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INDIVIDUAL DIFFERENCES IN PUPILLARY RESPONSE TO CHROMATIC STIMULI

by Michael Moss

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, 1979

ABSTRACT

Individual Differences in Pupillary Response to Chromatic Stimuli[1]

The relationship between the Eysenckian (1967) extraversion dimension and the neo-Pavlovian dimension of strength of the nervous system (Eysenck, 1967; Gray, 1964), with introverts, the weak nervous system type, proposed as reaching the level of transmarginal inhibition at lower levels of stimulus intensity, was explored with the pupillary light reflex. Fifty-one subjects, divided equally into groups of introverts, ambiverts, and extraverts, and equated for low to moderate neuroticism and psychoticism on the basis of EPQ scores, observed a series of red and blue chromatic light stimulations under both a high- and low-intensity condition while the pupillary light reflex was continuously monitored. Subjects were also tested for red and blue hue discrimination ability. Magnitude of maximum constriction, latency and rate of constriction, magnitude of maximum redilation, latency and mean rate of redilation, maximum redilated pupil size, mean tonic dark-adapted pupil size, frequency of V- and W-waves, trials-to-criterion-fatigue, and eyeblink frequency during rest

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[1] Michael Moss, Master's thesis presented to the School of Graduate Studies of the University of Ottawa, Ontario, 1979, xviii-218 p.

and stimulation were measured. It was hypothesized that extraverts, characterized by a greater degree of cortical inhibition, would initially manifest a greater degree of oculomotor inhibition as shown in less extensive pupillary light reflexes than introverts, and that introverts, reaching their threshold of transmarginal inhibition at a lower level, would show less extensive pupillary light reflexes than extraverts at the end of the series of light presentations.

No main effects due to extraversion were observed for any of the thirteen components of the pupillary light reflex, pupillary response, or fatigue indices under any of the hue or intensity conditions. Significantly fewer trials-to-criterion-fatigue indicated that introverts fatigued faster than extraverts to the blue hue during the low-intensity level. This was the only indication of a relationship between extraversion, sensitivity, stimulus intensity, and psychophysiological reactivity, and is in the hypothesized direction.

The hypothesis that introverts are more perceptually sensitive, and manifest more intense, prolonged, or immediate psychophysiological reactivity to low-intensity stimulation, was not confirmed. Holmes' (1967) contention that high levels of acetyl-

choline, inferred from rapid pupillary constriction is related to introversion, is questioned. Significantly less extensive constriction and redilation, slower rates of constriction and redilation, larger redilated pupil sizes, and a greater frequency of fatigue effects were obtained for the red hue. In comparison with the low-intensity condition, significantly more extensive constriction and faster rates of redilation occurred for the high-intensity condition, consistent with previous descriptions of pupillary light reflex activity (Lowenstein & Loewenfeld, 1952, 1969). Extraversion was not related to hue discrimination ability.

With respect to the balance of parasympathetic and sympathetic mechanisms of the pupillary light reflex, the results of the correlational analyses of pupillary components were consistent with the findings of Lowenstein and Loewenfeld (1950, 1969). The results are discussed in terms of individual differences in the pupillary light reflex, the effects of stimulus intensity, individual response specificity, and unexercised controls and methodological problems inherent in previous studies. The pupillary light reflex is indicated as a useful means for investigating habituation and fatigue and a new scoring procedure is introduced.

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CURRICULUM STUDIORUM

Michael Moss was born December 9, 1950, in Westville, Nova Scotia. He received a Bachelor of Arts degree in Psychology from the University of Ottawa in 1976.

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INTRODUCTION

In recent years, substantial advances have been made towards a more complete understanding of the psychophysiological concomitants of such basic psychological processes as perception, learning, memory, and emotion. The search for biological factors underlying individual differences observed in these fundamental psychological processes has done much to increase present knowledge bearing on one of neurophysiology's central problems, i.e., understanding of the principle of neural interconnections proposed to mediate many forms of gross behaviour in general, and maladaptive expression in particular. The specification and elaboration of anatomical pathways and control systems hypothesized to underly behavioural descriptions of differences in socialization and maladaptive neurotic expression have become critical issues. There is a great proliferation of literature advocating various theoretical approaches to describe relationships between psychological, social, and biological functions, from both an experimental and clinical point of view. Within this wide spectrum, one such controversial theoretical approach is the hypothesis of biologically based determinants of individual differences between introverts and extraverts (Eysenck, 1947, 1952, 1967).

Eysenck's (1967) theory of personality has been influential in suggesting to many psychologists that contemporary neurophysiological research on diffusely activating mechanisms in the central nervous system is relevant to research into a wide range of behavioural phenomena. This approach is unique because it attempts to relate individual differences in personality, human behaviour, and sensitivity to a biological basis. More specifically, Eysenck's (1967) hypothesized identification of two orthogonal type-level factors of extraversion and neuroticism with differences in levels of activity in corticoreticular and limbic system loops, the development of a dimensional, quantitative personality classification, and the attempt to relate psychological and physiological processes, have contributed to the elucidation of individual differences in human behaviour and perception.

Eysenck (1967) has proposed that personality differences along the introversion-extraversion dimension depend on individual differences in cortical arousal and inhibition which are modulated in the corticoreticular loop. Introverts have been characterized by increased levels of activity in the reticular formation, which accounts for greater efficiency in processing of sensory information, faster and more complete conditioning and socialization, and enhanced sensitivity. The more cortically inhibited extravert was proposed to manifest reduced sensitivity as a result of presumably lower levels of corticoreticular activity. After a decade of psychophysiological research propogated by Eysenck's (1967) excitation-inhibition proposal, a barrage of disparate results have accumulated, and the controversy born of the theory remains largely unresolved.

Recent advances in the realm of pupillometry hold considerable promise that the pupillary response may provide a sensitive, objective index for investigating the proposed excitation-inhibition hypothesis underlying Eysenck's (1967) theory of extraversion. As indices of autonomic activity, pupillary movements have been studied extensively (Goldwater, 1972; Janisse, 1974). Most of the research, however, has investigated pupillary activity independent of both personality factors and changes in illumination.

An abundant literature exists advocating that the recording of pupillary reactivity offers a promising technique for studying hypotheses concerning cortical and subcortical mechanisms which have been proposed in the rationale for the physiological basis of personality. There is, however, a paucity of such demonstrations. The pupillary light reflex has yet to be exploited as a measure of autonomic reactivity, particularly as related to personality, and no normative data of the reflex is available. Rationale for the use of the light reflex in examining hypotheses in relation to inferred corticoreticular activity rests on Lowenstein and Loewenfeld's (1950, 1952, 1969) description of the anatomical and physiological mechanisms of the reflex, as well as the adaptive role of the pupil in determining the amount of light energy admitted to the visual system by the organism.

The pupillary light reflex is bi-directional in nature, with both branches of the autonomic nervous system involved in the elicitation of the reflex. Constriction is mediated by parasympathetic activity via the ciliary ganglion; dilation is under the control of sympathetic impulses arising in the superior cervical ganglion. Inhibition of the light reflex by sensory or emotional stimuli occurs when impulses from the central nervous system and brainstem reticular system impulses inhibit the oculomotor nucleus and prevent extensive pupillary constriction.

The pupillary light reflex gradually reduces when the eye is exposed to repeated light stimuli at short intervals. This has been understood as a fatigue effect and explained in terms of efferent parasympathetic inhibition of the pupillary sphincter due to supranuclear impulses. It should, therefore, be possible to assess the degree of cortical inhibition characterized by a greater degree of oculomotor nucleus inhibition manifested in the light reflex.

As differential responsiveness between introverts and extraverts has been reported with other physiological measures, individual differences in inhibition and fatigue of the pupillary light reflex, predicted from Eysenck's (1967) proposal, might provide a test of the hypothesized cortico-reticular mechanisms presumed to mediate behaviours along the extraversion dimension. Because of their presumed enhanced sensitivity, introverts should initially manifest faster and more extensive constriction and redilation of the pupillary light reflex, and fatigue faster during a series of repeated light stimulations.

A model for the observed relationship between introversion, speed of conditioning, and synaptic transmitter substances as indexed by speed of pupillary constriction and redilation, has been proposed by Rubin (1960, 1964) and elaborated by Holmes (1967). Holmes (1967) has related speed or efficiency of neural transmission at cholinergic synapses with amount of acetylcholine present, speed of pupillary constriction, conditionability, and introversion. If these results can be partially replicated, employing a more exact measure of pupillary reactivity, further support for the hypothesis relating introversion with high levels of acetylcholine would be provided. In addition, in view of the well defined physiology of the light reflex, specification of the strength and dominance of sympathetic and parasympathetic interaction for individuals differing in degree of extraversion might be accomplished. By attempting a more thorough analysis of the pupillary light reflex than has been previously reported, the significance of specific fatigue indices and additional pupillary measures to psychophysiology are also analyzed. The possibility that different adaptive and fatigue characteristics and motor outlets in the form of eyeblinks are adopted by individuals differing in terms of inferred cortical excitability is assessed.

This thesis attempts to ascertain whether components of the pupillary light reflex, fatigue indices, and eyeblinks to chromatic light stimuli may be used to differentiate individuals differing in degree of extraversion. The use of chromatic light stimuli stems primarily from investigations linking extraversion with individual differences in sensitivity to hues, speculated links between personality and hue preference, and research indicating differential arousal potential and stimulus energy for hues at opposite ends of the spectrum. An attempt will also be made to link extraversion to sensitivity to hues by employing measures of hue discrimination, and to relate hue discriminatory ability to the pupillary light reflex characteristics.

To accomplish these aims, the basic strategy of the present study essentially consists of administering the Eysenck Personality Questionnaire (EPQ), (Eysenck & Eysenck, 1975) to a group of volunteers, selecting three subgroups based on their extraversion scores, and recording measures for hue discrimination ability and the pupillary reactions to chromatic light stimuli. The pupillary response and hue discrimination data are then measured and compared.

Chapter I presents a review of the relevant research on which the questions to be explored are based. Attention focuses on Eysenck's personality theory and on the psychophysiological findings addressing the hypothesis of individual differences in corticoreticular activity between introverts and extraverts. Research pertaining to pupillary reactivity and excitation is then reported, and the dynamics of the pupillary response are described. The relevant research relating hue with personality and psychophysiological reactivity is presented, followed by a statement of the hypotheses.

The second chapter presents a description of the classification of the subjects, psychological instruments and apparatus, experimental and statistical procedures, and scoring methodology. The results are presented in Chapter III. The final chapter involves a discussion of the results and considers implications and potential research.

CHAPTER I

REVIEW OF THE LITERATURE

This chapter presents a review of the theoretical models and relevant research findings which led to the formulation of the questions to be explored in the present investigation. A review of Eysenck's bi-dimensional personality theory is followed by the psychophysiological research bearing directly on this proposal. A description of the anatomical and physiological mechanisms involved in the pupillary response is then presented, followed by research relating the pupillary response with psychophysiological excitation and personality. The literature relating individual differences in personality to the psychophysiological effects of hue is outlined, and in the final section a summary and statement of the hypotheses are presented.

Eysenck's Theory of Personality

The exploration, analysis, and explanation of the biological basis of personality have been accelerated by the work of Eysenck (1947, 1952, 1955, 1967). Based on evidence from a large number of factor analytic studies of self-report inventories, Eysenck (1967) has identified the two orthogonal type-level factors of extraversion and neuroticism as the main contributors to a description of personality, and has put forward a dimensional , quantitative schemata as an alternative to the more categorical, non-quantitative, psychiatric personality classification. In reporting two major orthogonal factors closely resembling the fundamental personality dimensions of Eysenck (1967), support for this proposal has been provided by Hildebrand (1958), Cattell (1965), Cattell and Scheier (1961), and Farley (1970). Factor analytic studies of the MMPI also support this view (Kleinmuntz, 1967; Lanyon & Goodstein, 1971).

The differences between introverted and extraverted personality types were originally explained by Eysenck (1947, 1952, 1955) with reference to the reactive inhibition construct borrowed from Pavlov (1927) and Hull (1943). Inhibition was considered as a central cortical process, and it was postulated that differences in the rate at which individuals accumulated reactive inhibition in response to stimulation accounted for the observed differences between introverts and extraverts on various paper-and-pencil and behavioural tests. Introverts were characterized by weaker and slower development of inhibition and a faster dissipation of inhibition than extraverts, and were predisposed to develop anxiety and depression symptoms, in contrast to extraverted, hysterical conversion and psychopathy, in case of neurotic breakdown (Eysenck, 1957, 1963).

More recently, Eysenck (1967), responding to developments in psychophysiology (Gellhorn & Loofbourrow, 1963; Gray, 1964, 1967; MacLean, 1958, 1960; Routtenburg, 1966; Samuels, 1959), has shifted his emphasis from the concept of reactive inhibition to those of arousal and excitation and the specification of the neural structures proposed to account for the excitation-inhibition hypothesis. The theoretical contention of a two-dimensional, bi-polar personality theory, mediated by a two-dimensional arousal system, (Eysenck, 1967), was proposed to integrate individual differences at the descriptive level with the general behavioural principles established by experimental and physiological psychology.

Of central importance was the specification of physiological determinants for understanding why neurotic expression in introverts frequently takes the form of such disorders as anxiety reactions, phobias, reactive depression, and obsessive-compulsive disturbances, while extraverted emotional instability appears most often in hysterical and psychopathic behaviours. Studies of identical twins brought up separately have indicated an influence of heredity on extraversion and neuroticism (Shields, 1962). The finding that an individual's position on the introversion-extraversion dimention can be shifted with drugs, depressants exerting an extraverting effect and stimulants being introverting, has provided another link with biological science (Eysenck, 1973). To explain these phenomena, differences in activity levels of two distinct neurophysiological loops were postulated as the regulators of constitutional differences proposed by the concepts of extraversion and neuroticism. Individual differences in extraversion were explained by differences in levels of activity in the corticoreticular loop, with introverts characterized by higher levels of activity.

According to this proposal (Eysenck, 1967), the cortex is maintained in a state of functional tonus by collaterals of the reticular formation mediating neural messages relayed along the classical ascending afferent pathways to the particular projection areas. The reticular formation continues to either transmit or inhibit arousal messages relayed to the cortex, depending on the nature of the information being transmitted.

Because of differences within this loop, the introvert is characterized by higher levels of cortical arousal and lower levels of inhibition than the extravert. This constitutional difference was proposed to explain the introvert's greater efficiency in the processing of sensory information, enhanced sensitivity, and faster and more complete conditioning. In contrast, the extravert, presumed to be more cortically inhibited due to lower levels of reticular activity, was expected to condition slower, show less efficiency in sensory information processing, and manifest reduced sensitivity. The importance of the reticular formation as a mediator of cortical excitation has been implicated from the initial work of Bremer (1935, 1936), Moruzzi and Magoun (1949), and Lindsley (1949, 1950).

Subsequent demonstrations have indicated a positive association between reticular activity, perceptual sensitivity, and attention (Gellhorn, Koella, & Ballin, 1954; Livingston, French, & Hernandez-Peon, 1953; Segundo & Arana, 1955). Eysenck's (1967) observations of differences in performance during sensory tasks between individuals differing in degree of extraversion have been cited as evidence linking introversion with cortical arousal.

Eysenck (1967) leans heavily on the Papez (1937) and MacLean (1958) theories of emotion in providing a physiological rationale for his concept of neuroticism. Neuroticism has been linked with differences in activity primarily in the limbic system, with differential thresholds for hypothalamic activity proposed to mediate differences in responsivity of the sympathetic nervous system. Such structures as the hypothalamus, amygdala, and hippocampus, as well as the reticular system, have been implicated in this second loop. It was proposed that collaterals from the visceral brain transmit arousal messages to the cortex via the reticular formation in a manner similar to information transmission via the ascending afferent pathways. Greater responsivity, excitability, and agitation characterized high neuroticism scorers. Low levels of autonomic activity, inferred from differences in sensitivity, attention, and conditioning between introverts and extraverts, contrasted with high levels of neurotic autonomic activation concomitant with expressions of fear, distress, or anger. Unlike extraversion, which is physiologically manifested via cortical control over the arousal impulses received from the reticular formation, in the case of neuroticism activating impulses from the reticular formation are not directly under the control of the cortex. Thus, sensory stimulation can produce cortical arousal without the involvement of the visceral brain.

Eysenck (1963, 1970, 1972, 1975) now accepts psychoticism as a third major personality factor, independent of extraversion and neuroticism. Support for the existence of this third major personality dimension has been provided by Royce (1972) in a factor-analytic review. However, because measurement of this third factor has only just recently been made possible (Eysenck & Eysenck, 1975), the nature of the dimension is extremely speculative.

Eysenck's (1967) excitation-inhibition hypothesis has been extended by the work of Gray (1964, 1967), who has proposed a rapproachment between the extraversion dimension and the Russian dimension of strength of the nervous system. It was hypothesized that the introvert's proposed higher levels of cortical arousal and lower levels of inhibition were highly similar or identical to the Russian weak nervous system individual, where cortical excitatory processes dominated. The extravert, characterized by presumably lower levels of cortical arousal and higher levels of inhibition, was similar to the strong nervous system individual (Eysenck, 1967; Gray, 1964, 1967). Gray has speculated that because of more easily triggered cortical activity in the thalamo-cortical inhibitory system, extraverted individuals suppress sensory input. Conversely, greater efficiency of sensory receptors was proposed to characterize introverted individuals (Gray, 1967).

Introverts, who apparently display activity congruent with the neo-Pavlovian weak nervous system dimension, have been shown to exhibit greater sensory sensitivity (Smith, 1968; Stelmack & Campbell, 1974), lower threshold levels of transmarginal inhibition (Frigon, 1976; Wigglesworth & Smith, 1976), and greater difficulty in extinguishing of the orienting response (Stelmack, Bourgeois, Chian, & Pickard, 1979). Results supportive of the introvert's proposed sensory sensitization as opposed to the extravert's sensory repression have been reported utilizing measures of pain threshold and sensitivity (Bartol & Costello, 1976; Haslam, 1967; Lynn & Eysenck, 1961), salivary activity (Corcoran, 1964; Eysenck & Eysenck, 1967), taste sensitivity (Fisher, Marks, Hill, & Rockey, 1968), sensory sensitivity (Siddle, Moorish, White, & Mangan, 1969), and vigilance (Bakan, 1959; Harkins & Geen, 1975; Krupski, Raskin, & Bakan, 1971).

In recently proposing a further modification of Eysenck's (1967) theoretical position, Gray (1970, 1972, 1973) has explicated more fully the role of specific emotional response patterning in the explanation of behaviours subsumed under the concepts of psychopathy and dysthymia, within the extraversion and neuroticism model. This modification, (Gray, 1970, 1972, 1973), with a shift in emphasis to limbic structures, has identified introversion with greater susceptibility to nonreward and punishment, as mediated by differential activity levels of the frontal cortex, medial septal area, hippocampus, and the ascending reticular system. A system linking the medial hypothalamus, medial forebrain, and septal area, mediating approach behaviour to signals of reward, was identified with extraversion. Support for this position has been provided from studies which have indicated an extraverting effect on behaviour due to both frontal cortex lesions and the drug sodium amobarbital (Gray, 1970, 1972).

The neuroticism dimension, according to this model, is mediated by both of these functionally distinct limbic subsystems, and manifested by increased sensitivity to both punishment and reward. Thus, introversion was related to susceptibility to punishment and a predominant emotional response predisposition of anxiety and fear in high-neuroticism individuals, and extraversion was identified with greater responsivity to appetitive stimuli and a predominant emotional response predisposition of anger, in high-neuroticism individuals. Congruence with Eysenck's (1967) contention of differential emotional reactive predispositions for introverts and extraverts is further enhanced in that the proposed heightened psychophysiological response for introverts, as mediated by reticular system activity, is subsumed within Gray's (1973) proposal outlining the physiological determinants of extraversion. The small variation in extraversion typically accounted for by many autonomic measures may be due to the less immediately relevant physiological structures Gray (1973) has proposed to account for the extraversion and neuroticism dimensions.

The hypothesized differences in corticoreticular activity and limbic system structures proposed by Eysenck (1967) and extended by the modifications cited, are of fundamental significance in exploring basic social and psychiatric behaviour. Although this theory has enriched experimental research into personality and its suitability to experimental psychology has been repeatedly demonstrated, after over ten years of research, controversy still remains regarding the hypothesis of differences in corticoreticular activity between introverts and extraverts. Psychophysiological research which has addressed this hypothesis will now be reviewed.

Extraversion and Psychophysiological Research

Because most of the research addressing the proposal of differences in level of corticoreticular excitation between introverts and extraverts has primarily employed indirect measures of gross autonomic reactivity, such as electrodermal and electrocortical activity, these studies will be emphasized in the present review. Electrodermal techniques have been widely employed in the study of the orienting reaction (OR) and hypotheses concerning cortical arousal (Lynn, 1966; O'Gorman, 1977; Sokolov, 1963). Sokolov's (1963) model of the OR as a basis for favourable stimulus reception involves components that have been described as either sensory (lowered sensory thresholds), somatic (orientation towards stimulation), autonomic (increased skin conductance, heart rate deceleration, pupillary dilation), or central (desynchronization of EEG).

According to Sokolov (1963), Anokhin (1965), and Maltzman and Raskin (1965), the OR is an holistic reflex occurring with any quantitative or qualitative change in a stimulus. The OR is independent of stimulus modality, subject to habituation or extinction on repeated stimulus presentations. The most widely accepted physiological rationale for the OR (Lynn, 1966; Sokolov,1963) has implicated a congruence between the attentional mechanisms of the Soviet model and the systems which Eysenck (1967) has proposed in his contention for the biological basis of extraversion, i.e., impulses relayed by way of collaterals from ascending sensory tracts are mediated via the reticular formation, which transmits activating impulses to the posterior hypothalamus, initiating autonomic components of the OR. When stimulus characteristics are matched with those of a pre-existing neuronal model in the cortex, inhibitory impulses are transmitted via the reticular formation to the collaterals transmitting impulses from the sensory organs, and habituation occurs. Because of the central role of cortical excitatory and inhibitory activity in OR elicitation and habituation, inferences regarding levels of corticoreticular activity have been made by comparing electrodermal response levels and from electrodermal habituation of the OR.

The proposed differences in extraversion, as reflected in the OR, are derived from the congruence of the Sokolovian (1963) and Eysenckian models of attention and excitation-inhibition. Extention of the OR concept to the investigation of the psychophysiology of extraversion is largely due to the work of O'Gorman (1977) and Stelmack (in press). In the Russian typology, greater OR amplitudes and longer rates of habituation are characteristic of the introverted, weak nervous system type (Eysenck, 1967; Gray, 1964, 1967; Nebylitsyn & Gray, 1972). Although at the present time it is not possible to specify the exact structures from which individual differences in response originate, the electrodermal response has generally served as a basis for examining hypotheses concerning corticoreticular activity and behavioural investigations along Eysenckian dimensions (Thompson, Groves, Teyler, & Roemen, 1973; Stelmack, in press).

From measures of both tonic and phasic electrodermal activity, introverts have been reported to exhibit greater levels of corticoreticular activity. Support for Eysenck's (1967) hypothesis has been provided by Bartol and Martin (1974), who reported greater electrodermal initial amplitudes for introverts to orange light stimuli. Greater initial amplitudes of the OR for introverts have also been observed by Wigglesworth and Smith (1976) to tones of 1000 Hz 80 dB SPL and 90 dB SPL intensity. Stelmack, Bourgeois, Chian, and Pickard (1979), in a series of studies, have also reported greater initial amplitudes of the skin conductance response for introverts to red, blue, and gray chromatic stimuli.

