	01	1	1	0	9
0.27916664D	01	1	1	0	10
0.33416662D	01	1	2	0	1
0.30666663D	01	1	2	0	2
0.27916663D	01	1	2	0	3
0.21916664D	01	1	2	0	4
0.25749995D	01	1	2	0	5
0.19083330D	01	1	2	0	6
0.36416664D	01	1	2	0	7
0.27999995D	01	1	2	0	8
0.33999997D	01	1	2	0	9
0.32249995D	01	1	2	0	10
0.31999997D	01	1	3	0	1
0.27749996D	01	1	3	0	2
0.32583329D	01	1	3	0	3
0.26166663D	01	1	3	0	4
0.26333330D	01	1	3	0	5
0.16833328D	01	1	3	0	6
0.34583329D	01	1	3	0	7
0.27499996D	01	1	3	0	8
0.31666662D	01	1	3	0	9
0.29833330D	01	1	3	0	10
0.29916663D	01	2	1	0	11
0.33916663D	01	2	1	0	12
0.36083330D	01	2	1	0	13
0.31166664D	01	2	1	0	14
0.22916663D	01	2	1	0	15
0.27749996D	01	2	1	0	16
0.32333330D	01	2	1	0	17
0.34249998D	01	2	1	0	18
0.23166661D	01	2	1	0	19
0.19749997D	01	2	1	0	20
0.35833329D	01	2	2	0	11
0.34416664D	01	2	2	0	12
0.30666663D	01	2	2	0	13
0.26358329D	01	2	2	0	14
0.24583332D	01	2	2	0	15
0.31583330D	01	2	2	0	16
0.26499996D	01	2	2	0	17
0.35333330D	01	2	2	0	18
0.18583329D	01	2	2	0	19
0.21333329D	01	2	2	0	20
0.30999997D	01	2	3	0	11
0.31249998D	01	2	3	0	12
0.30749995D	01	2	3	0	13
0.33749996D	01	2	3	0	14
0.24166663D	01	2	3	0	15
0.31999996D	01	2	3	0	16
0.26083330D	01	2	3	0	17
0.32166663D	01	2	3	0	18
0.16333330D	01	2	3	0	19
0.29666662D	01	2	3	0	20
0.35749997D	01	3	1	0	21
0.24333330D	01	3	1	0	22
0.34916663D	01	3	1	0	23
0.33749997D	01	3	1	0	24
0.40749997D	01	3	1	0	25
0.31999997D	01	3	1	0	26
0.38583329D	01	3	1	0	27
0.32749996D	01	3	1	0	28
0.36499997D	01	3	1	0	29
0.30499996D	01	3	1	0	30
0.30999995D	01	3	2	0	21
0.22916663D	01	3	2	0	22
0.42583330D	01	3	2	0	23
0.35916662D	01	3	2	0	24
0.32749996D	01	3	2	0	25
0.34749996D	01	3	2	0	26
0.27333330D	01	3	2	0	27
0.31583330D	01	3	2	0	28
0.35083330D	01	3	2	0	29
0.29249997D	01	3	2	0	30
0.23083330D	01	3	3	0	21
0.22916664D	01	3	3	0	22
0.36749996D	01	3	3	0	23
0.34666662D	01	3	3	0	24
0.32416664D	01	3	3	0	25
0.32416662D	01	3	3	0	26
0.29916662D	01	3	3	0	27
0.33999996D	01	3	3	0	28
0.32749995D	01	3	3	0	29
0.30166663D	01	3	3	0	30

Legend:

A - Neuroticism
- 1 - Low
- 2 - Moderate
- 3 - High

B - Stress Condition
- 1 - Pre-stress
- 2 - Stress
- 3 - Post-stress

C - Trials (summed)

D - Subject (1 - 30)