Crider and Lunn (1971) have noted a greater number of spontaneous electrodermal fluctuations for introverts to 1300 Hz 80 dB SPL and 90 dB SPL tones. Further support for the introvert's greater reactivity has been provided by Coles, Gale, and Kline (1971), who reported shorter latencies along with a greater number of spontaneous electrodermal fluctuations for introverts to a 1000 Hz 75 dB SPL tone. Similarly, Sadler, Mefferd, and Houck (1971) have reported a greater mean number of electrodermal responses to auditory stimulation for introverts. Desjardins (1976), in two experiments which employed visually presented abstract and concrete word stimuli, reported that extraversion was significantly inversely related to spontaneous electrodermal fluctuations. Higher skin conductance levels were also reported for introverts in the study by Desjardins (1976) and in two separate experiments reported by Fowles, Roberts, and Nagel (1977) which utilized tones at 1000 Hz 75 dB and 83 dB intensity levels. These results were interpreted as supportive of the view of congruence of the extraversion dimension with the dimension of strength of the nervous system (Eysenck, 1967, Gray, 1964, 1967).

In an attempt to directly investigate the apparent similarities between the extraversion and neo-Pavlovian strength-sensitivity dimensions, Mangan and O'Gorman (1969) observed longer trials to habituation for introverts to 380 Hz 60 dB SPL and 1000 Hz 60 dB SPL tones.

Crider and Lunn (1971) also noted that introverts habituated slower than extraverts to 1300 Hz 90 dB intensity tone stimuli. Further support for Eysenck's (1967) hypothesis has been provided in the three experiments of Stelmack et al. (1979), where longer trials to criterion electrodermal rate of habituation for introverts were noted for both chromatic and neutral, affective, and taboo word stimuli. Investigations which have related longer OR habituation rates and higher electrodermal conductance levels with both number of spontaneous responses and initial amplitude of the OR (Büll & Gale, 1973; Siddle & Heron, 1976) add further support to these studies.

Although the cited studies cannot easily be dismissed, the balance is adjusted by investigations which have reported negative and contradictory findings. Among these, negative results have been reported by Sadler, Mefford, and Houck (1971), who noted no significant differences in the rate of electrodermal habituation to the three auditorily presented 60 dB alphabetical letters employed in their study.

Siddle (1971) noted no relationship between extraversion, trials to criterion habituation rate, and electrodermal initial amplitude to a 1000 Hz 60 dB intensity tone. Similarly, nonsignificant results have been reported by Koriat, Averill, and Malmstrom (1973), for both electrodermal and cardiac measures of habituation to 1000 Hz 75 dB tones. No significant differences between extraversion groups were observed by Coles, Gale, & Kline (1971) to the 1000 Hz 65 dB tone stimuli employed in their study. Feij and Orlebeke (1974) reported no significant differences between extraversion groups for either electrodermal habituation, electrodermal amplitude, or heart rate to 1000 Hz 60 dB tones during periods before and during a 3-min mathematical task.

Disparate results have also been reported by Mangan and O'Gorman (1969), who attempted to differentiate introverts and extraverts with electrodermal criteria. Because of the design employed, neuroticism was a confounding factor, with faster habituation rates to the 1000 Hz 60 dB tone observed for both high-neuroticism introverts and low-neuroticism extraverts than for low-neuroticism introverts. In a separate study, (Mangan & O'Gorman, 1969), extraverts were shown to exhibit higher initial amplitudes of the electrodermal OR than introverts to a 380 Hz 57 dB tone. These results are contrary to Eysenck's (1967) hypothesis.

No significant differences between extraversion groups were observed for either skin conductance level or trials to habituation to chromatic light stimuli in the study reported by Bartol and Martin (1974). Similarly, Wigglesworth and Smith (1976) did not observe any significant differences due to the extraversion factor for trials to criterion habituation rate of skin resistance to either 1000 Hz 80 dB SPL tones, either alone or following a paired-associate learning task.

In an investigation into the effects of high- and low-intimacy self-disclosure, no differences between introverts and extraverts were observed on measures of both heart rate and electrodermal reactivity (Ashworth, Fruman, Chaikin, & Derlega, 1976). Similar nonsignificant results have been reported in a series of four investigations by Fowles, Roberts, and Nagel (1977), where skin conductance levels following an easy and difficult paired-associate learning task to 1000 Hz 80 dB and 100 dB tones were analyzed. In a separate sample, extraverts showed higher skin conductance levels than introverts to 1000 Hz 100 dB SPL tones following the difficult paired-associate learning task.

The controversy propagated by Eysenck's (1967) theory of personality is further extended by the collage of disparate findings where more direct electrocortical indices of psychophysiological activation have been employed. Increased levels of corticoreticular activity for introverts, as inferred from low amplitude, high frequency activity in the 8-13 Hz frequency range, have been reported by Savage (1964). A study by Gale, Coles, and Blaydon (1969) in which reclining subjects opened and closed their eyes has also identified introversion with increased levels of cortical arousal. Similarly, Marton (1972) reported significantly higher levels of cortical activity for introverts, as inferred from electrocortical habituation measures to low frequency tone stimuli. Significant positive correlations between extraversion and mean alpha abundance have been reported in an investigation into the relationship between extraversion, imagery, and alpha abundance, where slide-presented words were employed as imagery stimuli (Morris & Gale, 1974). Further support for Eysenck's (1967) hypothesis is gleaned from the work of Frigon (1976) who, investigating the congruence of the Russian strength of the nervous system and extraversion dimensions (Eysenck, 1967; Gray, 1964), observed faster extinction of CS-UCS pairings with reinforcements for introverts. Greater cortical arousal for introverts was inferred from greater mean duration of alpha blocking during CS of the CS-UCS pairings of pictorial slides with a 70 dB tone.

The conflicting results of the electrodermal OR research are reinforced by electrocortical studies which have failed to support Eysenck's (1967) hypothesis. Non-significant results have been reported by Fenton and Scotton (1967) and Gale, Coles, Kline, and Penfold (1971) in independent efforts to relate extraversion with alpha abundance as well as basal and response measures, during habituation of the OR. Nonsignificant results have also been reported by Winter, Broadhurst, and Glass (1972), who ~~measured~~ EEG amplitude under conditions proposed to induce low arousal (eyes closed) and high arousal (eyes opened and closed during arithmetic problem-solving). Employing a German translation of the Maudsley Personality Inventory (Brengleman & Brengleman, 1960), Becker-Carus (1972) also observed no relationship between extraversion, vigilance, and the EEG.

Results endorsing the contrary hypothesis of higher levels of arousal for extraverts have been provided by Broadhurst and Glass (1969). The possibility of confounding effects attributable to sex differences was discussed, and the classification procedure employed may also be questioned. Support for this contrary hypothesis has also been provided by Gale, Harpham, and Lucas (1972) in a study designed to consider time of day effects on EEG arousal indices. However, small sample size and score distributions favouring extraversion limited the implications of this study.

Measurement of cortical evoked potentials (EP) has also been employed in testing hypotheses along the

Eysenckian dimensions of sensory sensitivity, activation, and attention. Although a direct relationship between sensitivity and the evoked response has not been reported, increased levels of attention have been inferred from enhanced evoked potential amplitudes (Näätänen, 1975). Shagass and Schwartz (1965) have reported levels of increased cortical activity for introverts, as reflected in the somatosensory evoked response. Hendrickson (1973) employed evoked response measures to 100 Hz 60 dB SPL tones, and observed significant negative correlations between extraversion and the amplitudes of both the N_1-P_2 and the N_2-P_3 components. Further support for the introvert's presumed higher levels of cortical arousal has been provided by Stelmack, Achorn, and Michaud (1977), who reported increased N_1-P_2 amplitudes for introverts in two separate studies in which 500 Hz 55 dB and 80 dB SPL tone stimuli were employed.

Results supporting the proposed linkage of extraversion with differences in hedonic tone have been observed from research investigating the effects of depressant and stimulant drugs on the magnitude of the contingent negative variation (CNV) (Ashton, Millman, Telford, & Thompson, 1974). Introverts were shown to exhibit faster rates of nicotine intake than extraverts, and from inferences from the percentage change in CNV magnitudes, the drug was shown to have a depressant effect on introverts and stimulant effect on extraverts. The results were interpreted in terms of differential strategies of nicotine intake between extraversion groups for maintaining optimal cortical arousal levels. Similarly, Janssen, Mattie, Gorcel, and Werre (1978) found that introverts showed a lower mean CNV amplitude to white noise in contrast to periods without the noise. These results concur with expectations of greater corticoreticular activity in introverts.

Although the electrocortical demonstrations carry significant import, the hypothesis of increased corticoreticular activity for introverts has not been unanimously endorsed. Negative results have been reported by Häseth, Shagass, and Straumanis (1969) and Burgess (1973) in separate attempts to relate extraversion with the somatosensory evoked response. Corrections for individual differences in perceptual sensitivity may have eliminated the differences of interest in these studies. Two separate attempts by Rust (1975) to replicate the investigations relating extraversion with amplitude of the auditory evoked response, employing 1000 Hz 95 dB, 75 dB, and 55 dB intensity tones, have been unsuccessful. In the investigation reported by Stelmack et al. (1977), no differences between extraversion groups were observed under the high frequency (8KHz) stimulation.

Summary: In view of the many differences in subject selection and preparation, measurement parameters, and recording and scoring methodologies utilized, at present it would seem that the demonstration of a relationship between extraversion and level of corticoreticular activity inferred from psychophysiological data remains equivocal. Based on available evidence, perhaps the only conclusion which may be drawn at the present time is that, under moderate stimulus conditions, the direction of the results is towards a confirmation of Eysenck's (1967) hypothesis.

The Pupillary Response

A rapidly increasing volume of literature has suggested that the registration of pupillary size and movements may serve as sensitive and accurate indices for studies investigating individual differences in corticoreticular and autonomic nervous system activity (Goldwater, 1972; Hess, 1964, 1965, 1972; Janisse, 1973, 1974, 1976; Lowenstein & Loewenfeld, 1952, 1969; Stelmack & Mandelzys, 1975). Changes in the shape of the iris, which controls the size of the pupil, are innervated by both branches of the autonomic nervous system, with constriction attributed primarily to parasympathetic control and dilation mediated primarily by sympathetic activity. The reflex of the pupil to an increase and subsequent decrease in light intensity is bi-directional. The chain of events between the stimulus (light flash) and the response (constriction and subsequent redilation with stimulus offset) of this fundamental form of reflexive behaviour has been elucidated by Lowenstein and Loewenfeld (1950, 1969): From the initial rapid pupillary constriction which occurs with the onset of light stimulation, activity of primarily parasympathetic origin can be inferred. Afferent reflex impulses travel through the exterior structures of the eye to the retina, and then via the optic tract to cross in the optic chiasm, emerging from the posterior third of the tract. Impulses then travel via the superior colliculi to synapse in cells of the pre-tectal nucleus. The light reflex impulses are then transmitted via pre-tectal fibres to the superior oculomotor nucleus. Efferent parasympathetic impulses are relayed to the smooth sphincter muscles innervating the iris, causing constriction of the pupillary aperature. Two phases of constriction have been identified: a fast ascending primary phase, primarily due to parasympathetic reflex activity, and a slower, descending secondary phase mediated by increasing sympathetic activity. Increased sympathetic opposition from efferent sympathetic impulses arising in the neocortex, thalamus, and hypothalamus exert a moderating effect and are thought to largely determine the shape of the reflex.

Similarly, redilation consists of two phases: an initial rapid phase, reflecting parasympathetic relaxation, followed by a negatively accelerating secondary phase mediated by peripheral sympathetic activity. With the offset of stimulation, the radial strands of the dilator pupillae are stimulated by impulses from the neocortex, thalamus, and hypothalamus via the cervical cord, superior cervical ganglion, and peripheral sympathetic chain, causing the pupillary aperature to dilate.

Inhibition of constriction of the light reflex occurs primarily due to central parasympathetic inhibition, with interfering impulses arising from higher brain centres and afferent reticular formation collaterals inhibiting efferent impulses from being transmitted from the oculomotor nucleus to the pupillary sphincter (Lowenstein & Loewenfeld, 1952, 1969). Strengthening of parasympathetic or sympathic nervous system activity as well as weakening of parasympathetic tonus have been shown to cause decreased and sluggish constriction and redilation of the light reflex (Loewenfeld, 1950). No explanation has been offered for this effect.

Both environmental and subject factors affect the pupillary light reflex. In accordance with its adaptive nature of regulating the amount of light admitted by the organism, it is common knowledge that the pupil constricts and dilates in proportion to the amount of light striking the retina. High intensity light stimuli have been found to elicit reflexes characterized by faster and more extensive constriction and subsequent redilation than low intensity stimuli (Bouma, 1962; Lowenstein & Loewenfeld, 1952, 1961, 1969; Reeves, 1920; ten Doesschate & Alpern, 1967). Indeed, the action spectrum of the light reflex has been shown to be highly similar to that of the psychophysical (foveal) luminosity curve (Alpern & Campbell, 1962).

Both sensory and psychologically induced stress have been shown to elicit pupillary dilation responses independent of the light reflex, as well as inhibition of the light reflex (Arima & Wilson, 1972; Janisse, 1973, 1974, 1976; Lowenstein & Loewenfeld, 1952; Lowenstein, Feinberg, & Loewenfeld, 1963; Plouffe & Stelmack, in press; Rubin, 1964, 1972). Gang (1945) has reviewed several studies in which the pupillary light reflex was inhibited by emotional pupillary dilation. In addition, greater tonic pupil sizes and less extensive light reflexes have been found for hyperexcitable subjects (Apley, Haslam, & Tulloh, 1971; Lowenstein & Loewenfeld, 1961; Lowenstein, Feinberg, & Loewenfeld, 1963). The extent of both effects has been shown to depend on both the intensity and suddeness of the stimulus and the general level of cortico-thalamo-hypothalamic activity (Lowenstein & Loewenfeld, 1952, 1969). Fatigue of the pupillary light reflex, as indicated by less extensive and slower rates of constriction and redilation, and the appearance of V, W, and tonohaptic wave forms, has been observed following repeated exposures to light stimulation. However, psychosensory stimulation has been found to quickly reestablish the exhausted reflex (Lowenstein & Loewenfeld, 1950, 1952).

Inferences of general activation level have been made employing the pupillary response under conditions prior to stimulation where tonic pupil size may be measured, or following psychosensory stimulation employing non-visual stimuli. Both psychosensory pupil constriction and dilation have been considered to result from changes in the degree of cortico-thalamo-hypothalamic activity (Lowenstein & Loewenfeld, 1958). Evidence has been provided suggesting that these physiological phenomena may be more complex than this and has implicated the importance of reticular formation and lateral geniculate structures (Legg, 1975; Schaeppi & Koella, 1964).

Psychosensory pupil constriction has been attributed to all of the following: to a decrease of sympathetic innervation, parasympathetic activity, decreases of central inhibition of the Edinger-Westphal nucleus, and the cholinergic transmitter substance acetylcholine. Psychosensory pupil dilation is thought to be caused by sympathetic innervation of the dilator pupillae, inhibition of the Edinger-Westphal nucleus, and increased epinephrine levels.

Sensory or emotional stimuli, as well as fatigue and spontaneous thought or emotions have been shown to increase pupillary activity (Hess, 1960, 1965; Janisse, 1973, 1975; Stelmack & Mandelzys, 1975). Psychosensory pupil dilation has been understood in terms of the Sokolovian (1963) OR model and the pupillary response to light has been shown to exhibit characteristics of a conditioned response (Lowenstein & Loewenfeld, 1952; Maltzman & Raskin, 1965; Stelmack & Mandelzys, 1975).

The light reflex is not dependent on light alone, but also upon sensory stimuli which maintain wakefulness. This has been known for a long time (Lowenstein & Loewenfeld, 1920). Further support for this contention is gleaned from the studies of Hodes and Magoun (1942), in which direct stimulation of the reticular formation was shown to produce both dilation of the pupil and inhibited light reflex responses. Fatigue, chronic clinical disorders as narcolepsy, central nervous system diseases as syphilis and epilepsy, lesions in the optic tract, and sleep deprivation have all been shown to inhibit or diminish pupillary response amplitudes (Geacintov & Peavler, 1974; Lowenstein & Loewenfeld, 1952, 1964; Yoss, Moyer, and Ogle (1969). Decreased pupillary size accompanying decreased wakefulness has also been reported by Lowenstein, Feinberg, and Loewenfeld (1963). In addition, decreased tonic pupil size, longer latencies to constriction, and greater variability of constriction and redilation have been shown to accompany increasing age (Birren, Casperson, & Botwinick, 1950; Feinberg & Podolak, 1965; Lowenstein, Feinberg, & Loewenfeld, 1963; McCawley, Stroebel, & Glueck, 1966; Weale, 1965).

Of particular relevance to the present study is the report that changes in hue result in rate-sensitive pupillary contractions (Clynes, 1962; Kohn & Clynes, 1960). Evidence also suggests that, in all liklihood, all rods and cones when independently chromatically stimulated, are capable of exciting pupillary constriction responses (Alpern, McCready, & Barr, 1963).

The pupil has been shown to exhibit properties similar to other psychophysiological indices which have addresses the hypothesis of differences in levels of corticoreticular activity, e.g., habituation on repeated stimulus presentations (Lowenstein & Loewenfeld, 1952, 1969; Plouffe & Stelmack, in press), parasympathetic rebound effects (Rubin, 1964, 1972), and a gradual arousal decrement (decrease in size) over time (Woodmansee, 1966).

In addition, in view of the fact that the eye and brain have developed from the same embryological tissue (Patten, 1968), it is surprising that the pupillary light reflex has not been employed more in psychophysiological research, particularly as related to personality. Advantages over other indices of psychophysiological reactivity include the factor that the light reflex is relatively free from extraneous factors due to spontaneous thoughts or emotions which typically confound electrodermal response measures in particular.

The clarity with which separate autonomic components and fatigue effects emerge also indicates the usefulness of the pupillary light reflex as a psychophysiological measure. The pupillary light reflex would seem to provide a particularly useful means for the investigation of habituation, since it does not extinguish (Plouffe & Stelmack, in press). The reflex is also unique in that the pupil provides the only autonomic response that is open to unaided observation (Janisse, 1976).

Pupillary Response, Psychophysiological Reactivity, and Extraversion

Although the pupillary light reflex has been infrequently employed in studies of individual differences, suggestions that the pupillary response might provide a useful indicator of activation are supported by a large literature. Most of the pupillometric studies have assessed changes in pupil size and pupillary movements either during dark or light adaptation, or to psychosensory stimulation, where light reflex artifacts were considered as independent or largely uncontrolled (Goldwater, 1972; Hess, 1964, 1965, 1969; Janisse, 1973, 1976; Lowenstein & Loewenfeld, 1966, 1969).

The history of pupillometrics is relatively young. The pioneering work in the realm of pupillometry was a series of studies by Hess and his co-workers at the University of Chicago. This research suggested that attitudes might be reflected by the degree of pupillary activity (Hess, 1964,1965; Hess & Polt, 1960, 1964). From these controversial studies came the proposal that pupillary dilation and constriction might be considered as consistent bi-directional indicators of interests, attitudes, and thought processes. The bi-directional nature of the pupillary response occurring independently of illumination, has remained a much debated issue. The prevailing opinion in the literature is that psychosensory dilation of the pupil is a general indicator of activation (Goldwater, 1972;

Janisse, 1976; Kahneman, 1973; Lowenstein & Loewenfeld, 1952, 1969; Stelmack & Mandelzys, 1975). The historical developments of pupillometry have been elucidated in two reviews by Hakerem (1967, 1974).

Lowenstein (1920) has related increases in arousal and attention to pupillary dilation, and more recently asserted that "all physiologic and sensory stimuli, with the exception of light, dilate the pupil, and none of them contract it." (Lowenstein, 1966, p. 293). This contention has, however, been questioned by Clynes (1967) who observed pupillary constriction to both dark flashes and changes in hue. No explanation has been offered for the former phenomenon, which has been termed "paradoxical pupillary constriction".

In addition to the study of fatigue and fatigue-related disorders, measurement of pupillary reactivity has been employed in the analysis of attentional and psychiatric disorders as schizophrenia and manic-depressive syndromes (Lowenstein & Loewenfeld, 1952; Lowenstein, Feinberg, & Loewenfeld, 1963; Ikushima & Matsunaga, 1977; Patterson, 1976; Rubin, 1964, 1972). Differences in reticular formation activity have been implicated in these disorders and such individual differences in corticoreticular activation are consistent with Eysenck's (1967) hypothesis. The positive association between perceptual sensitivity, awareness of environmental stimuli, and physiological reactivity reported in these studies, has been reflected in smaller tonic pupil sizes and inhibition of the light reflex for the chronically fatigued, unconscious, and schizophrenic patients.

Libby, Lacey, and Lacey (1973) have also reported that attention to the environment leads to sympathetic-like pupillary dilation and parasympathetic-like cardiac slowing, i. e., directional fractionation. The contention of a positive relationship between environmental sensitivity and pupillary dilation is enhanced by the demonstration that increases in pupillary diameter have accompanied cortical desynchronization, whereas decreases in pupillary diameter have been reported with cortical synchronization, whether occurring spontaneously or through direct or indirect stimulation of the reticular formation (Naquet, 1960).

Although the measurement of pupillary reactivity as an indicator of general psychophysiological reactivity is far from being resolved, research centering on pupillary activity has generally supported a positive link between psychosensory pupillary dilation and cortico-reticular activation (Kahneman & Beatty, 1966; Libby, Lacey, & Lacey, 1973; Maltzman and Raskin, 1965; Nunally, Knott, Duchnowski, & Parker, 1967; Stelmack & Mandelzys, 1975). Psychosensory pupillary dilation has been associated with problem difficulty level (Kahneman, 1973; Kahneman & Beatty, 1966), social and political attitudes (Hess, 1965; Woodmansee, 1967), sexually arousing stimuli (Bernick, Kling, & Borowitz, 1971; Hess, Seltzer, & Shlien, 1965; Zuckerman, 1971), social familiarity and interpersonal attraction (Boddicker, 1969; Fitzgerald, 1968; Karp, 1972), imagery (Colman & Paivio, 1969; Paivio & Simpson, 1966), stress and anxiety (Adams, 1968; Francis, 1969; Janisse, 1973, 1974, 1976; Patrick, 1969; Walters, 1975), deception (Berrien & Huntington, 1943; Ekman & Friesen, 1969; Heilveil, 1976), low reasoning ability (Crough, 1968), and increased cognitive load, information processing and retrieval (Berthold & Slowiaczek, 1975; Gardner, Beltramo, & Krinsky, 1975; Gardner & Kahneman, 1973). Nunally, Knott, Duchnowski, and Parker (1967), in an investigation which assessed the sensitivity of the pupillary response to five widely differing types of stimulation representing activating situations of varying response systems, concluded that pupillary dilation was a general indicator of all types of activation.

In addition to these types of studies, some work has been done in attempts to relate pupillary reactivity with other autonomic indices. Under hypothalamic stimulation, L

Ranson and Magoun (1933) positively associated pupillary dilation with rate of respiration. Harsh, Beebe-Center, and Stevens (1939) related pupillary dilation with cardiac acceleration to voluntary breathing changes. In other animal studies, Lindsley and Sassaman (1939) positively correlated pupillary dilation with both skin potential and heart rate during pilomotor activity.

In human subject research, Kahneman, Tursky, Shapiro, and Crider (1969) noted a positive association between pupil size, electrodermal response, and heart rate. Under conditions designed to increase autonomic activation, Scott, Wells, Ward, and Morgan (1967) reported a significant positive correlation between psychosensory pupil dilation and the electrodermal response. Similarly, Mandelzys (1973), employing neutral, affective, and taboo word stimuli, noted that electrodermal latency and amplitude corresponded to pupillary reactivity for groups differing in degree of extraversion. No association between the impulsive pupillary response and visual evoked potentials was reported in a recent study by Klix and Klassa (1975) investigating the relationship between cognitive requirements and psychophysiological reactivity. However, the hypothesis of a monotonic relationship between the amplitude of the pupillary reaction and the measure of difficulty of the experimental situation was confirmed.

Patterson (1976), employing a sample of male schizophrenics, has recently related fast skin conductance recovery to non-signal tones to slow pupillary constriction in the light-dark reflex. Conversely, slow skin conductance recovery was related to fast pupillary constriction. Several studies have indicated the superiority of pupil size as a more sensitive peripheral measure of autonomic activation than electrodermal (Colman & Paivio, 1969), heart rate (Gibney, 1966), and corticosteroid level measurements (Bernick, Kling, & Borowitz, 1971).

There have been relatively few studies relating pupillary reactivity with individual differences in personality dimensions such as extraversion. Holmes (1967) light-adapted the pupils of 16 subjects to white light, photographed them a 5-, 10-, and 15-sec intervals following stimulus offset, and measured the extent of dilation. On the basis of pupil size during these intervals, mean dilation measures were computed, and subjects were classified into two groups of 8 fast and slow dilators. Although these results failed to reach significance, fast dilators were found to have relatively higher extraversion scores on the Maudsley Personality Inventory (MPI) (Eysenck, 1962). Subjects were also classified into two groups of 8 fast and slow constrictors on the basis of photographs taken at 1-, 2-, and 3-sec intervals following the onset of a light stimulus. The fast constrictors were observed to have lower extraversion scores. The results were interpreted as consistent with Rubin's (1960, 1964) proposed model relating speed of pupillary constriction with amount of acetylcholine present at cholinergic synapses, with speed of pupillary dilation positively associated with amount of adrenergic transmitter substance. Greater amounts of acetylcholine, as inferred from speed of pupillary constriction, were linked with the greater sensitivity, environmental awareness, and rapid verbal conditionability of introverts.

Several attempts have been made to assess the effects of both Eysenckian (1967) extraversion and neuroticism on pupillary reactivity. Francis (1969), employing auditory stimulation, related pupillary dilation with the neuroticism dimension of the Eysenck Personality Inventory (EPI) (Eysenck & Eysenck, 1968). Boddicker (1972) attempted to relate both extraversion and neuroticism with pupillary activity. By classifying 40 subjects into four quadrants on the basis of their EPI scores, it was noted that low extraversion and low neuroticism scorers tended to exhibit higher pupillary reactivity, as reflected in the pupillary OR response to positive, neutral, and negative affect word stimuli. These results failed to reach significance however, and the contaminating effect of neuroticism is clear.

Plouffe and Stelmack (in press) attempted to rectify the confounding effects of neuroticism and extraversion found in many studies by measuring the light reflex to low-intensity white light for three groups differing in degree of neuroticism, but equated for moderate extraversion. The light reflex was measured under pre-stress, physiological stress elicited with cold pressor stimuli, and post-stress conditions. The reflex failed to differentiate individuals differing in terms of EPI neuroticism, but was found to be inhibited under the sensory induced stress condition.

Stelmack and Mandelzys (1975) measured the pupillary response, independent of the light reflex, to neutral, affective, and taboo word stimuli. Introverts were shown to have greater prestimulus pupil sizes and significantly greater dilation responses from prestimulus levels than extraverts, particularly to the taboo word stimuli. These results were interpreted as indicative of higher levels of tonic arousal for introverts, with greater psychosensory pupillary dilation reflecting the introvert's increased levels of corticoreticular activation.

The effects of auditory stimulation on both pupil size and the pupillary light reflex have been recently investigated along Eysenckian lines by Frith (1977).

The pupils of 33 male subjects who had been administered the Eysenck Personality Questionnaire (EPQ) (Eysenck & Eysenck, 1975) were photographed on 16 mm film at 3 frames per sec. Pupil size was measured under conditions of no stimulation, following the presentation of a green light stimulus, a 100 msec 95 dB tone, a 6-sec 95 dB tone, and a 6-sec 95 dB tone paired with the light flash. Both smaller pupil sizes during the no stimulus condition and less extensive constriction of the pupillary light reflex were positively correlated with scores on the impulsivity scale (a subfactor of extraversion). These results were interpreted as indicative of less corticoreticular activity for the more impulsive extraverted subjects.

Finally, of particular relevance to the present study is the observation that frequency of eyeblinks as motor outlets (Francis, 1969) and indicators of muscle tension (Harris, Thackray, & Schoenberger, 1966; Meyer, 1953) has been found to be greater for introverts than extraverts (Franks, 1963; Holland, 1960). However, no relationship between extraversion and eyeblink frequency was observed by Mandelzys (1973).

All of the studies cited are essentially idiosyncratic in the methodological and scoring procedures employed. An absence of replications, coupled with the uncertainty and questionable reliability of scoring, limits implications from such studies. Characteristically, pupillometric research has been beset with many methodological problems (Janisse, 1973, 1976; Loewenfeld, 1966; Tryon, 1975; Woodmansee, 1966). In the majority of pupil size studies, light reflex artifacts, differences in shading pattern of the stimuli, lack of adequate focal points, inadequate definition of stimuli and variables, and the influence of subject factors such as spontaneous thoughts or emotions, as well as time of day and fatigue effects, have remained uncontrolled. Francis (1969), for instance, simply monitored the pupil on a video screen and checked for changes in pupil size. Hess (1960, 1964, 1965), Holmes (1967), and Frith (1977) measured pupil diameter with a mm ruler and the effects of fatigue, visual acuity, age, and light intensity levels are unclear. The presence of eyeblinks and poor film quality has also resulted in such unreliable scoring procedures that many of the subjects must often be eliminated from the study.

Continuous measurement of the pupillary light reflex, under clearly definable and well controlled conditions, may serve as a useful indicator for investigating individual differences along Eysenckian (1967) dimensions. Fatigue of the pupillary light reflex, as indicated by decreased amplitudes of constriction and redilation and the presence of fatigue-related indices as V- and W-waves (Lowenstein & Loewenfeld, 1950, 1969), might provide a test of the cortico-reticular mechanisms hypothesized to mediate individual behavioural differences due to extraversion. In addition to providing a test for investigating postulated differences in stimulus sensitivity between introverts and extraverts, the dependence of the light reflex on reticular formation activity at different light intensity levels might be ascertained. Individual differences in reticular activity have been implicated in inhibition of the pupillary light reflex and in the explanation of Eysenck's (1967) biological basis of personality.

Extraversion, Hue, and Psychophysiological Reactivity

The rationale for employing stimuli varying in hue and intensity is largely based on evidence from a wide variety of research traditions which has established associations between extraversion and hue preference, hue sensitivity, and psychophysiological reactivity to hues. Long wavelength hues such as red and yellow have historically been associated with experiences as "warm" and "dynamic", and reported as excitingly unpleasant-stimulating-hot; short wavelength hues such as blue and green have been linked with mood tones described as "cool" and "passive" and reported as pleasant-depressing-cold (Lewinski, 1938). The underlying dynamics of the relationship between hue and personality have remained relatively obscure.

Colour preference studies have provided evidence that introverted individuals generally prefer hues of short wavelength like blue or green, whereas extraverted individuals have been shown to prefer long wavelength hues such as red or yellow (Birren, 1961; Choungourian, 1964, 1968; Eysenck, 1941; Jaensch, 1930; Rickers-Ovsiankina, 1943, 1977; Schaie, 1966; von Goethe, 1840). Birren (1961) has associated preferences for hues of short wavelengths through to hues of long wavelengths with the introversion-extraversion continuum. Götz and Götz (1974) have observed that introverts preferred tertiary hues (earth colours) and achromatics, whereas extraverts and ambiverts preferred more dynamic, bolder, primary and secondary hues (light clear and dark clear tones). Methodological difficulties, anecdotal conjecture, semantic confusion, and the influence of socio-cultural learning have limited inferences from such studies.

Red hues have been shown to increase bodily tension, to strongly activate the autonomic nervous system, and to have a disruptive effect on performance. Conversely, short wavelength hues, such as blue or green, have been shown to release tension, to have a lesser psychophysiological effect, and to be facilitatory on intellectual and motor tasks (Birren, 1961; Goldstein, 1963; Schaie, 1966; Smets, 1969). Staples (1932) has found infants more responsive to red than blue hue stimuli. Increased anxiety states, as indicated by the State-Trait Anxiety Inventory, to red and yellow illumination have been reported by Jacobs (1975). Blue and green illumination was associated with lower levels of anxiety.

Miller (1967), in an attempt to validate the pupillary response independent of the light reflex, as an objective measure of the generalized response of the organism, photographed the pupils of subjects who viewed three chromatic and one achromatic slide-projected stimuli. Although no hue differences were observed, significantly more responsivity, as indicated by a greater change in pupil diameter, was reported for the chromatic stimuli. A greater psychophysiological effect of red as compared with green hues, inferred from significant correlations between post-stimulus alpha percentage and threshold level for word stimuli has been reported (Dixon, 1966). Increased alpha percentage, heart rate, and respiration rate, have also been observed for red as opposed to blue hue stimuli (Gerard, 1958). Similarly, increased electrodermal amplitudes and conductance levels have been reported for red and violet stimuli as compared with green (Nourse & Wilson, 1971; Wilson, 1966).

Further support for the implication that sensitivity to short wavelength hues is decreased by sympathetic activation, while the opposite effect is obtained by parasympathetic activity, has been provided by Dixon (1960). Support for this contention is provided in an investigation by Allen and

Schwartz (1940) who reported increased sensitivity to green and depressed sensitivity to red hue stimulation under experimentally-induced sympathetic activation accomplished by the presentation of loud noise, strong tastes and odours, and retinal stimulation. Thus, it would appear that stimuli varying in hue which do not themselves elicit a particular response, when paired with stimuli that do elicit the response can indirectly influence the size of the response.

There has been little research directly addressing the relationship between the psychophysiological effects of hue, sensitivity to particular hues, and personality dimensions such as extraversion. Evidence from Rorschach psychology has suggested such a link, with the extravert typically reacting more to red hue stimuli prevalent in the inkblots (Barrat & Eaton, 1946; Ellis, 1900; Goldstein, 1939; Rickers-Ovsiankina, 1960; Rorschach, 1942; Schachtel, 1966; Shapiro, 1956). Frank (1976), however, has recently reported evidence which questions the assumption of differential affect in response to colour on the Rorschach.

Smith (1974) has provided evidence which implies that the association between sensitivity to hues and extraversion may be more complex than has been thought. Introverts were reported to be more sensitive to blue hues, whereas extraverts were more sensitive to red hues. These results were interpreted in terms of differences in autonomic dominance between introverts and extraverts, with introverts showing more sympathetic dominance and extraverts presumably showing more parasympathetic activity. This result has yet to be replicated. One possibility implicit in this research is the similarity between stimulus levels for hues of long and short wavelengths and stimuli of other modalities where differences in hedonic tone between introverts and extraverts have been reflected in transmarginal inhibition (Eysenck, 1963, 1967; Gray, 1964). The greater sensitivity of introverts at lower levels of stimulation and opposite effect for extraverts is consistent with Eysenck's (1963, 1967) and Gray's (1964) proposal of differences in hedonic tone, with introverts, the weak nervous system type, preferring low-intensity stimuli and reaching the level of transmarginal inhibition at lower levels of stimulus intensity than extraverts. The results of the OR studies of Frigon (1976) and Wigglesworth and Smith (1976) are consistent with this proposal. Greater responsiveness at low stimulus intensities and a decline in responsiveness at high stimulus intensities were also reported for introverts in the electrodermal study of Fowles, Roberts, and Nagel (1977). Consistent with these results is the observation that introverts have displayed significantly more cardiac ORs to blue stimuli than extraverts, whereas extraverts showed more cardiac ORs to red (Stelmack et al., 1979).

Bourgeois (1972), employing a signal detection analysis, failed to find any relationship between hue and extraversion, although it was observed that the sensory capacity for blue was greater than for red over the whole sample tested. Electrodermal change in resistance and conductance measures have also been employed in investigating the relationship between extraversion and responsivity to red and blue hues (Pickard, 1975). The results failed to replicate the association between sensitivity to hues, autonomic nervous system dominance, and extraversion. These nonsignificant results reflected in electrodermal activity do not exclude the possibility that individual differences in psychophysiological response to hue might be reflected in the pupillary light reflex, which has been found to be indirectly affected by reticular formation activity. This rationale has direct bearing on the present study, which attempts to explore the relationship between entraversion and the dependence of the pupillary light reflex on reticular formation activity.

Summary and Statement of Hypotheses

This chapter has reviewed various theoretical models and studies which have indicated a rapproachment between the Eysenckian (1967) dimension of extraversion and the neo-Pavlovian strength of the nervous system dimension. The introverted, weak nervous system individual has been considered as more perceptually sensitive and more psychophysiologically reactive. This has characteristically been manifested in lower absolute sensory thresholds, lower thresholds of arousal, persisting orienting responses, and greater electrodermal, electrocortical, cardiac, and pupillary activity than has been observed for the extraverted, strong nervous system individual. Evidence from psychophysiological research, however, has not unanimously endorsed Eysenck's (1967) hypothesis of greater levels of corticoreticular activity for introverts. Gray (1964, 1967) has extended Eysenck's (1967) hypothesis and postulated that, compared with extraverts, introverts show greater responsiveness at low stimulus intensities and a decline in responsiveness at high stimulus intensities.

It has been shown that pupillary reactivity may provide a useful indicator of general environmental reactivity, awareness, and sensitivity. Since the same anatomical and physiological systems have been implicated, individual differences in the pupillary reflex to light would appear to offer a technique for examining hypotheses concerning cortical and subcortical mechanisms theorized as the underlying mediators in Eysenck's (1967) proposal. Measurement of the pupillary reflex to light stimuli varying in hue and intensity has yet to be applied to this problem. The rationale for its use rests on the knowledge of the physiological mechanisms involved, the adaptive nature of the reflex in controlling the amount of light stimulation admitted by the organism, and on evidence suggested by Lowenstein and Loewenfeld (1969) that fatigue of the light reflex might provide a test of corticoreticular mechanisms hypothesized to mediate behaviour along the extraversion dimension.

Although far from conclusive, it has been demonstrated that introverts are more sensitive to blue hues than extraverts, and extraverts are more sensitive to red. Similarly, introverts have been shown to be more psychophysiologically reactive and to have lower sensory thresholds for low intensity stimulation than extraverts, while extraverts have exhibited greater responsivity and lower sensory thresholds to high intensity stimulation. From research which has employed electrodermal, electrocortical, cardiac, and pupillary measures, there is evidence that introverts reach their optimal levels of stimulation at lower levels of intensity than extraverts. This phenomenon has been understood in terms of differential hedonic tone and the Pavlovian concept of transmarginal inhibition.

In view of evidence which has suggested greater psychophysiological reactivity to long as compared with short wavelength hues, it would appear that the relationship between sensitivity to hues and personality might be investigated at the level of the pupillary light reflex, where sympathetic and parasympathetic components are clearly distinguishable. Specification of the strength and dominance of sympathetic and parasympathetic interaction, along with inferred levels of differential transmitter substances which have been implicated between individuals differing in degree of extraversion, might be elaborated.

The principal objective of the present investigation is to identify changes in the components of the pupillary light reflex within the context of Eysenck's (1967) theory of extraversion. An attempt is made to refine and elaborate existing pupillometric scoring methodology as well, with the aim of providing an economical and reliable scoring technique. Normative data of the pupillary light reflex will also be provided.

The sensitivity, accuracy, and stability of the light reflex is analyzed by examining seven distinct components and six additional pupillary response and fatigue indices. The degree with which individuals differing in terms of extraversion and inferred cortical excitability manifest variations in these indices is assessed. In addition, since extraverts have been shown to display greater sensitivity to red hues than introverts, and introverts have been shown to be more sensitive to blue hues, an attempt will be made to replicate these findings by employing discrimination measures for red and blue hues. Hue sensitivity will be related to the pupillary light reflex characteristics elicited by the chromatic light stimuli.

The principal question posed in this study is as follows: Can introverts be distinguished from extraverts by measuring pupillary reactivity to light stimuli varying in hue and intensity? More specifically, the following hypotheses are advanced: If, as Eysenck (1967) and Gray (1964, 1967) have proposed, introverts are more perceptually sensitive and psychophysiologically responsive than extraverts, they will manifest greater pupillary reactivity and develop fatigue symptoms more readily. This will be shown in initially faster and more extensive constriction and subsequent redilation, greater fatigue manifested by a greater frequency of V, W, and tonohaptic wave forms, fewer trials necessary to elicit fatigue symptoms, and a greater degree of peripheral defensive reaction, in the form of a higher frequency of eyeblinks. Since the introvert is presumably in a state of higher cortical arousal, this should also be manifested in greater mean dark-adapted pupil diameters. From evidence that introverts reach their threshold of transmarginal inhibition as well as optimal level of stimulation at lower levels of intensity than extraverts, one would also expect introverts to show slower and less extensive pupillary light reflexes than extraverts at the end of a series of repeated presentations of light stimuli. Conversely, if, as Eysenck (1967) has suggested, extraverts are characterized by a greater degree of cortical inhibition, this should be manifested in slower and less extensive pupillary light reflex constrictions than introverts, due to the greater degree of inhibition of the oculomotor nucleus. Furthermore, because there is some evidence of differential responsiveness to chromatic stimuli using other measures, one may speculate that these differences will emerge with the pupillary light reflex, which has been shown to be differentially sensitive to specific wavelengths and intensities. It is also expected that on a measure of hue discrimination, introverts will show greater sensitivity to blue hues and extraverts will be more sensitive to red.

CHAPTER II

METHOD

This chapter presents the methodology of the experiment. The selection of the subjects is described, and the psychological instruments and classification data for the introvert, middle, and extravert groups are presented. This is followed by a description of the apparatus used in the phases of hue discrimination ability testing, and in the stimulus presentation, recording, and measurement of the pupillary light reflex components. The hue stimuli are described and an analysis of the procedure of the study is then detailed. Subsequently, the scoring and quantification methodology for the pupillary light reflex and hue discrimination data are presented. The chapter concludes with a statement of the experimental design and statistical procedures employed in the testing of the hypotheses and investigative relationships of interest outlined in Chapter I.

Subjects and Classification Procedure

The subjects were 51 male students selected from a population of undergraduate and graduate students registered in psychology courses at the University of Ottawa. Subjects were solicited in person or by telephone, and participation in the experiment was voluntary and gratis, although some subjects received experimental credit for their assistance. All subjects were screened for colour defective vision with a Bausch and Lomb Modified Orthorater and the Dvorine Color Perception Training Charts (Dvorine, 1944).

Sample selection proceeded in three stages. In the first stage, a sample of 121 male volunteers, ranging in age from 18 to 38 years, (*M* = 21.2, *SD* = 3.9), was administered the Eysenck Personality Questionnaire (EPQ) (Eysenck & Eysenck, 1975). The mean extraversion, neuroticism, psychoticism, and lie scores for the total population group tested were 13.46, 10.57, 3.82, and 5.74, with corresponding standard deviations of 5.23, 5.21, 2.79, and 3.95, respectively, In addition, the subjects were asked to answer several questions pertaining to colour blindness, known visual or organic anomalies, use of prescription medication, and general health.

In the second classification stage, subjects were equated for low to moderate neuroticism, psychoticism, and lie scores, utilizing cut-off scores established from the normative data of the EPQ for a sample of normal English males in the 20 to 29 year age-range. All subjects not meeting these criteria were eliminated. The mean extraversion, neuroticism, psychoticism, and lie scores for the total sample were 12.80, 8.55, 3.33, and 5.08, respectively, with corresponding standard deviations of 6.07, 3.76, 2.11, and 3.23. These values are in close agreement with the norms for male students provided in the EPQ manual (Eysenck & Eysenck, 1975).

In the third stage, subjects were differentiated into three equal groups of 17 subjects on the basis of their extraversion scores, with the aim of ensuring a broad score distribution (1-21). Selection was such that the 17 lowest, intermediate, and highest scorers were designated respectively as the introvert group, the middle group, and the extravert group. The range of scores for the extraversion dimension for the introvert group was 1 to 8 (M = 5,35, SD = 2.00), for the middle group, 10 to 17 (M = 13,76, SD = 2.36), and for the extravert group, 18 to 21 (M = 19.29, SD = 0.99). The mean ages for the introvert, middle, and extravert groups were 23.6, 20.6, and 20.2 years, with corresponding standard deviations of 5.18, 2.59, and 1.56 years, respectively.

The means of the neuroticism dimension for the introvert, middle, and extravert groups were 8.76, 8.65, and 8.24 respectively, with corresponding standard deviations of 3.05, 4.11, and 4.22. The means for the psychoticism dimension for the introvert, middle, and extravert groups were 3.59, 2.59, and 3.82, with standard deviations of 2.18, 1.77, and 2.27, respectively. For the lie scale, the means for the introvert, middle, and extravert groups were 4.71, 6.06, and 4.47, with respective standard deviations of 3.50, 3.17, and 2.96.

Analysis of variance for the sample data revealed that the three groups of subjects differed significantly from each other on the extraversion factor ($\underline{F}(2/48) = 238.70$, $\underline{MS}_e = 3.51$), but not with respect to the neuroticism factor ($\underline{F}<1$), the psychoticism factor ($\underline{F}(2/48) = 1.68$, $\underline{MS}_e = 4.35$), nor on the lie scale ($\underline{F}(2/48) = 1.21$, $\underline{MS}_e = 10.35$). The homogeneity of variance assumption, as assessed by Cochrans C test, was met for each of the EPQ dimensions analyzed. The Newman-Keuls procedure indicated that all three groups differed significantly from each other and consisted of three homogeneous subgroups with respect to the extraversion factor. Table 1 presents the EPQ score and age distributions for the total population group, the total sample group, the introvert, middle, and extravert groups.

Table 1

EPQ Score and Age Distributions for Extraversion (E), Neuroticism (N), Psychoticism (P), and Lie Score (L), for the Total Population Group, Total Sample Group, Introvert, Middle, and Extravert Groups.

Group	N	(E)		(N)		(P)		(L)		Age	
		M	SD	M	SD	M	SD	M	SD	M	SD
Total Population	121	13.46	5.23	10.57	5.21	3.82	2.79	5.74	3.95	21.19	3.92
Total Sample	51	12.80	6.07	8.55	3.76	3.33	2.11	5.08	3.23	21.51	3.73
Introverts	17	5.35	2.00	8.76	3.05	3.59	2.18	4.71	3.50	23.65	5.18
Ambiverts	17	13.77	2.36	8.65	4.10	2.59	1.77	6.06	3.17	20.65	2.60
Extraverts	17	19.29	.99	8.24	4.22	3.82	2.27	4.47	2.96	20.24	1.56

Note. EPQ scores and ages for the Introverted, Middle, and Extraverted subjects are presented in Appendix B.

Psychological Instruments and Apparatus

Eysenck Personality Questionnaire (EPQ). Developed through a series of approximately 20 factorial studies, the EPQ is a self-descriptive questionnaire, which requires approximately 20 minutes to complete, and which professes to measure three distinct and orthogonal personality dimensions: introversion-extraversion (E), neuroticism-stability (N), and psychoticism (P). Sixty-nine "yes" or "no" items, comprising 21, 23, and 25 statements, measure the extraversion, neuroticism, and psychoticism dimensions, respectively. A "Lie Scale" (L), intended to measure a tendency on the part of subjects to answer the questions in a socially desirable manner or "fake good" is comprised of the remaining 21 items. In addition to being regarded as an indicator of dissimilation, this latter scale has been speculated as measuring some form of social naivete or other stable personality factor.

The Eysenck Personality Questionnaire was designed as a psychological instrument to replace traditional, non-qualitative, categorical, psychiatric classifications with a dimensional, quantitative, personality schemata. Some test items have been adapted and developed from the Minnesota Multiphasic

Personality Inventory (MMPI) (Hathaway & McKinley, 1943), the Maudsley Medical Questionnaire (MMQ) (Eysenck, 1952), the Maudsley Personality Inventory (MPI) (Eysenck, 1962), and the Eysenck Personality Inventory (EPI) (Eysenck & Eysenck, 1968). The EPQ differs from the EPI and its earlier forerunner tests by both updating and improvements in development of the scales, and the addition of the P scale. Evidence for the psychometric independence of the EPQ personality dimensions has been provided by Royce (1972) and supported by studies of Cattell (1959), Hildebrand (1958), Cattell and Scheier (1961), Eysenck (1963, 1970), Gorsuch and Cattell (1967), and Farley (1970).