LATENCY TO MAXIMUM CONSTRICTION

MEAN		SUBSCRIPT SET A	B	C	D
0.25249997D	01	1	1	0	1
0.27583329D	01	1	1	0	2
0.25666664D	01	1	1	0	3
0.26999996D	01	1	1	0	4
0.25666663D	01	1	1	0	5
0.25583332D	01	1	1	0	6
0.26416664D	01	1	1	0	7
0.26916664D	01	1	1	0	8
0.26333331D	01	1	1	0	9
0.25833330D	01	1	1	0	10
0.21249997D	01	1	2	0	1
0.27249996D	01	1	2	0	2
0.27083329D	01	1	2	0	3
0.27583329D	01	1	2	0	4
0.25416664D	01	1	2	0	5
0.21416664D	01	1	2	0	6
0.25166665D	01	1	2	0	7
0.26249996D	01	1	2	0	8
0.26166662D	01	1	2	0	9
0.27416663D	01	1	2	0	10
0.20166664D	01	1	3	0	1
0.26916663D	01	1	3	0	2
0.26583331D	01	1	3	0	3
0.28249997D	01	1	3	0	4
0.29666661D	01	1	3	0	5
0.19249998D	01	1	3	0	6
0.24749997D	01	1	3	0	7
0.24749997D	01	1	3	0	8
0.24833331D	01	1	3	0	9
0.25999996D	01	1	3	0	10
0.23749998D	01	2	1	0	11
0.27666662D	01	2	1	0	12
0.25916664D	01	2	1	0	13
0.27166663D	01	2	1	0	14
0.24999998D	01	2	1	0	15
0.26999997D	01	2	1	0	16
0.25999998D	01	2	1	0	17
0.27749999D	01	2	1	0	18
0.24666664D	01	2	1	0	19
0.26833332D	01	2	1	0	20
0.25999997D	01	2	2	0	11
0.26416663D	01	2	2	0	12
0.25083329D	01	2	2	0	13
0.25999997D	01	2	2	0	14
0.25916665D	01	2	2	0	15
0.26916663D	01	2	2	0	16
0.26583330D	01	2	2	0	17
0.27416664D	01	2	2	0	18
0.25333330D	01	2	2	0	19
0.26583330D	01	2	2	0	20
0.27583331D	01	2	3	0	11
0.26999996D	01	2	3	0	12
0.25166663D	01	2	3	0	13
0.26333330D	01	2	3	0	14
0.25499999D	01	2	3	0	15
0.27083330D	01	2	3	0	16
0.25833331D	01	2	3	0	17
0.26249997D	01	2	3	0	18
0.23916663D	01	2	3	0	19
0.27499995D	01	2	3	0	20
0.26583331D	01	3	1	0	21
0.25583331D	01	3	1	0	22
0.27499997D	01	3	1	0	23
0.27333330D	01	3	1	0	24
0.27083331D	01	3	1	0	25
0.24833330D	01	3	1	0	26
0.27416661D	01	3	1	0	27
0.27555562D	01	3	1	0	28
0.27249996D	01	3	1	0	29
0.24666665D	01	3	1	0	30
0.25166664D	01	3	2	0	21
0.26833331D	01	3	2	0	22
0.26999997D	01	3	2	0	23
0.26499998D	01	3	2	0	24
0.24499997D	01	3	2	0	25
0.26416663D	01	3	2	0	26
0.25499997D	01	3	2	0	27
0.26833330D	01	3	2	0	28
0.25999997D	01	3	2	0	29
0.23666663D	01	3	2	0	30
0.24916663D	01	3	3	0	21
0.24999998D	01	3	3	0	22
0.28916665D	01	3	3	0	23
0.24666663D	01	3	3	0	24
0.25999997D	01	3	3	0	25
0.24333330D	01	3	3	0	26
0.26833329D	01	3	3	0	27
0.26416663D	01	3	3	0	28
0.24999998D	01	3	3	0	29
0.24249998D	01	3	3	0	30