To ensure orthogonality of the EPQ dimension for subjects in the present study, as well as to assess the degree and direction of relationships over a large sample, Pearson correlation coefficients were computed for the total population group tested and for the total sample. The intercorrelations between EPQ scores for the respective groups are shown in Tables 2 and 3. The resulting low, nonsignificant correlations between the EPQ measures support Eysenck's (1967, 1975) contention of independence of the categories. The significant negative correlations between psychoticism and lie scores are in general agreement with Eysenck's (1975)

Table 2

Correlation Matrix of EPQ Scores for the Total Sample Population

	Extraversion	Neuroticism	Psychoticism	Lie Score
Extraversion	____	-.123	-.004	-.026
Neuroticism		____	-.041	-.008
Psychoticism			____	-.231*
Lie Score				____

N = 121
* $p < .01$

Table 3

Correlation Matrix of EPQ Scores for the Total Sample Group

	Extraversion	Neuroticism	Psychoticism	Lie Score
Extraversion	—	-.106	+.026	-.020
Neuroticism		—	-.195	+.041
Psychoticism			—	-.420*
Lie Score				—

N = 51
* $p < .001$

observations.

For purposes of the present study, the test norms established on a normal English male population were used (Eysenck & Eysenck, 1975). For males ranging in age from 20 to 29 years, the mean E, N, P, and L scores are 13.72, 9.81, 4.19, and 6.50, with corresponding standard deviations of 4.79, 5.09, 3.26, and 3.88, respectively. The reliability and validity data presented in the EPQ manual, (test-retest: ranging from .80 to .90; internal consistency: approx. .80; Eysenck & Eysenck, 1975) appeared adequate for use of the test in the present experiment. The EPQ is presented in Appendix A.

<u>Farnsworth-Munsell 100 Hue Test</u>. Subjects were tested for hue discrimination ability with the Farnsworth-Munsell 100 Hue Test (Munsell Color Company, 1957). The test, consisting of 93 black-rimmed, removable, plastic caps, in which paint-empregnated papers are mounted on a matt surface, presented the subject with hue stimuli having the same spectral characteristics from any angle, with slight differences in chroma and value. The material was encased in four wooden compartments, each case consisting of two hinged panels enclosing 21 numbered, removable caps. To serve as pilot colours, two disks were repeated and fixed at opposite ends of each panel. The disks were

arranged in random order prior to testing and the subject's task was to take them from one panel and re-arrange them in order, transferring them to the adjacent panel to form a regular colour series between the pilot disks. The order of presentation of each panel was counterbalanced within groups, so that each panel appeared in the first, second, third, and fourth order of presentation an equal number of times. Testing was carried out in a large air conditioned laboratory under fluorescent illumination approximating standard daylight conditions (25 ftC; 269 lx), as measured by a model 1970-PR Spectra Pritchard Photometer. The line of illumination was from directly above.

<u>Hue Stimuli</u>. The pupillary light reflex was elicited by repeated presentations of red and blue light stimuli. This was accomplished by back-illuminating two circular, opaque, plastic light filters, each measuring 15 cm in diameter, manufactured by the Grass Medical Instruments Company. The light source was provided by the external lamp of a Scientific Prototype 3-channel tachistoscope, model GB. The levels of illumination, designated as high and low intensity, were 13 ftC (140 lx) and 2 ftC (21.5 lx), respectively, as measured at the surface of the stimuli with a model 1970-PR Pritchard Photometer.

The chromatic light filters were mounted in a support constructed of plywood 10 mm in diameter, measuring 30 cm by 30 cm , which afforded facilitation of smooth filter interchange.. The supporting framework was coated with optical black paint and mounted on a 23 cm by 21 cm opaque rear projection screen. The viewing distance was 55 cm. A small white ring measuring 10 mm in diameter, with a distance between the adjacent inside rims of 5 mm, was centred on each filter in order to provide a focal point for the subjects.

Pupillometric Apparatus. A Polymetric Pupillometer System, Model V-1165-IR, was used to record the pupillary light reflex. This is a video monitoring unit which utilized an image transducer that converted the optical image of the pupil into electrical signals used to drive the pen on a chart recorder. The system consisted of an RCA silicon movie camera (Model 20-331) equipped with a 75 mm Soligar lens, with maintaining supports and standard tilt head mount, an eyelamp equipped with an infrared filter to illuminate the subject's right eye in darkness, a back-lit stage and stimulus presentation unit, and head and chinrests used to stabilize the subject's head. A video monitor (ITC), modified to operate on a high resolution random-1029 interfacing line count, provided a magnified screen image of the subject's eye. An overlay display delineated the measurement area.

An analyzer unit containing the signal analyzer circuitry, as well as operating controls and associated circuitry for monitoring and recording of pupil diameter, was contained in an adjacent component. Other system components included a Watanabe Multi-Corder (Model MC11-L) which provided synchronous graphic recording of the stimulus parameters and ongoing pupillary output variables. A 300 mm/min chart speed and a 10-in pen sweep, which provided a measurement sensitivity of approximately 1 mm to each 1 in deflection, were utilized during stimulus presentations and the last 1-min of the dark adaptation intervals. During the early phases of dark adaptation, and at all other times, a chart speed of 1200 mm/hr was employed. Calibration of the pupillometer was established with the aid of a metal test-plate with bored holes of 5.0 mm and 7.5 mm diameter. The psychophysiological laboratory where the pupillometric testing took place was a sound attenuated, 2 m by 3 m standard industrial partitioned room. A diagrammatic illustration of the pupillometer system used in the experiment is presented in Appendix C.

X-Y Digitizer. Scoring of the pupillary light reflex characteristics was accomplished with the use of a Computer Equipment Digi-Grid System. System components included a digi-grid table, with contained circuitry and mounting supports, an analyzer unit, LED digital display unit, cross-haired target trigger apparatus, and an IBM 29 automatic computer card punch.

The system measured and produced (x,y) coordinates for each point located on the pupillographic records. These coordinates were displayed on a digital read-out, and points digitized were automatically entered on computer cards for subsequent analyses. For this study, the x-coordinate corresponded to time and the y-coordinate cooresponded to pupil diameter.

Procedures

Experimental Procedure

Each subject attended a one and one-half hour laboratory session. Experimentation was conducted in the morning, afternoon, and evening. Group time-delegation to the laboratory was counterbalanced within extraversion groups in an effort to control for individual biorhythmic and fatigue effects (Horne & Östberg, 1975, 1977; Lowenstein

& Loewenfeld, 1969, Sollberger, 1965; Stroebel, 1967). Upon arrival at the laboratory, the subject was administered the tests for defective colour vision and verbally screened for intake of prescription tranquilizing or stimulant drugs and known organic illnesses. The test for hue discrimination was then administered. The subject was subsequently seated comfortably at the pupillometer and presented with a brief description of the apparatus. Subjects were asked to remove corrective lenses prior to pupillographic recording, as light reflection would interfere with reliably recording the pupillary light reflex.

A small amount of powdered talc was applied to the subject's right eyelid and surrounding area as an added precaution to eliminate extraneous light reflection due to excessive skin oil. The camera lens' focus and infrared lamp were adjusted so that a finely textured and highly resolved image of the subject's eye was obtained on the video monitor. After the pupillometer had been calibrated, the subject was instructed to try and relax as much as possible and to focus upon the small ring in the centre of the chromatic filter directly in front of him, to refrain from talking and making head or eye movements, and to inhibit blinking as much as possible. The subject was instructed to try and restrict his blinking to the periods when the light was off, as blinks would prevent accurate recording of the light reflex. The subject was also assured that simple visual stimuli and no noxious stimulation would be presented. At this point, a 10-min dark adaptation period was allotted, during which pupil size was recorded as it reached a relatively stable baseline level. The first series of 15 consecutive chromatic light stimuli was then presented. Stimulus duration was 3 sec, with an interstimulus interval of 11 sec. This interval permitted full redilation of the pupil to occur. Retinal adaptation to light was prevented by the sufficiently brief stimulus duration (Lowenstein, 1961).

Following the presentation of the appropriate first hue series (e.g., red, high-intensity) the subject was allotted a 5-min rest period and pupil size was recorded as a dark-adapted diameter was reached. The chromatic filter was changed, tachistoscope reset, and the second series of repeated hue stimuli (e.g., blue, high-intensity) was presented in the identical sequence following the procedure just outlined. A third (e.g., blue, low-intensity) and fourth (e.g., red, low-intensity) stimulus series followed two subsequent 5-min dark adaptation periods. At no time were the lights in the experimental room switched on. The order of presentation of the stimuli was randomized and each subject received all variable hue and intensity conditions. Following the fourth treatment condition, the pupillometer was recalibrated, the subject shown his pupillographic record, and an overall reaction to the experiment was elicited. An explanation of the hypotheses being tested was then offered, and the subject was asked not to discuss the experiment with anyone who was yet to participate in the study.

Data Quantification and Scoring Procedures

Quantification of Pupillary Response Data

The pupillary light reflex was subdivided into seven measures. (1) The magnitude of maximum constriction (MC) was measured in mm, from prestimulus pupil diameter at stimulus onset to point of maximum constriction. (2) The latency to maximum constriction (LC) was measured in sec from stimulus onset to the point of maximum pupil constriction. (3) The rate of constriction (RC), expressed in mm/sec, was defined as the ratio of magnitude : latency. (4) The magnitude of maximum redilation (MR) was defined as the difference, in mm, between pupil diameter at stimulus offset and point of maximum redilation. (5) The latency to maximum redilation (LR) was measured, in sec, from stimulus offset to point of maximum redilation. (6) The mean rate of redilation (RR) was measured by averaging the rate per mm increase in pupil size from stimulus offset to point of maximum redilation. (7) The maximum redilated pupil size (MP) was the largest pupil size reached during the interstimulus interval.

In addition to these seven characteristics of the light reflex, six additional pupillary response measures and indices of fatigue were independently analyzed. (1) The average pupil size during the last 1-min of dark adaptation was obtained by measuring pupil size at 4-sec intervals and averaging these values to obtain the measure of mean resting dark-adapted pupil size (RP). (2) A frequency count was made of V-waves (spontaneous, sharp redilations of the pupil during light presentation which produced a characteristic V-shape on the pupillograph). (3) A frequency count was recorded of W-waves (pupillary redilation and subsequent constriction during light presentation, producing a characteristic W-shape on the pupillograph). (4) The number of trials necessary to elicit fatigue symptoms, defined as the occurrence of V, W, or tonohaptic wave shape, constituted the trials-to-criterion-fatigue measure (TF). (5) A frequency count of eyeblinks (instantaneous, spiked deflections of the pen to zero or near zero level) during the last 1-min of dark adaptation, constituted the measure of resting blink rate (RBR). (6) A frequency count of eyeblinks during stimulus presentation (SE) was also recorded. Figures 1 and 2 present diagrammatic illustrations of the pupillary light reflex measures and fatigue indices, respectively.

Scoring Procedure for Pupillary Light Reflex Data

The pupillographic records were computer scored to obtain measures of the seven pupillary light reflex characteristics with the aid of a Computer Equipment Digi-Grid System. Each subject's pupillographic record was subdivided according to hue and intensity conditions and placed on the electromagnetic grid of the digitizer. The records were aligned so that the zero point on the pupillographs coincided with zero baseline on the digital display. The points digitized for each light stimulus consisted of the stimulus onset, the point of minimum constricted diameter, the stimulus offset, the points for the mean rate of redilation (1 point per mm increase of pupil size), and the point of maximum redilation. This required the digitizing of approximately 500 data points per subject.

As coordinates were digitized, they were automatically

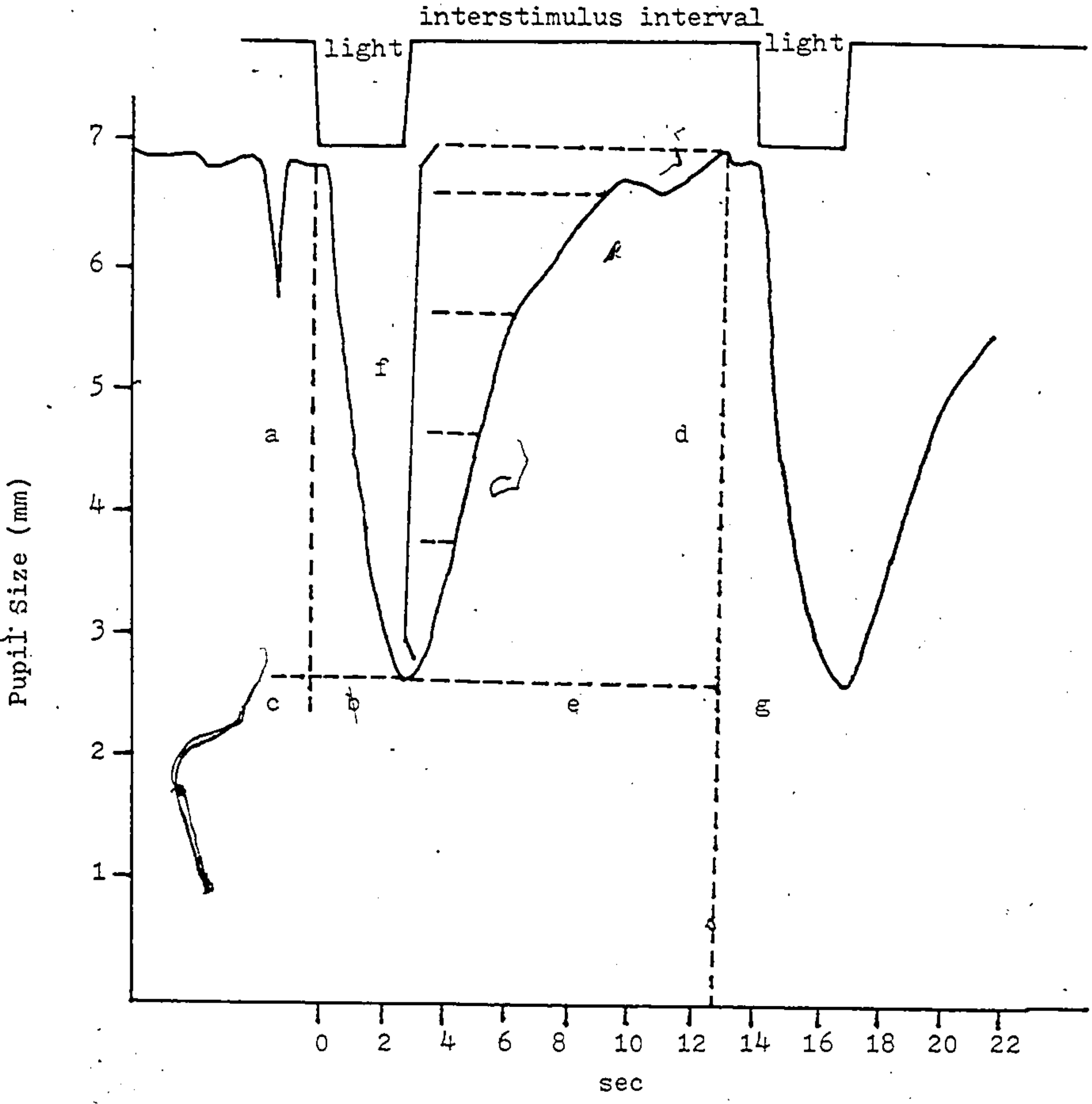
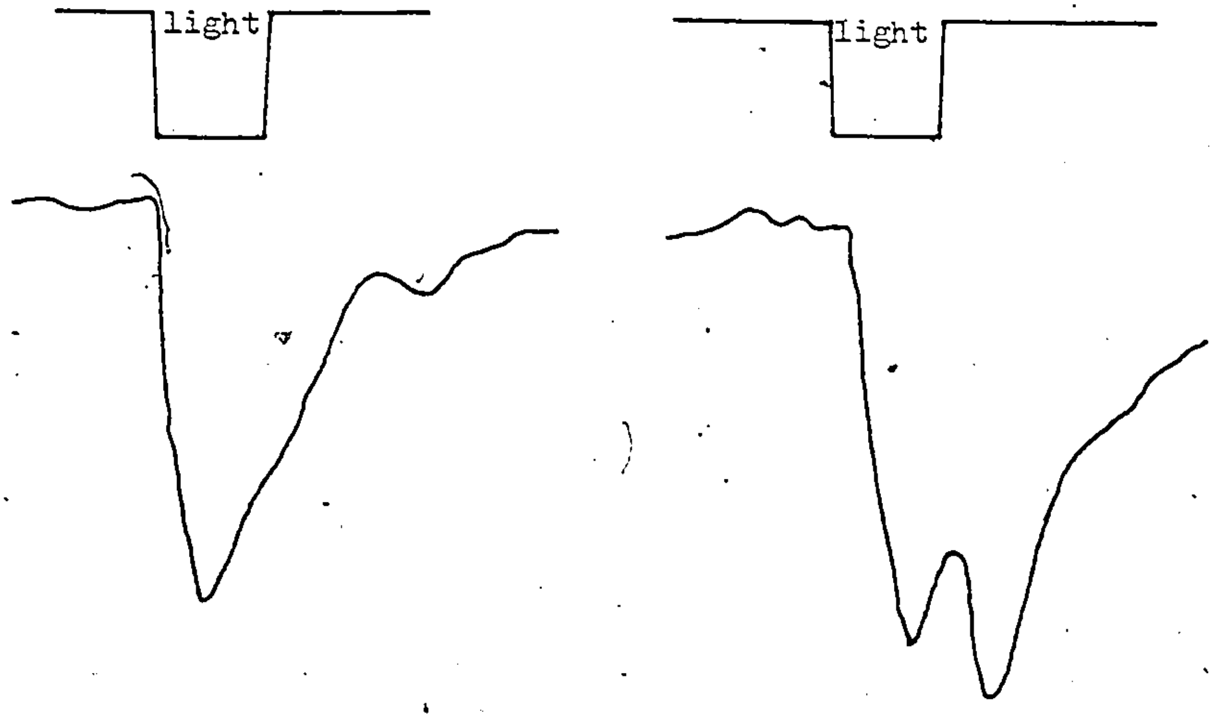
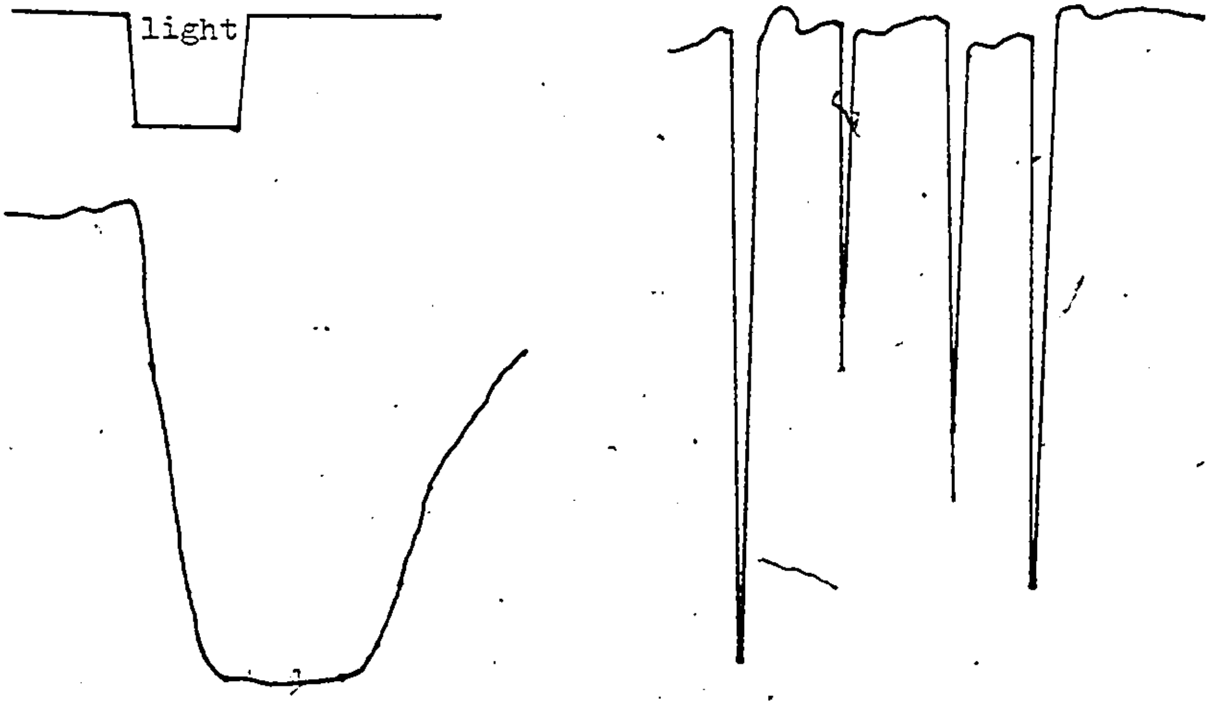


Figure 1. Light reflex pupillograph

a) magnitude of maximum constriction
b) latency to maximum constriction
c) rate of constriction
d) magnitude of maximum redilation
e) latency to maximum redilation
f) mean rate of redilation
g) maximum redilated pupil size



V-wave W-wave



tonohaptic wave shape eyeblinks during dark adaptation

Figure 2. Additional pupillary response measures and indices of fatigue.

entered on IBM data cards for subsequent analysis. The coordinates corresponded to the (x, y) coordinates of the respective points which had been digitized. The same procedure was followed for each of the stimulus trials.

The data were then manually separated into trials, hue and intensity conditions, and subjects. These processed data were used to calculate the pupillary light reflex components with the use of a computer program developed for this purpose. The program yielded the seven pupillary measures for each subject, separated into extraversion groups, hue and intensity conditions and trials. There is no precedent for the use of such a procedure in the scoring of pupillometric data.

Quantification of Hue Discrimination Data

Following the scoring procedure suggested by Farnsworth (1957), total error scores for the red and blue hues were obtained by summing the differences between the respective colour disk number and the numbers of the colour disks adjacent to it. A scoring diagram was completed for each subject and a total red and total blue error score were independently obtained by summing the scores on each radial line for the respective hues, counting the inner circle of the diagram as zero. Lower total error scores for a particular hue corresponded with better discrimination performance for that hue. A general index of the subject's overall hue discrimination performance, designated as the total hue error score, was obtained by summing the individual error scores for the red and blue hues. A reproduction of the Farnsworth-Munsell 100 Hue Test scoring diagram appears in Appendix D.

Experimental Design and Statistical Analyses

Four-way analysis of variance, Extraversion X Hue X Intensity X Trials, with repeated measures on the hue, intensity, and trials factors (Winer, 1971) was applied to each of the seven pupillary light reflex characteristics. The principal independent variables of this study were: (A) three levels of the Extraversion factor (the Introvert group, the Middle group, and the Extravert group); (B) two levels of the hue factor (red and blue); (C) two levels of the intensity factor (low and high); and (D) the 15 trials constituted the Trials factor. The fatigue indices were analyzed with a three-way analysis of variance, Extraversion X Hue X Intensity, with repeated measures on the hue and intensity factors (Winer, 1971). To establish differences between extraversion groups with respect to the EPQ dimensions, as well as to test for differences between mean tonic pupil size, frequency of eyeblinks between conditions, and hue discrimination, a one-factor analysis of variance was applied. To test for differences between hue discrimination ability for red and blue within both the extraversion groups and the total sample, _t_-ratios for correlated samples were computed (Ferguson, 1971). Cochrans C test was employed to test for homogeneity of variance. The Newman-Keuls procedure was employed for a posteriori comparisons among means. The 0.05 level of confidence was adopted for all statistical tests. Additional descriptive relationships between extraversion, hue discrimination, and the components of the pupillary light reflex were established with Pearson correlation coefficients.

CHAPTER III

RESULTS

In this chapter the results of the statistical analyses of the data are presented. The first section includes the results of the analyses of the pupillary light reflex measures, followed by a presentation of the analyses of the additional pupillary response and fatigue indices. This is followed by a presentation of the results of the hue discrimination analyses, the relationship between extraversion, hue discrimination, and the pupillary measures. The chapter concludes with a summary of the main findings and the presentation of the intercorrelations between pupillary measures.

Pupillary Light Reflex Measures

Magnitude of Maximum Constriction (MC). For the analysis of the magnitude of maximum constriction measures, no significant main effects due to extraversion were observed ($F<1$). Significant main effects due to hue were noted ($F(1/48) = 182.89$, $MS_e = 1.12$), with the mean magnitude of maximum constriction to blue (3.61) greater than to red (3.09). The effect of intensity was also significant ($F\ (1/48) = 31.74$, $MS_e = 1.42$), with the high (3.47) eliciting a greater mean magnitude of constriction than the low (3.23). Significant main effects due to trials were observed ($\underline{F}(14/672) = 59.79$, $\underline{MS}_e = 0.11$), with greater mean magnitudes obtained for the initial trials. Figure 3 presents the average response curve for the mean magnitude of maximum constriction measures. Data points are the averages for all subjects, across all hue and intensity levels, plotted as a function of trials. The decline in magnitude of constriction over trials is very systematic. Individual comparisons among means indicated that the mean magnitude of maximum constriction to the initial 3 trials was significantly greater than to trials 9 to 15, with the magnitude of constriction elicited for the initial trial significantly greater than that to all subsequent trials.

Of all the interactions, the only to exceed chance expectancy was that observed between hue and intensity ($\underline{F}(1/48) = 14.71$, $\underline{MS}_e = 0.49$). Figure 4 presents the mean values for the magnitude of maximum constriction in the interaction of hue and intensity. Greater mean magnitudes of constriction were observed for the blue hue in the high-intensity level (3.68), and moderate constriction was noted for both the blue in the low-intensity (3.54) and red in the high-intensity level (3.26). Smaller mean constriction extents were obtained for the red hue in the low-intensity level (2.92).

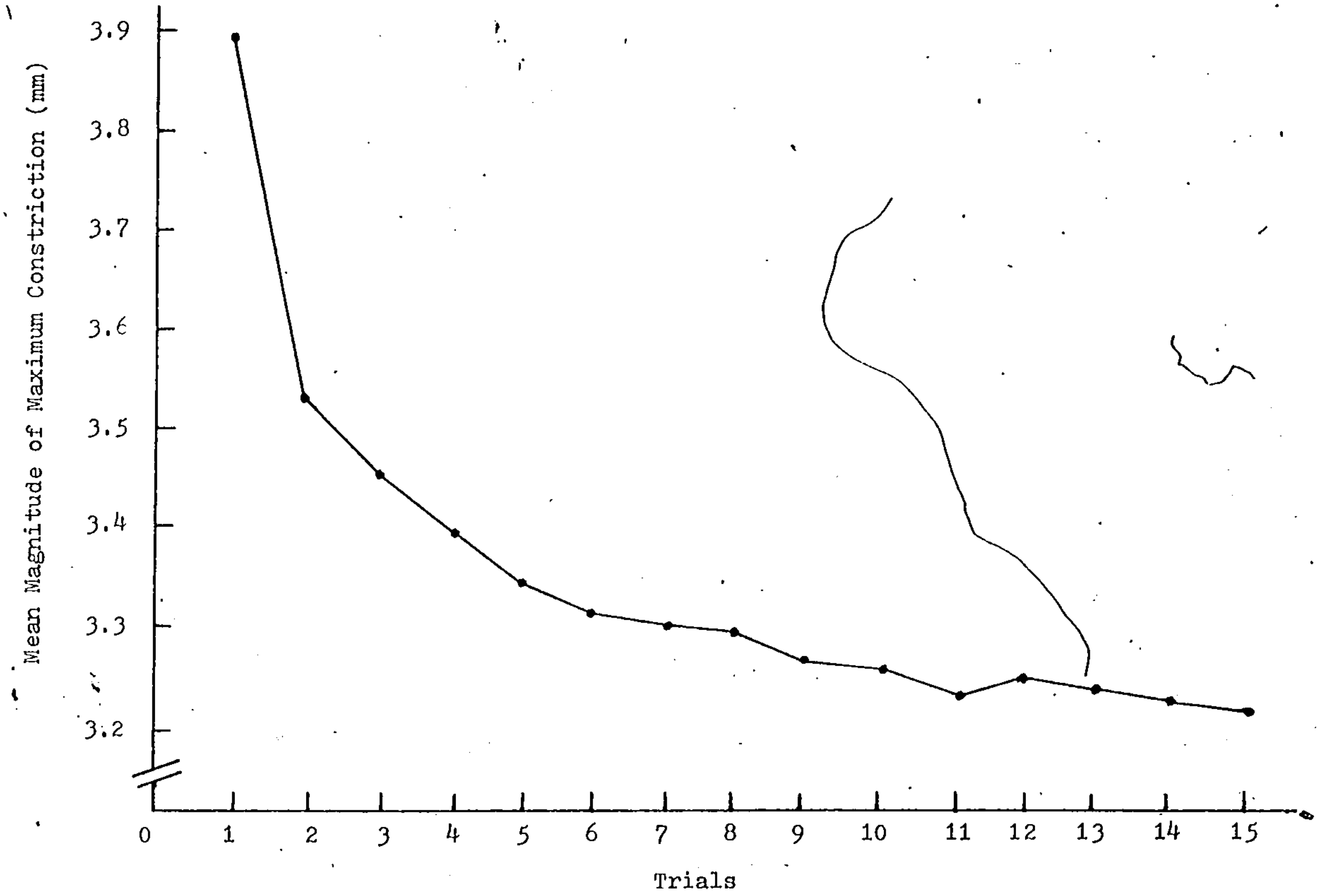


Figure 3. Mean magnitude of maximum constriction

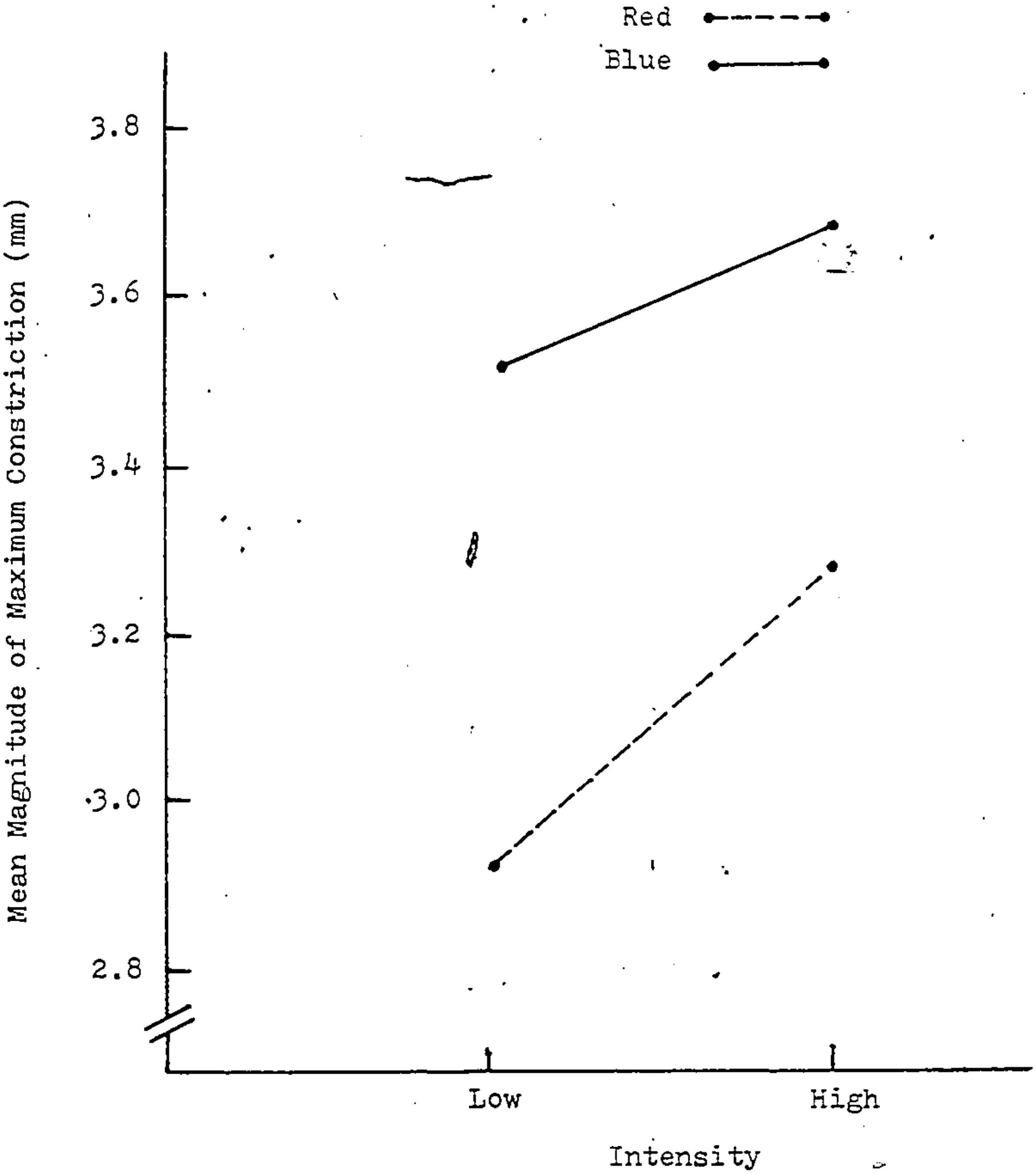


Figure 4. Mean magnitude of maximum constriction in the Hue X Intensity interaction

Individual mean comparisons indicated that mean magnitudes of maximum constriction for all possible interactions of hue and intensity were significantly different.

Latency to Maximum Constriction (LC). No significant differences due to extraversion were revealed in the analysis of the latency to maximum constriction measures ($F < 1$). Significant main effects were observed due to hue, ($F(1/48) = 17.14$, $MS_e = 0.92$), with the blue (2.67) eliciting longer mean latencies than the red (2.53). The main effect of intensity was also significant ($F(1/48) = 55.13$, $MS_e = 0.60$), with the mean latency to high (2.70) greater than to low (2.50). Significant effects were also noted across trials ($F(14/672) = 16.11$, $MS_e = 0.37$), with longer mean latencies to the initial 4 trials than to trials 11, 12, and 15. A systematic decrease in mean latency to maximum constriction over trials was evident. Variability in latencies increased over trials, particularly from trial 11 onwards. The average response curve for the mean latency to maximum constriction values obtained over the 15 trials is graphically presented in Figure 5.

Significant interaction effects were observed between hue and intensity ($F(1/48) = 6.00$, $MS_e = 0.69$), as well as between hue and trials ($F(14/672) = 2.16$, $MS_e = 0.34$). All other interactions were statistically

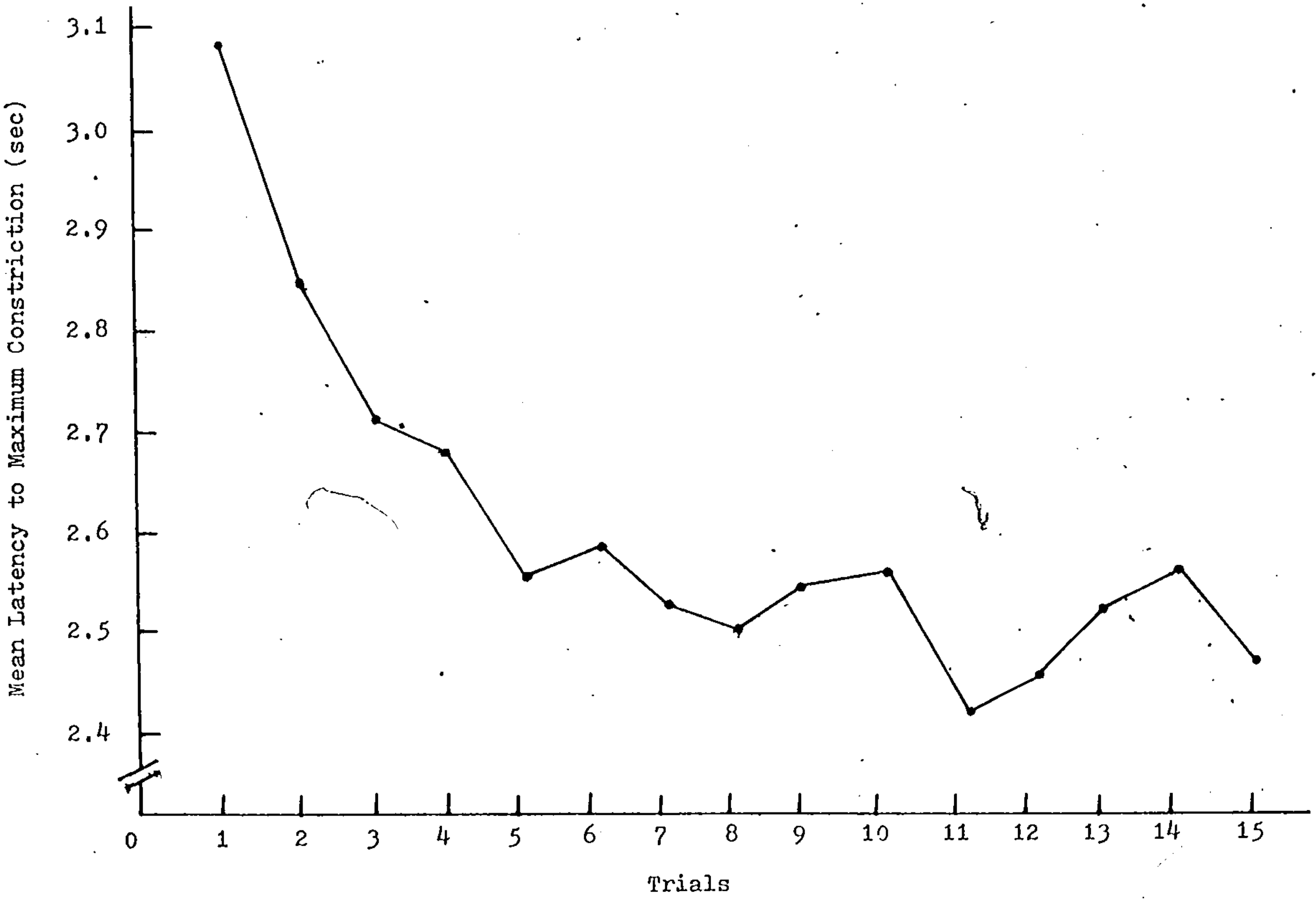


Figure 5. Mean latency to maximum constriction

nonsignificant. Comparisons among individual means indicated that the mean latency to maximum constriction for the blue in the high-intensity level (2.74) was significantly longer than to both the blue (2.60) and red (2.39) in the low-intensity level. The mean latency to the red in the low-intensity level (2.39) was significantly shorter than mean latencies obtained for both the blue (2.74) and red (2.67) in the high-intensity level, and the blue in the low-intensity level. No significant differences were noted between mean latencies to either hue in the high-intensity level. The mean latency to maximum constriction measures for the red and blue in each intensity level are graphically presented in Figure 6.

For the interaction of hue and trials, as can be seen from the average response curves presented in Figure 7, greater variability in latency to maximum constriction occurred for the red, particularly from trials 8 onwards. Comparisons among the individual trial means indicated that this interaction was primarily due to the significantly longer mean latencies for the blue to trials 4, 6, 8, 10, 11, and 15.

Rate of Constriction ~~(RC)~~. Analysis of the rate of constriction measures yielded nonsignificant effects due to both extraversion ($F<1$), and intensity

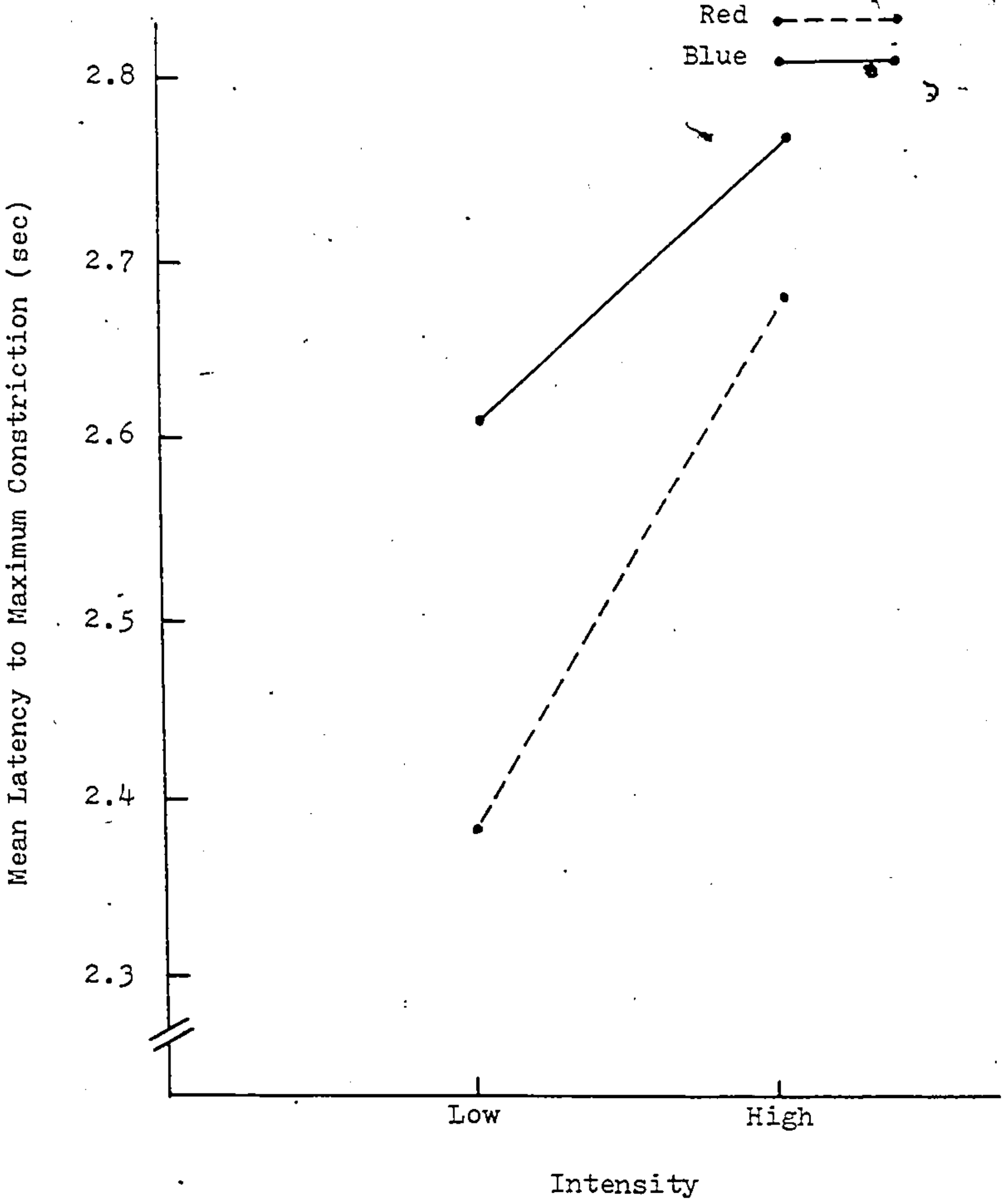


Figure 6. Mean latency to maximum constriction in the Hue X Intensity interaction

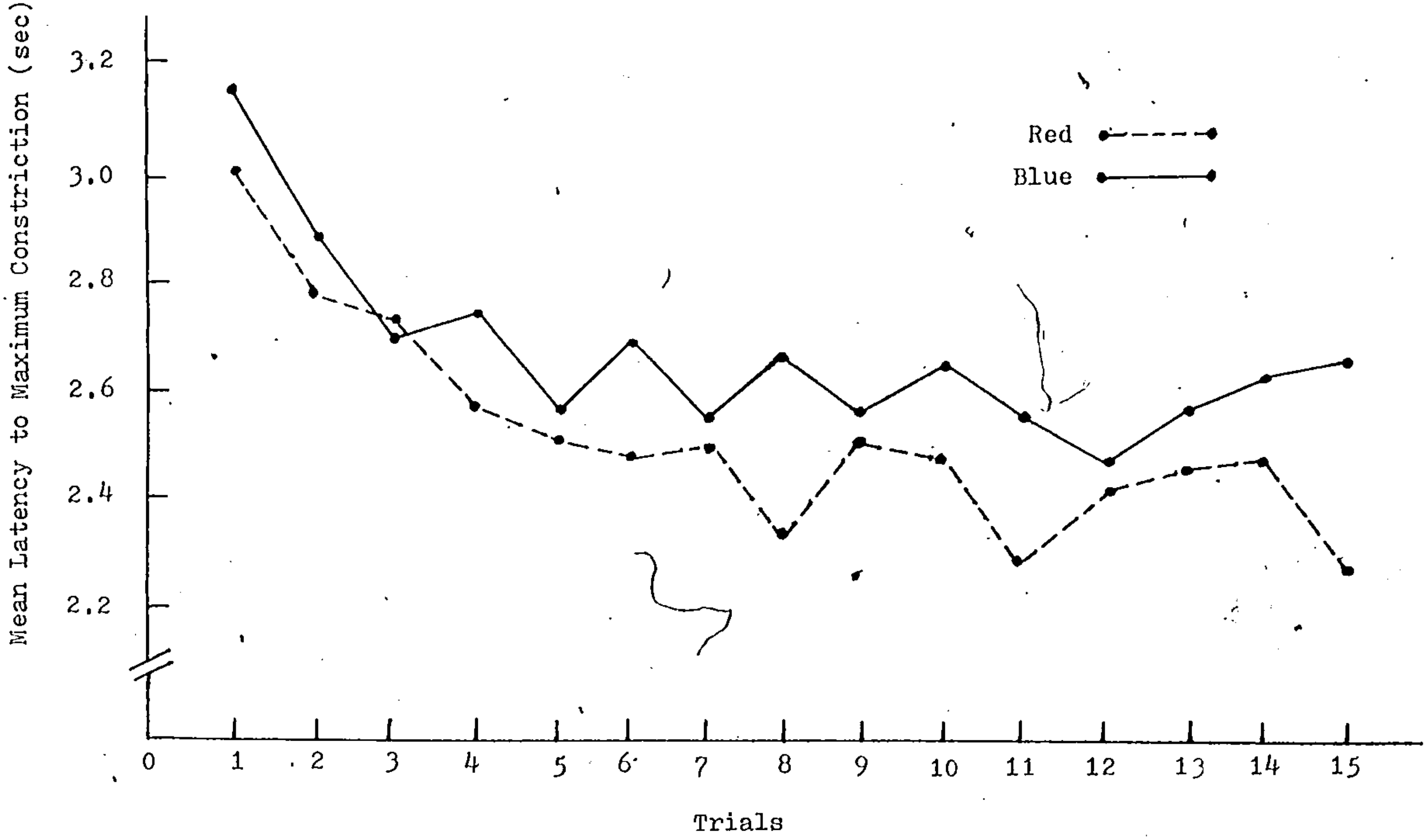


Figure 7. Mean latency to maximum constriction in the Hue X Trials interaction

($\underline{F}(1/48) = 2.56$, $\underline{MS}_e = 0.41$). Significant main effects due to hue were observed ($\underline{F}(1/48) = 18.35$, $\underline{MS}_e = 0.35$), with a faster mean rate of constriction obtained for the blue (1.43) than for red (1.34). Significant effects due to trials were also noted ($\underline{F}(14/672) = 3.44$, $\underline{MS}_e = 0.17$), with a slower mean rate of constriction obtained for the initial trial than for trials 11 and 12. Figure 8 presents the mean rate of constriction measures over trials. The greatest variation in rate was observed during the latter trials, particularly from trial 11 onwards.