RATE OF CONSTRICTION

MEAN		SUBSCRIPT SET A	B	C	D
0.14649996D	01	1	1	0	1
0.11358328D	01	1	1	0	2
0.10283332D	01	1	1	0	3
0.95166648D	00	1	1	0	4
0.11066664D	01	1	1	0	5
0.11374997D	01	1	1	0	6
0.10791665D	01	1	1	0	7
0.11574996D	01	1	1	0	8
0.15666661D	01	1	1	0	9
0.10858331D	01	1	1	0	10
0.15874997D	01	1	2	0	1
0.11266664D	01	1	2	0	2
0.10299998D	01	1	2	0	3
0.79333331D	00	1	2	0	4
0.97416655D	00	1	2	0	5
0.87999984D	00	1	2	0	6
0.14474997D	01	1	2	0	7
0.10649999D	01	1	2	0	8
0.12999996D	01	1	2	0	9
0.11749996D	01	1	2	0	10
0.15974996D	01	1	3	0	1
0.10324998D	01	1	3	0	2
0.12241663D	01	1	3	0	3
0.93083327D	00	1	3	0	4
0.99083330D	00	1	3	0	5
0.87749998D	00	1	3	0	6
0.14116662D	01	1	3	0	7
0.11158331D	01	1	3	0	8
0.12833329D	01	1	3	0	9
0.11133331D	01	1	3	0	10
0.12733329D	01	2	1	0	11
0.12258328D	01	2	1	0	12
0.13949996D	01	2	1	0	13
0.11466663D	01	2	1	0	14
0.93999997D	00	2	1	0	15
0.10291665D	01	2	1	0	16
0.12458329D	01	2	1	0	17
0.12[illegible]58328D	01	2	1	0	18
0.94333325D	00	2	1	0	19
0.73499997D	00	2	1	0	20
0.13841662D	01	2	2	0	11
0.13424995D	01	2	2	0	12
0.12308329D	01	2	2	0	13
0.10099998D	01	2	2	0	14
0.95083331D	00	2	2	0	15
0.11749995D	01	2	2	0	16
0.99749986D	00	2	2	0	17
0.12933329D	01	2	2	0	18
0.74333328D	00	2	2	0	19
0.80166663D	00	2	2	0	20
0.13266654D	01	2	3	0	11
0.11516664D	01	2	3	0	12
0.12333330D	01	2	3	0	13
0.12849995D	01	2	3	0	14
0.95666651D	00	2	3	0	15
0.11833328D	01	2	3	0	16
0.10124999D	01	2	3	0	17
0.12308330D	01	2	3	0	18
0.69249997D	00	2	3	0	19
0.10783331D	01	2	3	0	20
0.13424997D	01	3	1	0	21
0.94016662D	00	3	1	0	22
0.12666662D	01	3	1	0	23
0.12274996D	01	3	1	0	24
0.15041661D	01	3	1	0	25
0.12908329D	01	3	1	0	26
0.14133329D	01	3	1	0	27
0.11824995D	01	3	1	0	28
0.13408329D	01	3	1	0	29
0.12433329D	01	3	1	0	30
0.11841663D	01	3	2	0	21
0.13583333D	01	3	2	0	22
0.15791663D	01	3	2	0	23
0.13033329D	01	3	2	0	24
0.13733330D	01	3	2	0	25
0.13191662D	01	3	2	0	26
0.10756664D	01	3	2	0	27
0.11808329D	01	3	2	0	28
0.13591661D	01	3	2	0	29
0.124[illegible]664D	01	3	2	0	30
0.93749995D	00	3	3	0	21
0.91999989D	00	3	3	0	22
0.13783330D	01	3	3	0	23
0.14358327D	01	3	3	0	24
0.12533329D	01	3	3	0	25
0.13441662D	01	3	3	0	26
0.11141667D	01	3	3	0	27
0.12874995D	01	3	3	0	28
0.13183330D	01	3	3	0	29
0.12458333D	01	3	3	0	30