The only interaction to exceed chance expectancy was observed between hue and trials ($\underline{F}(14/672) = 2.10$, $\underline{MS}_e = 0.15$). As can be seen from the average response curves for the mean rate of maximum constriction to red and blue presented in Figure 9, a consistent increase in rate of constriction over trials was evident for both hues, particularly the red. Comparisons among individual means indicated that significantly faster mean rates of constriction occurred for the blue hue to trials 2, 3, 5, 7, 9, 12, 13, and 14. A somewhat greater variability was shown in the rate of constriction to the red, particularly from trial 8 onwards.

<u>Magnitude of Maximum Redilation (MR)</u>. For the measures of maximum redilation, the analysis indicated

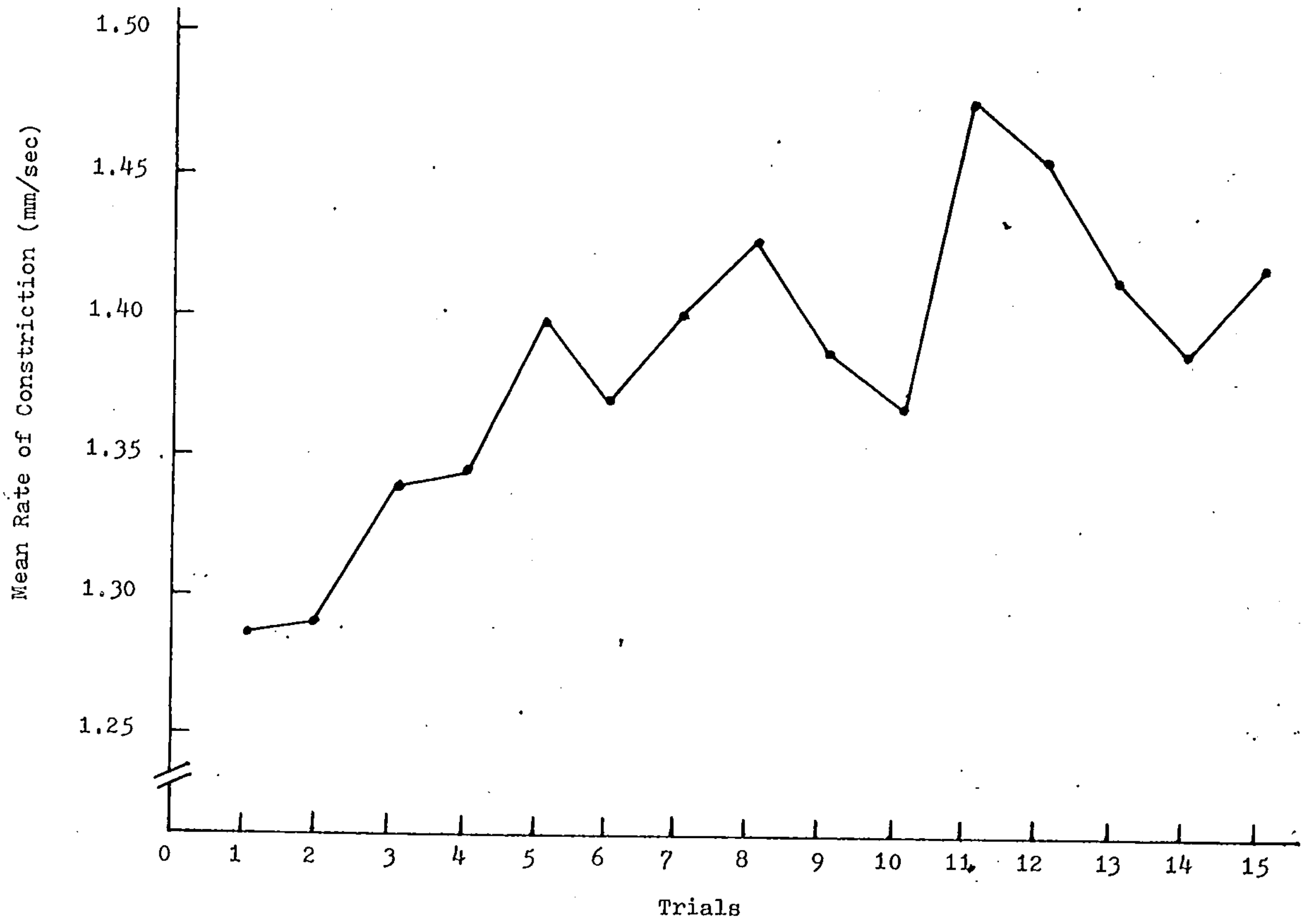


Figure 8. Mean rate of constriction

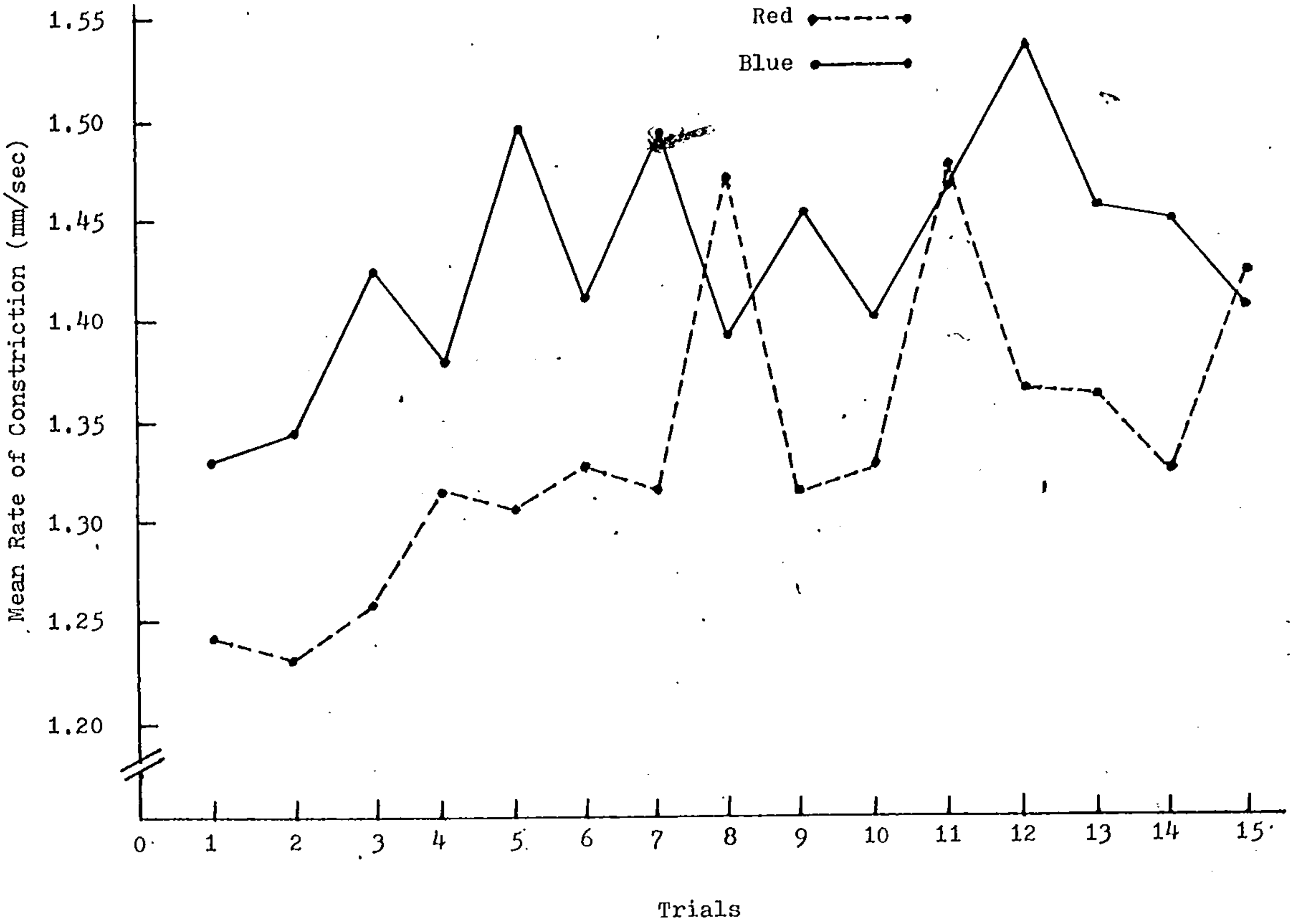


Figure 9. Mean rate of constriction in the Hue X Trials interaction

that the extraversion factor was nonsignificant ($\underline{F} < 1$). A significant difference between the mean magnitude of maximum redilation to blue (3.48) and red (2.92) was noted, ($\underline{F}(1/48) = 198.75$, $\underline{MS}_e = 1.19$). A significant difference between the mean redilation extent to the high (3.32) and low-intensity (3.07) was also found ($\underline{F}(1/48) = 30.36$, $\underline{MS}_e = 1.57$). Significant main effects due to trials were also observed ($\underline{F}(14/672) = 10.21$, $\underline{MS}_e = 0.12$). As noted for mean magnitude and latency of maximum constriction, there was a relatively consistent decrease in mean magnitude of redilation as trials progressed. Comparisons among individual means indicated that significantly greater mean magnitudes of redilation occurred for the initial 3 trials than for trials 9 and 11 to 15, respectively. Figure 10 shows the mean magnitudes of redilation obtained over the 15 trials.

The interaction of hue and intensity was also significant ($\underline{F}(1/48) = 10.75$, $\underline{MS}_e = 0.75$). The greatest mean redilation was obtained to the blue hue in the high-intensity level (3.55); the least amount of redilation was observed for the red hue in the low-intensity level (2.74); intermediate magnitudes of redilation were obtained for the blue hue in the low-intensity (3.40) and the red hue in the high-intensity

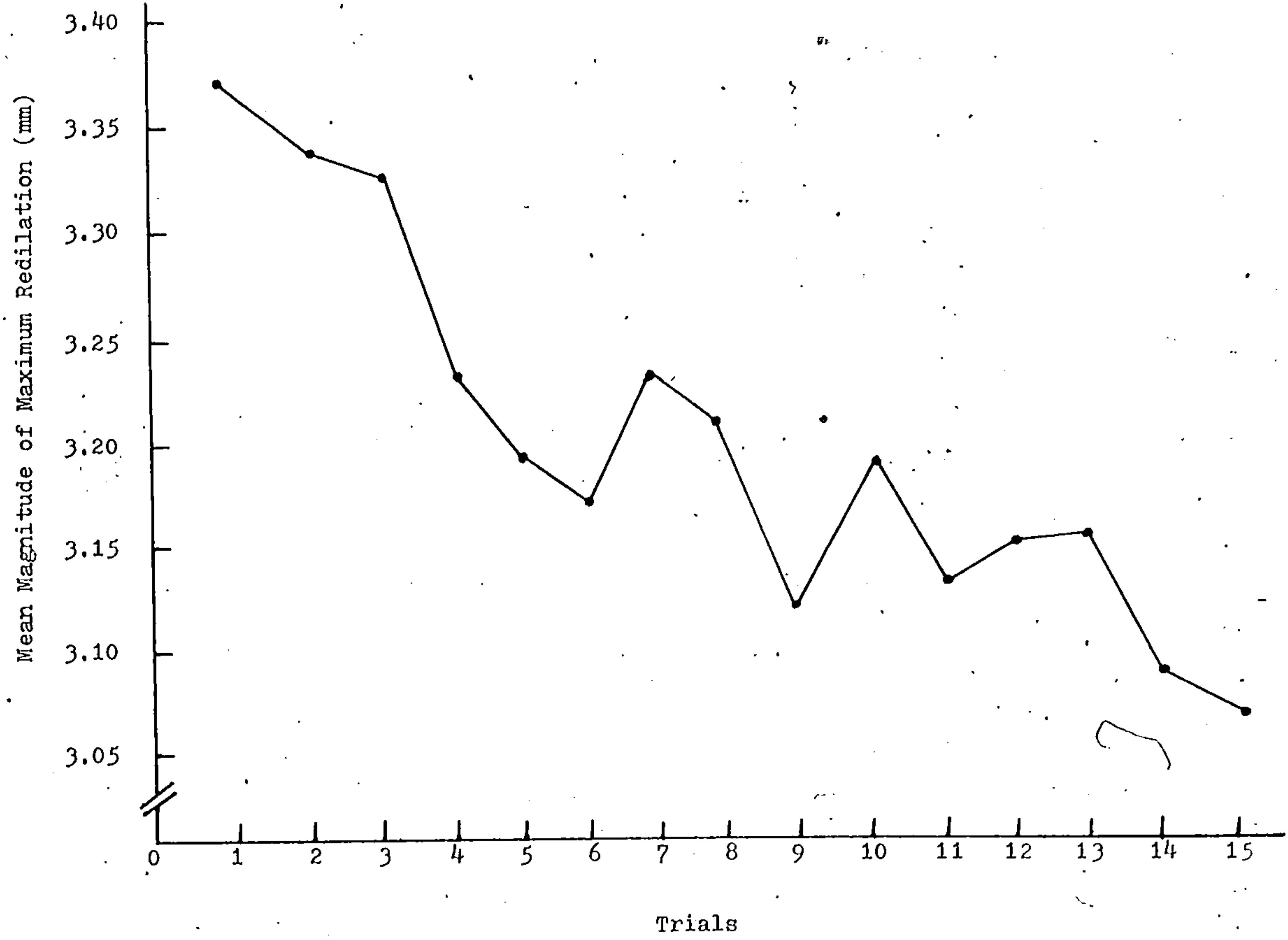


Figure 10. Mean magnitude of maximum redilation

level (3.10). As noted for the mean magnitude of constriction measures, comparisons among individual means indicated that mean magnitudes of redilation for all the combined hue and intensity conditions differed significantly from one another. Figure 11 presents the mean magnitude of maximum redilation to red and blue for the high- and low-intensity levels.

A significant interaction between hue and intensity and trials was also observed (F(14/672) = 2.27, $\underline{MS}_e$ = 0.12). The mean magnitudes of maximum redilation to red and blue for both intensity levels, over the 15 trials, are graphically plotted in Figure 12. As can be seen from the curves, the decrease in magnitude of redilation over trials is less variable for the red under both intensity levels, with the sharpest decline in redilation over trials occurring for the red in the low-intensity level. Comparisons among individual means indicated that the differences between mean redilation magnitudes obtained for the blue in the high-intensity level and for the red in both intensity levels prevailed over all trials. For the red in the low-intensity level, each mean value for trials 6, 9, and 11 to 15 was significantly smaller than the corresponding trial means for the red in the high-intensity level. The difference between high- and low-intensity levels for the blue hue,

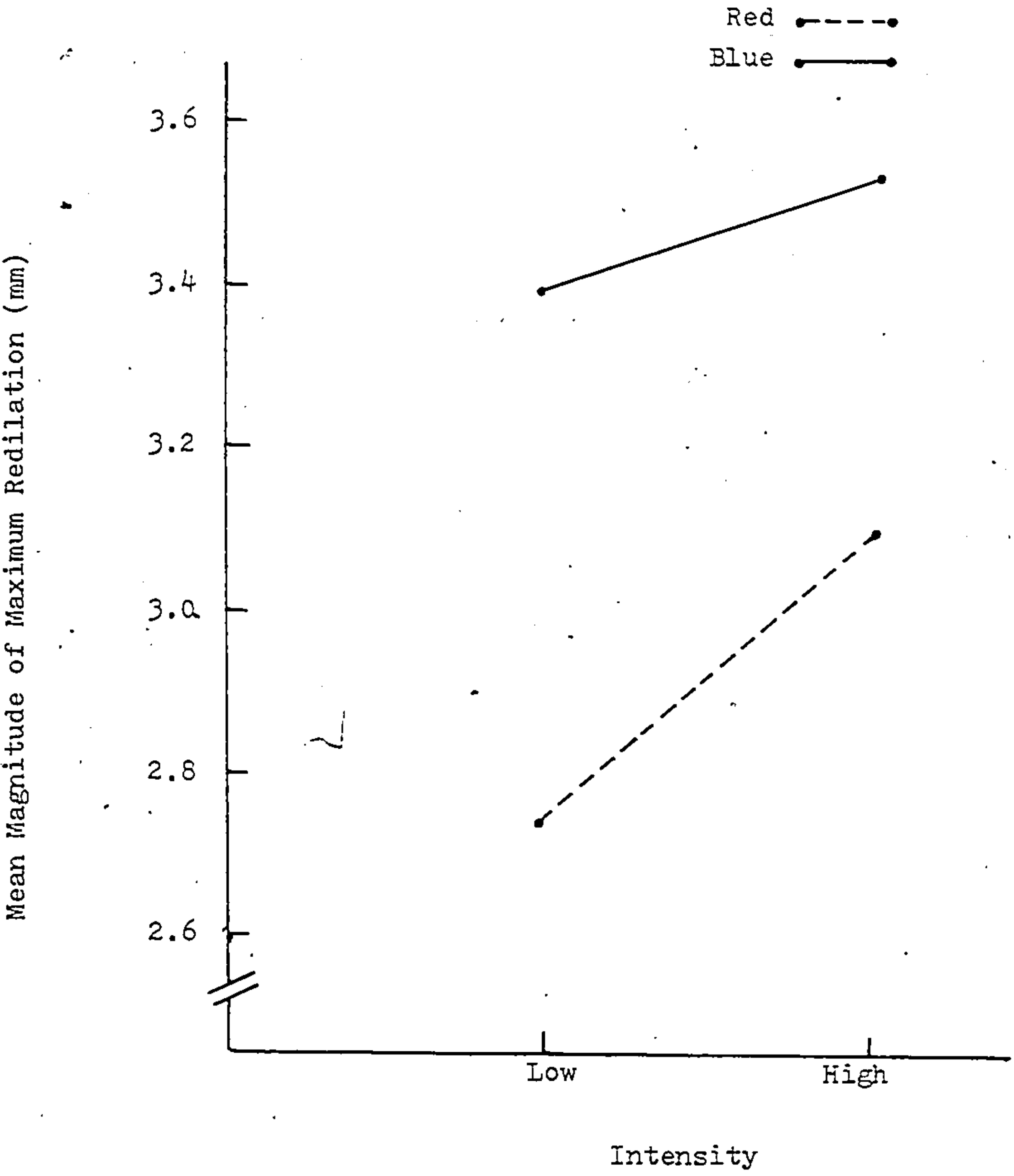


Figure 11. Mean magnitude of maximum redilation in the Hue X Intensity interaction

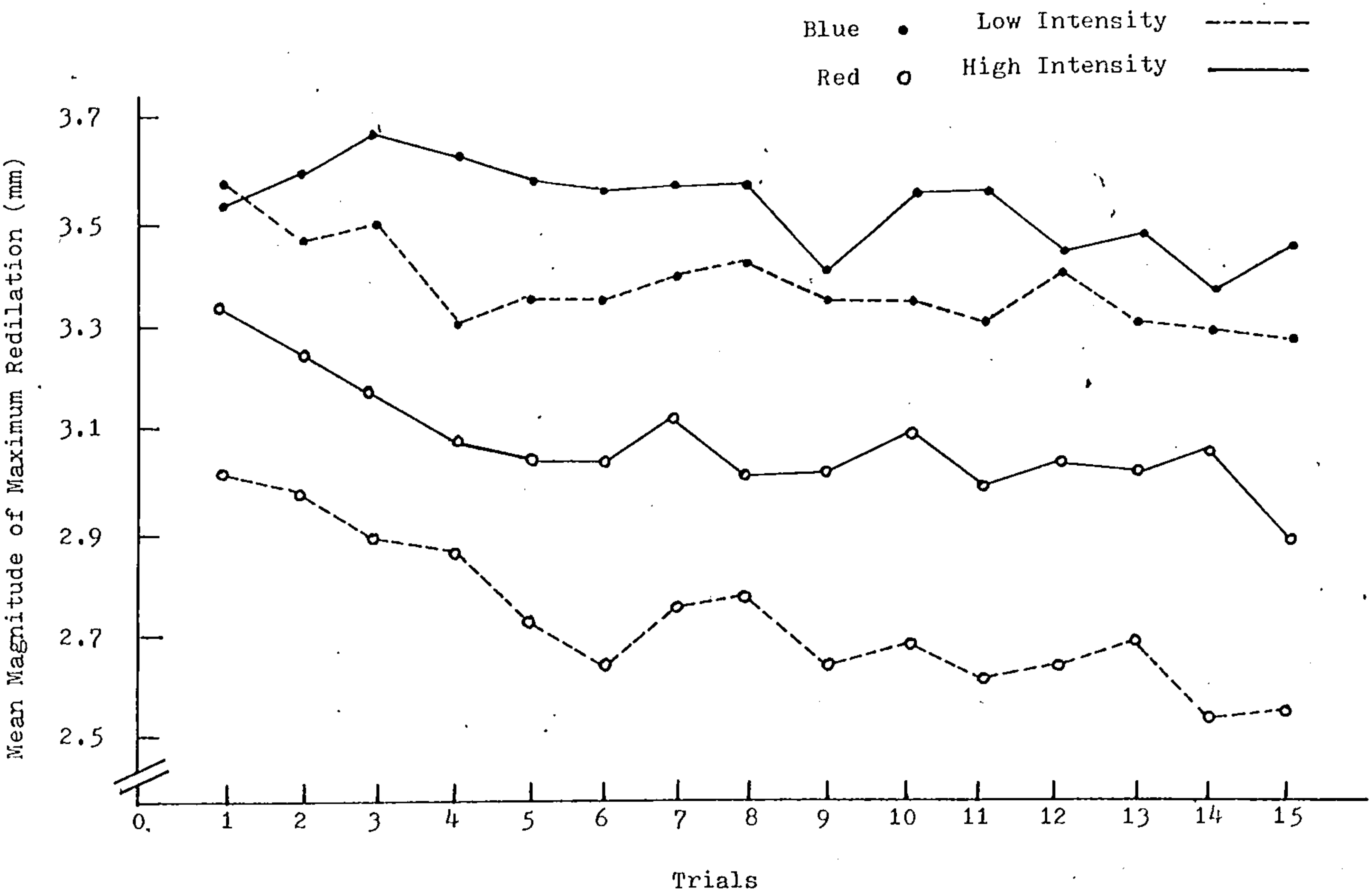


Figure 12. Mean magnitude of maximum redilation in the Hue X Intensity X Trials interaction

was primarily due to the significantly greater mean redilation extents to the high-intensity level to trials 4, 5, 6, 10, and 11. No significant change in magnitude of redilation over trials was demonstrated for the blue hue in either the high- or low-intensity level.

<u>Latency to Maximum Redilation (LR).</u> In the analysis of latency to maximum redilation measures, no significant main effects were observed due to extraversion ($\underline{F} < 1$), intensity ($\underline{F}(1/48) = 1.13$, $\underline{MS}_e = 3.90$), or trials ($\underline{F} < 1$). Significant main effects due to hue were noted ($\underline{F}(1/48) = 5.89$, $\underline{MS}_e = 2.73$), with the mean latency to maximum redilation to blue (9.95) longer than to red (9.80). No significant interaction effects were observed.

<u>Mean Rate of Redilation (RR)</u>. In the mean rate of redilation analysis, no significant main effects due to extraversion were observed ($\underline{F} < 1$). A significant difference between the mean rate of redilation to the blue (.61) and red (.50) was noted, ($F(1/48) = 65.08$, $\underline{MS}_e = 0.14$). A significant difference between the mean redilation rate to the high- (.57) and low-intensity (.54) was also observed ($\underline{F}(1/48 = 4.84$, $\underline{MS}_e = 0.18$). Significant effects were also noted due to trials ($\underline{F}(14/672) = 4.29$, $\underline{MS}_e = 0.06$), with the mean rate of redilation to the initial 2 trials significantly greater than for

trials 9, 11, 12, 14, and 15. The mean rates of redilation over trials are shown in Figure 13. A general decrease in mean rate of redilation as trials progressed may be observed, with greater variability in mean rates occurring during the initial 5 trials.

The interaction of hue and intensity was also significant (F(1/48) = 4.72, $\underline{MS}_e$ = 0.13). The mean rate of redilation measures for the red and blue hues in both intensity levels are graphically presented in Figure 14. Significantly faster mean redilation rates occurred for the blue hue in both low- (.61) and high- (.61) intensity levels than for both the red hue in the low- (.47) or high-intensity level (.53). The difference between mean rates of redilation to the red in the high- and low-intensity levels was also significant. No significant difference between intensity levels was observed for the blue.

The interaction between hue and trials was the only other effect to exceed chance expectancy (F(14/672) = 1.77, $\underline{MS}_e$ = 0.06). Figure 15 shows the mean rates of redilation for the red and blue over the 15 trials. Individual comparisons among the mean rates of redilation to red and blue over the 15 trials indicated that, with the exceptions of trials 1 and 4, significantly faster rates of redilation for the blue prevailed

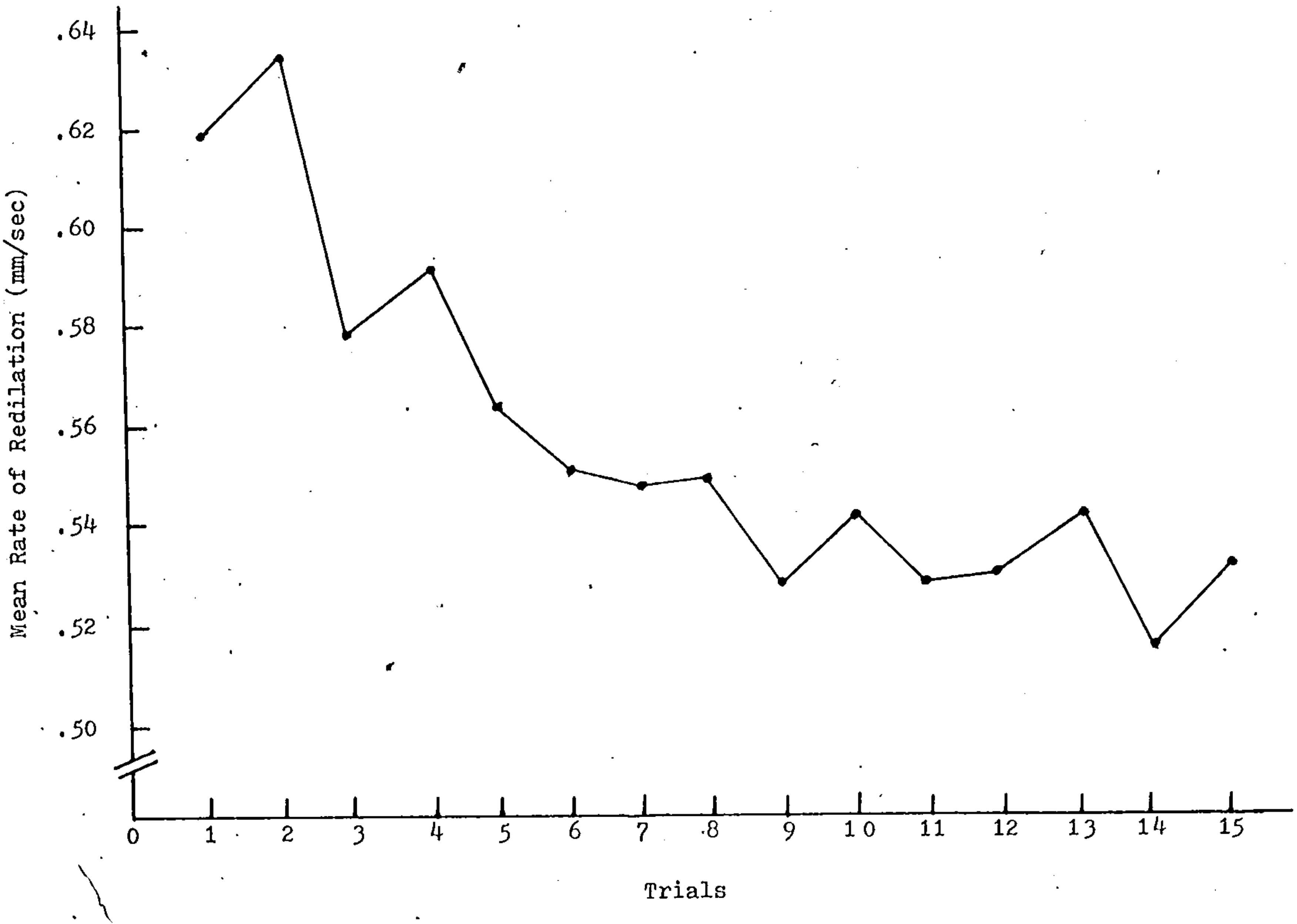


Figure 13. Mean rate of redilation

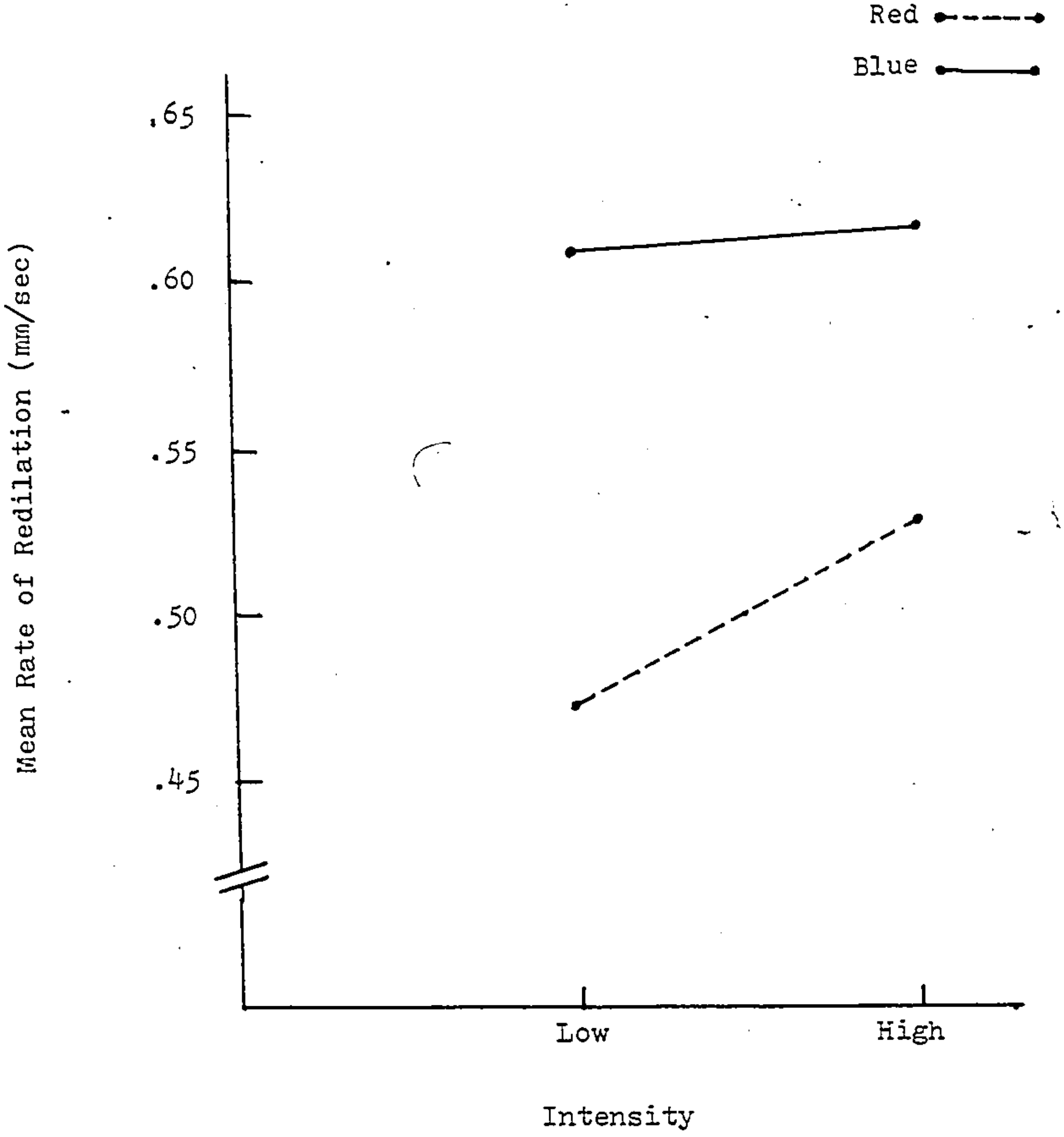


Figure 14. Mean rate of redilation in the Hue X Intensity interaction

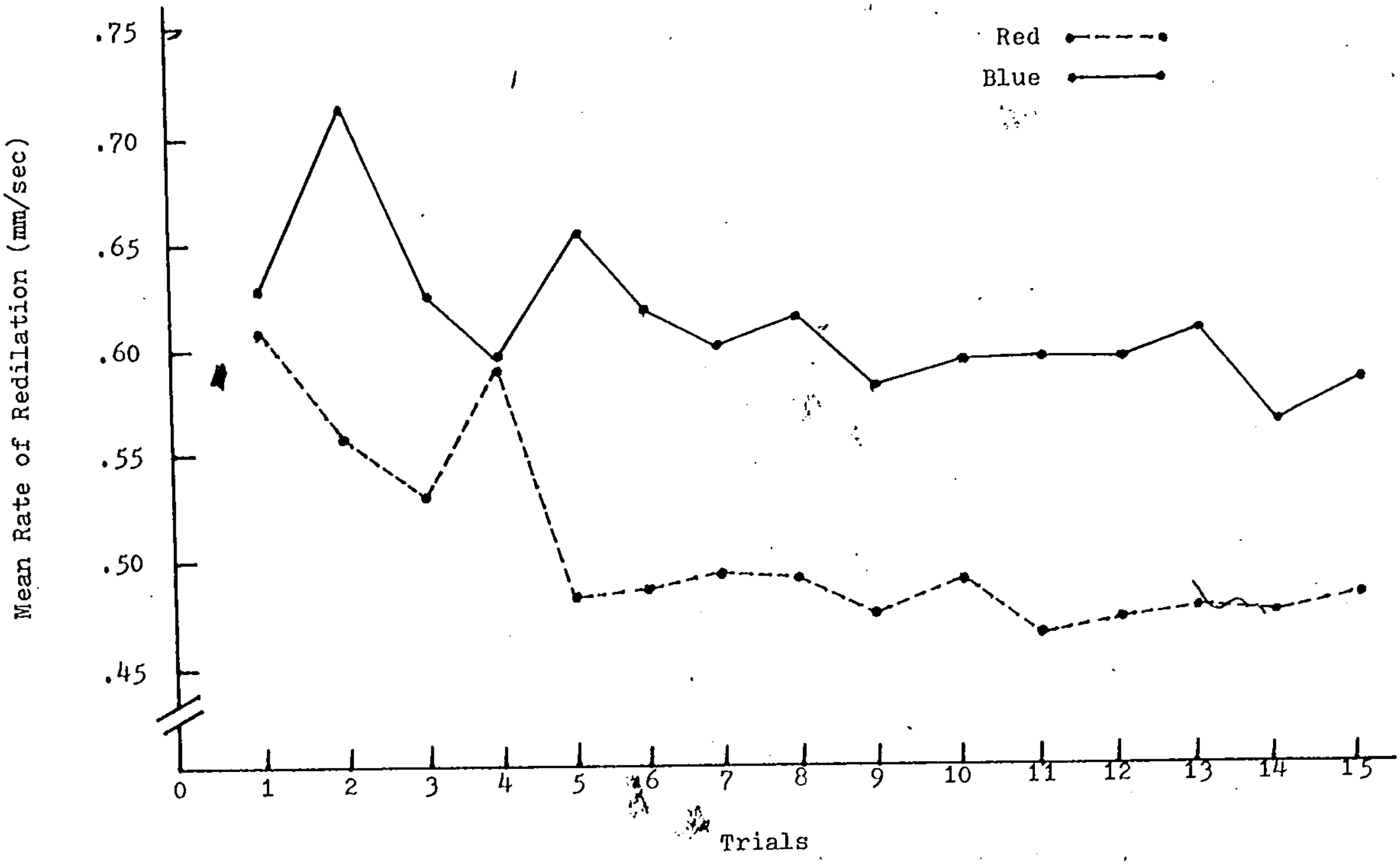


Figure 15. Mean rate of redilation in the Hue X Trials interaction

over all respective trials. Mean rates or redilation to the red hue showed a more systematic progressive decrease in the earlier trials, with the exception of trial 4, which, in view of the downward trend, is probably due to chance fluctuation.

Maximum Redilated Pupil Size (MP). For the analysis of maximum redilated pupil size, neither differences between extraversion groups ($\underline{F} < 1$), or intensity levels ($\underline{F}(1/48) = 1.73$, $\underline{MS}_e = 1.95$), were significant at an acceptable level of confidence. Significant main effects due to hue were observed ($\underline{F}(1/48) = 6.75$, $\underline{MS}_e = 1.78$), with the mean maximum redilated pupil size to red (6.56) greater than to blue (6.43). The effect of trials was also significant ($\underline{F}(14/672) = 3.33$, $\underline{MS}_e = 1.00$). As shown in Figure 16, a progressive decrease in mean redilated pupil sizes, particularly over the earlier trials, was observed. Individual comparisons indicated that the mean redilated pupil size to the initial trial was significantly greater than to individual trial means 10 to 15. No significant interaction effects were observed.

Additional Pupillary Response Measures and Indices of Fatigue

Frequency of V-Waves. No significant main effects due to extraversion ($\underline{F} < 1$), or intensity ($\underline{F}(1/48)$

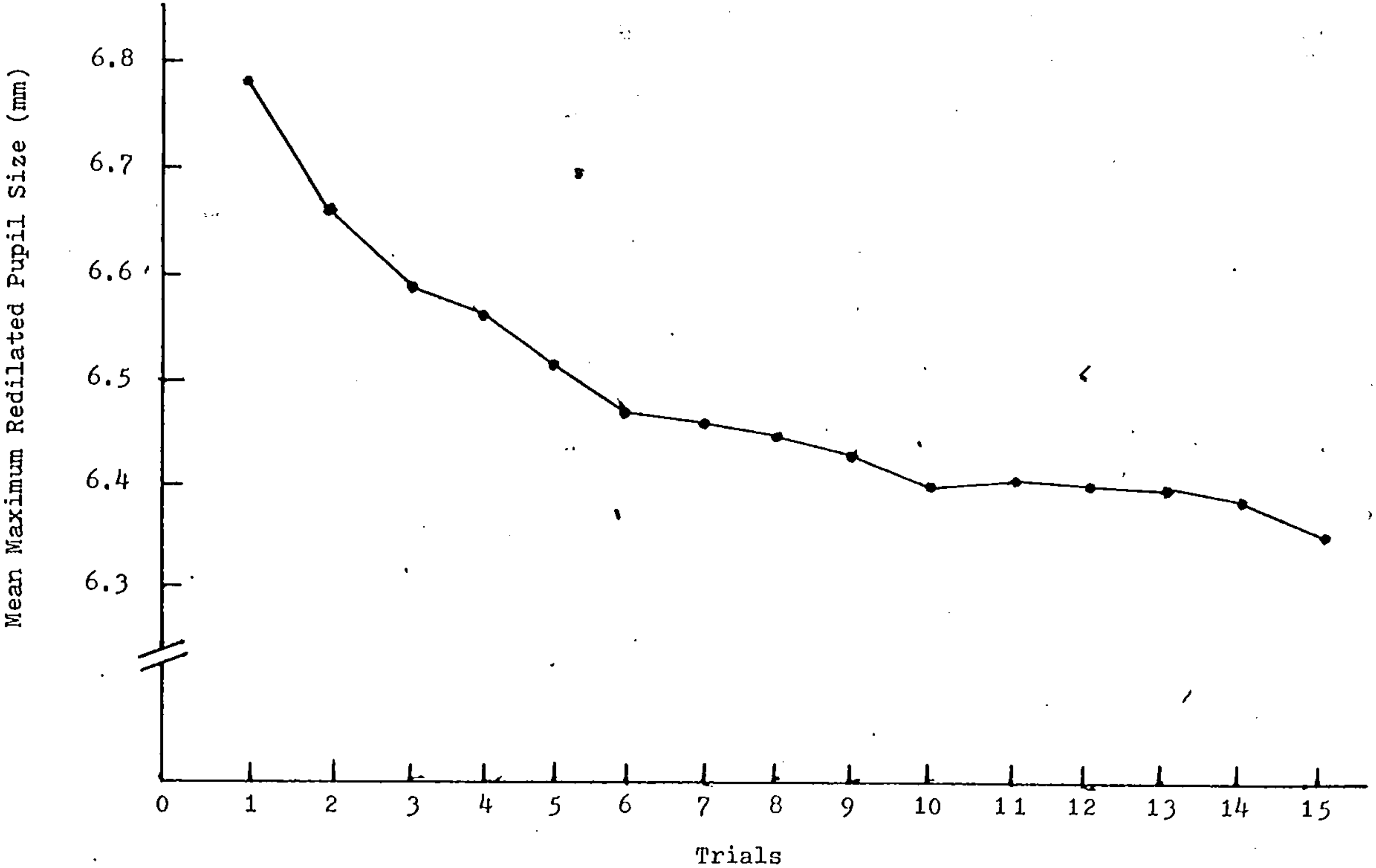


Figure 16. Mean maximum redilated pupil size

= 1.74, $MS_e = 4.51$), were demonstrated with respect to the frequency of V-waves measure. Significant main effects due to hue were observed ($F(1/48) = 12.25$, $MS_e = 3.39$), with the mean frequency of V-waves to red (2.7) greater than to blue (1.8). All interactions were nonsignificant.

Frequency of W-Waves. In the analysis of the frequency of W-waves, no significant effects were observed for the extraversion factor ($F < 1$). The main effect of hue was significant ($F(1/48) = 47.52$, $MS_e = 10.71$), with the red (10.06) eliciting a greater frequency of W-waves than the blue (6.90). A significant difference between the mean W-wave frequency to the low- (9.13) and high-intensity (7.83) was also found, ($F(1/48) = 21.96$, $MS_e = 3.90$). No significant interaction effects were observed.

Trials-to-Criterion-Fatigue (TF). In the trials to criterion fatigue analysis, neither the extraversion nor intensity main effects were significant ($F < 1$). Significant effects due to hue were observed ($F(1/48) = 19.61$, $MS_e = 4.36$), with the mean number of trials to fatigue to blue (3.39) greater than to red (2.09). With the exception of a significant interaction between extraversion and hue and intensity ($F(2/48) = 4.37$, $MS_e = 5.21$), all interaction effects were nonsignificant.

Figure 17 shows the mean number of trials-to-fatigue for each of the extraversion groups to the red and blue in both intensity levels. Individual comparisons indicated that the mean number of trials necessary to elicit fatigue symptoms to the blue in the low-intensity level was significantly greater for the extravert (4.00) than for the introvert group (2.53), while the mean number of trials-to-criterion-fatigue to the blue in the high-intensity level was significantly greater for both the extravert (3.82) and introvert (3.47) than for the middle group (2.06). No significant differences in mean trials-to-fatigue between the introvert and extravert group were demonstrated to the blue hue in the high-intensity level. The middle group required the greatest number of trials to elicit fatigue symptoms to the blue hue in the low-intensity level (4.47) and conversely, the least number of trials to the red hue in the low-intensity level (1.35). None of the extraversion groups differed significantly from each other for the number of trials-to-fatigue to the red hue in the high-intensity level. For the red in the low-intensity level, the middle group (1.35) showed a significantly smaller mean number of trials-to-fatigue than either the introvert (2.23) or extravert group (1.76).

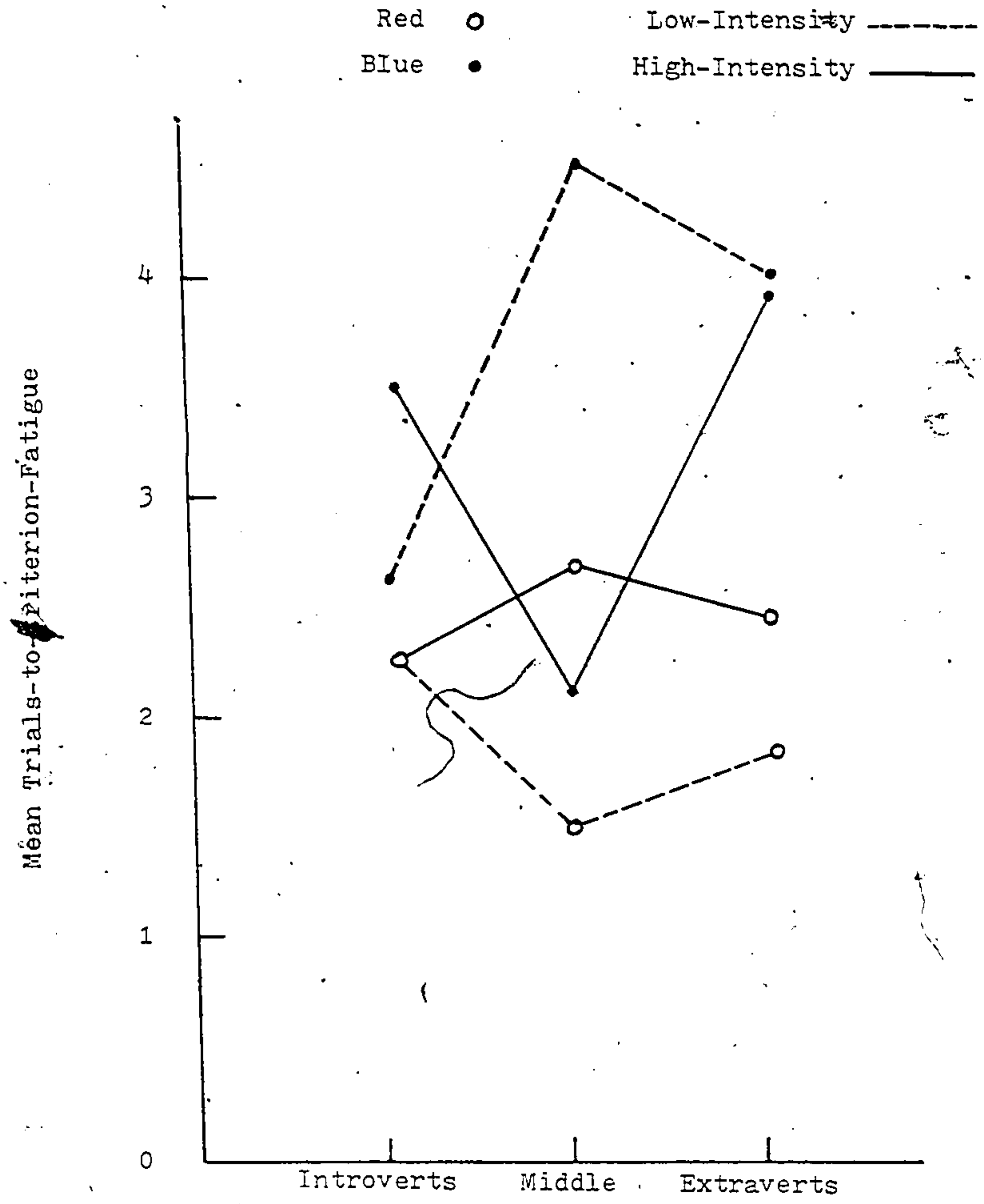


Figure 17. Mean trials-to-criterion-fatigue in the Extraversion X Hue X Intensity interaction

Frequency of Eyeblinks During Stimulation (SE). For the analysis of the frequency of eyeblinks during stimulation, no significant main effects were observed due to extraversion ($F < 1$), hue ($F < 1$), or intensity ($F(1/48) = 1.37$, $MS_e = 217.67$), and all interaction effects were statistically nonsignificant.

Mean Resting Dark-Adapted Pupil Size (RP). No significant effects due to extraversion were demonstrated with respect to mean resting dark-adapted pupil size ($F < 1$).

Resting Blink Rate. For the resting blink rate analysis, no significant effects due to extraversion were observed ($F < 1$).