MAGNITUDE OF REDILATION

MEAN		A	B	C	D
0.64166661D	01	1	1	0	1
0.85833331D	01	1	1	0	2
0.83666662D	01	1	1	0	3
0.70083330D	01	1	1	0	4
0.69749995D	01	1	1	0	5
0.70833330D	01	1	1	0	6
0.73249995D	01	1	1	0	7
0.84249996D	01	1	1	0	8
0.88083330D	01	1	1	0	9
0.68249995D	01	1	1	0	10
0.86166662D	01	1	2	0	1
0.89416663D	01	1	2	0	2
0.87499996D	01	1	2	0	3
0.66083330D	01	1	2	0	4
0.68083328D	01	1	2	0	5
0.83166662D	01	1	2	0	6
0.76499996D	01	1	2	0	7
0.83749994D	01	1	2	0	8
0.96916662D	01	1	2	0	9
0.74166663D	01	1	2	0	10
0.80166662D	01	1	3	0	1
0.87166663D	01	1	3	0	2
0.86583330D	01	1	3	0	3
0.68083329D	01	1	3	0	4
0.66333330D	01	1	3	0	5
0.78333329D	01	1	3	0	6
0.67833330D	01	1	3	0	7
0.82999998D	01	1	3	0	8
0.89999997D	01	1	3	0	9
0.65749997D	01	1	3	0	10
0.73249995D	01	2	1	0	11
0.83999995D	01	2	1	0	12
0.79749996D	01	2	1	0	13
0.65999998D	01	2	1	0	14
0.67583330D	01	2	1	0	15
0.84833330D	01	2	1	0	16
0.62166663D	01	2	1	0	17
0.75083329D	01	2	1	0	18
0.57916662D	01	2	1	0	19
0.68499996D	01	2	1	0	20
0.74249996D	01	2	2	0	11
0.86833330D	01	2	2	0	12
0.86499998D	01	2	2	0	13
0.74749997D	01	2	2	0	14
0.62833331D	01	2	2	0	15
0.87999997D	01	2	2	0	16
0.61666663D	01	2	2	0	17
0.73916663D	01	2	2	0	18
0.66166661D	01	2	2	0	19
0.69833330D	01	2	2	0	20
0.70666663D	01	2	3	0	11
0.80749997D	01	2	3	0	12
0.79583330D	01	2	3	0	13
0.72166663D	01	2	3	0	14
0.59749997D	01	2	3	0	15
0.83916663D	01	2	3	0	16
0.53833330D	01	2	3	0	17
0.75249996D	01	2	3	0	18
0.61083330D	01	2	3	0	19
0.75583330D	01	2	3	0	20
0.88999997D	01	3	1	0	21
0.51083329D	01	3	1	0	22
0.77333329D	01	3	1	0	23
0.57583371D	01	3	1	0	24
0.81666663D	01	3	1	0	25
0.76666663D	01	3	1	0	26
0.88999997D	01	3	1	0	27
0.83749997D	01	3	1	0	28
0.82666661D	01	3	1	0	29
0.58916663D	01	3	1	0	30
0.78166661D	01	3	2	0	21
0.10708333D	02	3	2	0	22
0.84499997D	01	3	2	0	23
0.85666662D	01	3	2	0	24
0.64583330D	01	3	2	0	25
0.81083330D	01	3	2	0	25
0.54249996D	01	3	2	0	27
0.84916662D	01	3	2	0	28
0.82833330D	01	3	2	0	29
0.55249997D	01	3	2	0	30
0.69916662D	01	3	3	0	21
0.65749997D	01	3	3	0	22
0.69166662D	01	3	3	0	23
0.80749995D	01	3	3	0	24
0.64249996D	01	3	3	0	25
0.77999994D	01	3	3	0	26
0.70833329D	01	3	3	0	27
0.78416663D	01	3	3	0	28
0.73166664D	01	3	3	0	29
0.49999996D	01	3	3	0	30

RATE OF REDILATION

MEAN		SUBSCRIPT SET A	B	C	D
0.[illegible]3333330D	00	1	1	0	1
0.[illegible]8333330D	00	1	1	0	2
0.[illegible]0833331D	00	1	1	0	3
0.[illegible]1666664D	00	1	1	0	4
0.[illegible]8333330D	00	1	1	0	5
0.[illegible]6499998D	00	1	1	0	6
0.43533330D	00	1	1	0	7
0.49416665D	00	1	1	0	8
0.75416664D	00	1	1	0	9
0.38916654D	00	1	1	0	10
0.69583331D	00	1	2	0	1
0.47583331D	00	1	2	0	2
0.57166663D	00	1	2	0	3
0.36666664D	00	1	2	0	4
0.43749998D	00	1	2	0	5
0.3[illegible]983330D	00	1	2	0	6
0.52666664D	00	1	2	0	7
0.50333330D	00	1	2	0	8
0.57583331D	00	1	2	0	9
0.4[illegible]666664D	00	1	2	0	10
0.60416664D	00	1	3	0	1
0.42833330D	00	1	3	0	2
0.63583331D	00	1	3	0	3
0.5691665[illegible]D	00	1	3	0	4
0.39166664D	00	1	3	0	5
0.40166664D	00	1	3	0	6
0.49399997D	00	1	3	0	7
0.39333330D	00	1	3	0	8
0.53416663D	00	1	3	0	9
0.778333[illegible]D	00	1	3	0	10
0.47916664D	00	2	1	0	11
0.54416664D	00	2	1	0	12
0.56999997D	00	2	1	0	13
0.64333330D	00	2	1	0	14
0.47499996D	00	2	1	0	15
0.46833330D	00	2	1	0	16
0.50499997D	00	2	1	0	17
0.44249997D	00	2	1	0	18
0.39666664D	00	2	1	0	19
0.39249996D	00	2	1	0	20
0.61499998D	00	2	2	0	11
0.50999997D	00	2	2	0	12
0.56666663D	00	2	2	0	13
0.60416664D	00	2	2	0	14
0.49416664D	00	2	2	0	15
0.53333331D	00	2	2	0	16
0.42333330D	00	2	2	0	17
0.45916664D	00	2	2	0	18
0.36749996D	00	2	2	0	19
0.39833330D	00	2	2	0	20
0.53733331D	00	2	3	0	11
0.57583331D	00	2	3	0	12
0.54999996D	00	2	3	0	13
0.59499997D	00	2	3	0	14
0.48749998D	00	2	3	0	15
0.56499997D	00	2	3	0	16
0.40249997D	00	2	3	0	17
0.44583331D	00	2	3	0	18
0.[illegible]3249997D	00	2	3	0	19
0.53749997D	00	2	3	0	20
0.64916664D	00	3	1	0	21
0.355[illegible]3330D	00	3	1	0	22
0.5[illegible]16664D	00	3	1	0	23
0.47916664D	00	3	1	0	24
0.7[illegible]D	00	3	1	0	25
[illegible]14166664D	00	3	1	0	26
[illegible]	00	3	1	0	27
0.431[illegible]	00	3	1	0	28
0.331[illegible]3D	00	3	1	0	29
[illegible]	00	3	1	0	30
0.47083330D	00	3	2	0	21
0.62083325D	00	3	2	0	22
0.66999997D	00	3	2	0	23
0.61416663D	00	3	2	0	24
0.54499997D	00	3	2	0	25
0.60249998D	00	3	2	0	26
0.40416667D	00	3	2	0	27
0.52333331D	00	3	2	0	28
0.53083330D	00	3	2	0	29
0.46416664D	00	3	2	0	30
0.36583330D	00	3	3	0	21
0.41249996D	00	3	3	0	22
0.52249997D	00	3	3	0	23
0.53749997D	00	3	3	0	24
0.51333332D	00	3	3	0	25
0.59249997D	00	3	3	0	26
0.50416663D	00	3	3	0	27
0.51499998D	00	3	3	0	28
0.47916664D	00	3	3	0	29
0.49833330D	00	3	3	0	30