Hue Discrimination

For the analysis of the hue discrimination measures, no significant effects due to extraversion were observed for the blue, red, or total discrimination error scores ($F < 1$). Although all of the groups showed slightly lower red hue discrimination error scores, t-tests for correlated samples indicated that this relationship failed to reach significance within the introvert ($t(16) = -0.70$, NS), middle ($t(16) = -0.03$, NS), extravert ($t(16) = -1.29$, NS), or overall sample group ($t(50) = -1.15$, NS). A summary of the score distributions for the hue discrimination measures is provided in Table 4.

Table 4

Farnsworth-Munsell 100 Hue Test Score Distribution for Total Blue Error Score, Total Red Error Score, and Total Hue Error Score for Total Sample Group, Introvert, Middle, and Extravert.

		Total Error Score					
		Blue		Red		Total	
Group	N	M	SD	M	SD	M	SD
Total sample group	51	8.90	7.46	7.61	6.91	16.51	11.93
Introvert group	17	9.00	5.49	7.94	7.07	16.94	10.78
Middle group	17	7.35	8.73	7.29	6.24	14.65	12.49
Extravert group	17	10.35	7.91	7.59	7.74	17.94	12.91

Note. The Farnsworth-Munsell 100 Hue Test error scores for the Introverted, Middle, and Extraverted subjects are given in Appendix E.

Summary: The main findings of the analyses of the pupillary light reflex characteristics, additional pupillary response measures and indices of fatigue, and hue discrimination data indicated that:

(1) No differences were observed due to extraversion for any of the pupillary light reflex measures, additional pupillary response and fatigue indices, or hue discrimination.

(2) A significant interaction of extraversion and hue and intensity was observed for the trials-to-criterion-fatigue measure, with introverts requiring significantly fewer trials than extraverts to elicit fatigue symptoms to the blue light in the low-intensity level. This was the only indication of a relationship between extraversion and the pupillary light reflex.

(3) The red hue stimuli elicited significantly less extensive constriction and redilation, shorter latencies to maximum redilation, slower rates of constriction and redilation, larger redilated pupil sizes, a greater frequency of V-waves, greater frequency of W-waves, and fewer trials-to-criterion-fatigue than the blue hue. No significant relationship was observed between hue and the frequency of eyeblinks.

(4) The high-intensity elicited significantly more extensive constriction and redilation, faster

mean rates of redilation, and fewer W-waves than the low-intensity. Intensity was not shown to have any consistent effect on rate of constriction, latency to maximum redilation, maximum redilated pupil size, V-wave frequency, number of trials necessary to elicit fatigue, or frequency of eyeblinks.

(5) With the exception of the latency to maximum redilation measure, significant main effects due to trials were observed for all of the pupillary light reflex characteristics, with a systematic decrease generally occurring over trials, with the exception of rate of constriction which increased. Significantly less extensive constriction and redilation, shorter latencies to maximum constriction, increased rates of constriction, slower mean rates of redilation, and decreased redilated pupil sizes were noted as trials progressed.

(6) Significant interactions of hue and intensity were observed, with the blue in the high-intensity level eliciting sharper, more pronounced light reflexes, characterized by significantly more extensive constriction and redilation, longer latencies to maximum constriction, and faster mean rates of redilation. Conversely, for the red in the low-intensity level, less extensive constriction and redilation,

shorter latencies to maximum constriction, and slower mean rates of redilation were observed. In general, moderate measures of the light reflex were obtained for the blue in the low-intensity and red in the high-intensity level, in respective decreasing order.

Correlations between Extraversion, Hue Discrimination, and Pupillary Response Measures

The relationship between extraversion scores, the indices of hue discrimination ability, and each of the pupillary response measures was further explored by means of Pearson correlations. Tables 5 and 6 respectively show the correlations obtained between extraversion scores and the pupillary light reflex components (averaged across levels of hue, intensity, and trials), and the additional pupillary response measures, and indices of fatigue (averaged across hue and intensity levels). In general, extraversion was nonsignificantly related to total red error scores, ($\underline{r}$ = -.02, NS), total blue error scores, ($\underline{r}$ = +.08, NS), or total hue error scores ($\underline{r}$ = +.04, NS). There was no indication of a relationship between extraversion and any of the individual pupillary response measures.

Total hue error scores varied consistently with both total red error scores ($\underline{r}$ = +.82) and total

Table 5

Pearson Correlations between Extraversion Scores (Extraversion), Total Red Error Scores (Red), Total Blue Error Scores (Blue), and Pupillary Light Reflex Measures

	Pupillary Light Reflex Measures						
	MC	LC	RC	MR	LR	RR	MP
Extraversion	+.07	+.11	-.02	+.04	-.06	+.06	+.01
Red	+.07	-.03	+.07	+.09	-.10	-.03	-.03
Blue	+.04	+.04	+.03	+.09	-.15	+.05	+.09

N = 51

Table 6

Pearson Correlations between Extraversion Scores (Extraversion), Total Red Error Scores (Red), Total Blue Error Scores (Blue), Pupillary Response Measures, and Fatigue Indices

	Pupillary Response Measures					
	V	W	TF	SE	RP	RBR
Extraversion	+.12	-.06	+.13	+.02	+.02	+.07
Red	+.07	+.15	+.07	+.04	-.07	+.002
Blue	+.14	+.27*	-.05	+.14	+.07	+.14

N = 51
* p .05

blue error scores ($\underline{r} = +.85$). A moderate positive relationship ($\underline{r} = +.38$) between total red and total blue error scores was also noted. The only other relationship of significance was the moderate correlation ($\underline{r} = +.27$) noted between total blue error scores and frequency of W-waves.

Intercorrelations between Pupillary Response Measures

The pupillary light reflex is a unitary autonomic reflex act involving both branches of the autonomic nervous system. Intercorrelations among the pupillary light reflex components were therefore computed to investigate the relationship between sympathetic and parasympathetic innervation of the light reflex as reflected by the subdivided characteristics. The internal consistency under the hue and intensity conditions was also assessed.

Pupillary Light Reflex Measures

The intercorrelations between the individual pupillary light reflex components, averaged across trials, within each hue and intensity condition are presented in Tables 7 to 10. The only indication of differences in relationships between components of

Table 7

Correlation Matrix of Pupillary Light Reflex Measure within the Red Hue Condition

	MC	LC	RC	MR	LR	RR	MP
MC	____	+.26*	+.67**	+.99**	+.13	+.83**	+.70**
LC		____	-.53**	+.31*	+.07	+.16	+.02
RC			____	+.61**	+.06	+.59**	+.59**
MR				____	+.07	+.85**	+.68**
LR					____	-.20	+.16
RR						____	+.60**
MP							____

N = 51
* $p < .05$
** $p < .001$

Table 8

Correlation Matrix of Pupillary Light Reflex Measures within the Blue Hue Condition

	MC	LC	RC	MR	LR	RR	MP
MC	———	+.21	+.66**	+.99**	+.21	+.83**	+.79**
LC		———	-.58**	+.25*	+.14	+.21	+.02
RC			———	+.62**	+.06	+.53**	+.63**
MR				———	+.21	+.83**	+.77**
LR					———	+.02	+.14
RR						———	+.67**
MP							———

N = 51
* $p < .05$
** $p < .001$

Table 9

Correlation Matrix of Pupillary Light Reflex Measures within the Low Intensity Conditions

	MC	LC	RC	MR	LR	RR	MP
MC	____	+.21	+.66**	+.99**	+.11	+.84**	+.65**
LC		____	-.58**	+.23*	+.11	+.13	+.10
RC			____	+.63**	-.03	+.59**	+.47**
MR				____	+.09	+.85**	+.64**
LR					____	-.12	-.02
RR						____	+.62**
MP							____

N = 51
* $p < .05$
** $p < .001$

Table 10

Correlation Matrix of Pupillary Light Reflex Measures within the High Intensity Condition

	MC	LC	RC	MR	LR	RR	MP
MC	—	+.22	+.71***	+.98***	+.26*	+.82***	+.81***
LC		—	-.51***	+.28*	+.07	+.17	-.01
RC			—	+.63***	+.16	+.58***	+.71***
MR				—	+.20	+.84***	+.80***
LR					—	-.06	+.32**
RR						—	+.64***
MP							—

N = 51

* $p < .05$

** $p < .01$

*** $p < .001$

the reflex due to the variable hue and intensity conditions were: Latency to maximum constriction was significantly related to magnitude of constriction during the red hue condition, but nonsignificantly related during both high- and low-intensity levels. For the high-intensity level, a significant positive relationship between magnitude of constriction and redilation latency was observed. Latency to redilation was nonsignificantly related to any of the pupillary reflex components during all intensity and hue conditions, with the exception of a significant positive relationship with absolute maximum redilation during the high-intensity condition. No significant differences were noted between any of the other correlations across any of the hue or intensity conditions.

Since the same general relationships between light reflex components were observed across all intensity and hue conditions, correlations between the pupillary light reflex measures for all combined hue and intensity conditions (averaged over levels of hue, intensity, and trials) were computed. The obtained correlations appear in Table 11. Latency to maximum constriction was nonsignificantly related to magnitude of maximum constriction, latency to maximum redilation, mean rate of redilation, and maximum redilated pupil size. A significant negative relationship between latency and rate of maximum constriction was obtained.

Table 11

Correlation Matrix of Pupillary Light Reflex Measures
over All Treatment Conditions

	MC	LC	RC	MR	LR	RR	MP
MC	—	+.22	+.69**	+.99**	+.18	+.85**	+.78**
LC		—	-.54**	+.27*	+.13	+.18	+.04
RC			—	+.65**	+.05	+.60**	+.63**
MR				—	+.14	+.86**	+.77**
LR					—	-.09	+.16
RR						—	+.69**
MP							—

N = 51
* p < .05
** p < .001

A significant positive relationship was also noted between magnitude of maximum redilation and latency to maximum constriction. Thus, slower rates of constriction and larger magnitudes of redilation were associated with longer latencies to constriction.

A significant positive correlation was observed between the magnitude and rate of constriction. Significant positive relationships were also obtained between the magnitude of maximum constriction and both mean rate of redilation and maximum redilated pupil size. The highest correlations obtained were found between magnitudes of maximum constriction and redilation ($r = +.99$), indicating an almost perfect correspondence between the two variables, i.e. between the parasympathetic and sympathetic divisions of the light reflex. A lack of any consistent relationship between magnitude of maximum constriction and latency to maximum redilation was observed.

Significant positive relationships between rate of constriction and both magnitude and mean rate of redilation were observed. As well, rate of constriction varied consistently with maximum redilated pupil size. Thus, slower rates of constriction were associated with smaller extents of redilation, slower redilation rates, and smaller redilated pupil diameters. No consistent relationship was observed between rate of constriction and latency to maximum redilation.

Low, nonsignificant r's were found between latency to maximum redilation and all of the other pupillary light reflex characteristics. Magnitude of maximum redilation correlated positively with both rate of redilation and maximum redilated pupil size. Between the mean rate of redilation and maximum redilated pupil size, a significant positive relationship was also observed.

Additional Pupillary Response Measures and Indices of Fatigue

Relationships between the additional pupillary response measures and indices of fatigue were also assessed by means of Pearson correlations. Data was reduced by averaging over hue and intensity levels. The resulting correlation coefficients are presented in Table 12. A significant inverse relationship between frequency of V-waves and number of trials necessary to elicit fatigue symptoms was observed. This was not unexpected in view of the definition of the trials-to-criterion-fatigue measure. Low, nonsignificant correlations indicated that V-wave frequency was not related to any of the other additional pupillary response and fatigue measures. Frequency of W-waves also showed a significant

Table 12

Correlation Matrix of Additional Pupillary Response and Fatigue Measures

	V	W	TF	SE	RP	RBR
V	___	+.10	-.37**	-.21	-.14	-.10
W		___	-.58**	-.07	+.26*	-.01
TF			___	+.08	-.34**	+.16
SE				___	+.12	+.75***
RP					___	+.09
RBR						___

N = 51
* $p < .05$
** $p < .01$
*** $p < .001$

inverse relationship with trials-to-fatigue, and a moderate positive relationship with mean resting dark-adapted pupil size. W-wave frequencies were not significantly associated with any of the other fatigue indices. There was no indication of a relationship between resting blink rate, frequency of V-waves, or frequency of eyeblinks during stimulation with mean dark-adapted pupil size. Resting blink rate was significantly related to frequency of eyeblinks during stimulation, but not with any of the other fatigue measures. Thus, subjects who blinked more while resting in the dark, also blinked more during stimulus presentation. Frequency of eyeblinks during stimulation was nonsignificantly related to all remaining pupillary response measures. Finally, the mean resting dark-adapted pupil size was shown to vary inversely with the trials-to-criterion-fatigue.

Intercorrelations Between Pupillary Light Reflex Measures and Additional Pupillary Response and Fatigue Indices

The Pearson correlations, averaged across levels of hue, intensity, and trials, obtained between the pupillary light reflex components and the additional pupillary measures and indices of fatigue appear in Table 13. Latency to maximum constriction was inversely related to both frequency of V-waves and W-waves, and

Table 13

Intercorrelations between Pupillary Light Reflex Measures and Additional Pupillary Response and Fatigue Indices

		Pupillary Light Reflex Measures						
		MC	LC	RC	MR	LR	RR	MP
Additional Pupillary Measures and Fatigue Indices	V	-.16	-.44***	+.18	-.22	+.05	-.22	-.06
	W	+.16	-.44***	+.48***	+.12	-.19	+.15	+.29*
	TF	-.22	+.43***	-.52***	-.17	+.05	-.24*	-.34**
	SE	-.02	+.19	-.15	+.01	-.12	+.09	+.22
	RP	+.73***	+.03	+.60***	+.72***	+.10	+.65***	+.93***
	RBR	-.12	+.27*	-.31**	-.11	-.06	-.07	+.11

N = 51
* $p < .05$
** $p < .01$
*** $p < .001$

positively related to both resting blink rate and trials-to-fatigue. No significant correlations were observed between latency to maximum constriction and either frequency of eyeblinks during stimulation or mean resting dark-adapted pupil size. Magnitude of maximum constriction was found to vary consistently with mean resting dark-adapted pupil size. Low, nonsignificant correlations were observed between magnitude of maximum constriction and all other indices of fatigue.

Rate of constriction was positively related to both frequency of W-waves and mean resting dark-adapted pupil size. A significant inverse relationship was found between rate of constriction and both the resting blink rate and trials-to-fatigue measures. No significant relationship between either V-wave frequency, or eyeblinks during stimulation, with the rate of constriction measures.

Latency to maximum constriction showed no significant relationship with any of the additional pupillary response or fatigue indices. With the exception of a significant positive association with the mean resting dark-adapted pupil size, magnitude of maximum constriction showed no significant relationship with any of the additional pupillary response measures.

Neither mean rate of redilation, nor maximum redilated pupil size varied consistently with frequency of V-waves, frequency of eyeblinks during stimulation, or resting blink rate. No consistent relationship between frequency of W-waves and mean rate of redilation was obtained. Mean rate of redilation was positively related to mean resting dark-adapted pupil size and showed a significantly moderate inverse association with trials-to-fatigue. Maximum redilated pupil size was significantly related to both frequency of W-waves and mean resting dark-adapted pupil size. A significant inverse relationship between maximum redilated pupil size and trials-to-criterion-fatigue was also observed.

Summary: The major findings of the correlational analyses between extraversion, the pupillary response measures, and hue discrimination data indicated that:

(1) Extraversion was not related to any of the pupillary response or hue discrimination measures for either red or blue.

(2) Hue discrimination for blue was positively related to both hue discrimination for red and total hue discrimination.

(3) Hue discrimination for blue varied consistently with frequency of W-waves.

(4) Magnitude of maximum constriction was

positively related to rate of constriction, magnitude and rate of redilation, maximum redilated pupil size and mean resting dark-adapted pupil size. Magnitude of maximum constriction was found to be more closely associated with rate than with latency to constriction.

(5) Latency to maximum constriction was positively related to mean magnitude of redilation, trials-to-criterion-fatigue, and resting blink rate, and inversely related to rate of constriction and frequency of V- and W-waves. Latency to maximum constriction was more closely associated with rate than with magnitude of constriction.

(6) Rate of constriction was positively related to magnitude of constriction, magnitude and rate of redilation, maximum redilated pupil size, frequency of W-waves, and mean dark-adapted pupil size, and inversely related to latency to maximum constriction, resting blink rate, and trials-to-criterion-fatigue. Rate of constriction was more closely associated with magnitude than with latency to constriction.

(7) Latency to maximum redilation was not related to any of the pupillary response measures.

(8) Magnitude of maximum redilation was positively associated with magnitude, latency, and rate of constriction, mean rate of redilation, maximum

redilated pupil size and mean resting dark-adapted pupil size. Magnitude of maximum redilation was found to be more closely related to rate than to latency of redilation.

(9) Mean rate of redilation was positively associated with magnitude of maximum redilation, magnitude and rate of constriction, maximum redilated pupil size, and mean resting dark-adapted pupil size, and inversely related to trials-to-criterion-fatigue. Mean rate of redilation was found to be more closely associated with magnitude than with latency of redilation.

(10) Maximum redilated pupil size was positively associated with magnitude and rate of redilation and constriction, mean resting dark-adapted pupil size, and frequency of W-waves, and inversely related to trials-to-criterion-fatigue.

(11) Frequency of V-waves was inversely related to latency to maximum constriction and trials-to-criterion-fatigue.

(12) Frequency of W-waves was positively related to rate of constriction, mean resting dark-adapted pupil size, and maximum redilated pupil size, and inversely related to latency to maximum constriction, and trials-to-criterion-fatigue.

(13) There was no indication of a consistent

relationship between V- and W-wave frequencies.

(14) Resting blink rate was positively related to frequency of eyeblinks during stimulation and latency to maximum constriction, and inversely related to rate of constriction.

(15) Mean resting dark-adapted pupil size was positively related to magnitude and rate of constriction and redilation, latency to constriction, mean redilated pupil size, and frequency of W-waves, and inversely related to trials-to-criterion-fatigue.

(16) Trials-to-criterion-fatigue was positively associated with latency to maximum constriction, and inversely related to rate of constriction and redilation, maximum redilated pupil size, frequency of V- and W-waves, and mean resting dark-adapted pupil size.

CHAPTER IV

DISCUSSION

The present study proposed to investigate differences in psychophysiological reactivity between introverts and extraverts reflected in the pupillary light reflex. In this chapter the pupillary measures applied are discussed and evaluated.

Pupillary Response Measures

This investigation failed to demonstrate a significant relationship between extraversion and any of the seven pupillary light reflex components, for either red or blue chromatic light stimuli, under both high- and low-intensity levels. The only indication of a relationship between extraversion and the pupillary response was a significant interaction of extraversion and hue and intensity for the number of trials-to-criterion-fatigue, with the middle group requiring significantly fewer trials to elicit fatigue symptoms than both the introvert and extravert groups, to both the blue hue in the high-intensity and the red hue in the low-intensity level. The significantly fewer trials-to-criterion-fatigue observed for the introvert group to the blue hue in the low-intensity level is consistent with the hypothesis that introverts would show faster fatigue of the pupillary light reflex than extraverts at lower levels of stimulus intensity as a result of transmarginal inhibition. The confidence in this effect would be enhanced if differences in fatigue indices between other conditions were consistent or orderly. This was not the case. Specifically, this was the only observation of the introvert's proposed greater sensitivity to blue hues and low-intensity stimulation. Consequently, the effect, interesting as it may be, stands as an isolated effect which must be entertained with a good deal of reservation.

The expectation that introverts would show more psychophysiological reactivity initially than extraverts, and fatigue faster, as manifested in decreased and slower constriction and redilation at the end of a series of repeated chromatic light stimuli, was not substantiated. No significant differences were found between extraversion groups for the components of pupillary reactivity under the conditions of the present investigation.

Hess's (1972) observation that introverts demonstrate more definitive pupillary responses than extraverts was not found with the pupillary light reflex. Holmes' (1967) conclusion that introversion is related to greater speed or efficiency of neural transmission at cholinergic synapses where acetylcholine is the transmitter substance, as inferred from measures of rate of pupillary constriction, was not supported. The assertion that the pupillary light reflex provides "a simple and reliable measure of transmitter substances and consequently, predictors of learning" as related to extraversion (Holmes, 1967, p. 98), is questioned.

However, owing to the widely differing methodologies, stimuli, subject selection, recording and measurement procedures, lack of adequate replications, and the paucity of studies employing the pupillary light reflex, comparisons with other studies are difficult to make. Only the two previous studies of Holmes (1967) and Frith (1977) have implicated individual differences in extraversion and impulsivity as a source of variance in the extent and rate of pupillary constriction to light. The two studies which have examined tonic pupil size as an indicator of basal levels of corticoreticular activity in relation to extraversion (Frith, 1977; Stelmack & Mandelzys, 1975) markedly differ in design.

A closer look is taken at the studies of Holmes (1967) and Frith (1977). The methodologies employed in both studies may be questioned on several accounts. In the Holmes' (1967) study, less than one third of the subjects and one half of the data were employed in the classification procedure and data analysis, respectively. The rationale for such a procedure of analysis is questionable. Effects of initial levels or trials were not presented. In addition, subjects were not screened for such factors as general health, fatigue, use of drugs, and no age data were presented. Any one of these confounding variables would preclude attributing differences to extraversion. Measurement was accomplished by projecting the developed negatives of the photographed pupils onto a screen and hand measuring the diameter of the pupil with a mm ruler. Problems with this technique such as hand measurement of photographs, tediousness of the process, scorer reliability, absence of data due to slight head movements or blinks, and uncontrolled variations in film quality and processing, have been reviewed by Hakerem (1967, 1974) and Janisse (1976). In many cases, the edge of the pupil is too indistinct to measure. For such a procedure, the confounding effect of iris colouration might also be expected to be a source of variation. Subjects with light irises have been shown to exhibit larger pupils and faster reactivity than have pupils surrounded by a dark iris (Beck, 1967; Gambell, Ogle, & Kearns, 1967). Such a result might be due to the more definitive pupil measurement because of the contrast with the light surrounding iris. In addition, the dull red glow of a .5 ftC light on either side of the visual field, combined with an adapting light 9 in from, and at a point 5 in below the plane of the subjects' eyes, coupled with the lack of an adequate focal point, would undoubtedly induce convergence and eye movements, as well as lending itself to the near vision reflex (Woodmansee, 1966). Pupillary constriction has been shown to occur with convergence of the eyes and accommodation of the lens upon viewing a near object (Alpern, 1969). Great individual differences have been observed in terms of how close near focusing must occur before constriction effects operate. In fact, this effect has been shown to elicit constriction responses of as much as 10% - 30% (Woodmansee, 1966). The accommodation vergence response elicited by lack of an adequate focal point and the nearness of objects has been reported to produce as much as a .22 mm decrease in pupil size (Alpern, Mason, & Jardinoco, 1961).

Similarly, Frith (1977) photographed subject's pupils on 16 mm film at 3 frames per second employing a similar version of the Hess Camera (1965). The difficulties and inaccuracies inherent in this method of monitoring pupil size and changes have similarly been well documented (Janisse, 1976; Loewenfeld, 1966; Tryon, 1975; Woodmansee, 1966). Similar confounding variables such as those which were not controlled for in the Holmes (1967) study were deficiencies. It is to be noted also that Frith (1977) utilized a subscale of the extraversion dimension (the impulsivity scale) in associating high scorers with smaller tonic pupil size and less extensive constriction.

The greater magnitude of pupil diameter observed for introverts within all conditions, including the prestimulus level, by Stelmack & Mandelzys (1975) and Frith (1977), indicating higher tonic levels of arousal maintained throughout the experiment, was not replicated under the conditions of the present study. No significant differences were observed for tonic levels of arousal, as reflected in both the resting dark-adapted pupil size and maximum redilated pupil size during the interstimulus intervals. Therefore, the results of this study do not support Eysenck's (1967) proposal that introverts, as defined by the EPQ, are characterized by higher tonic levels of arousal than extraverts, in as far as this is reflected in tonic pupil size under the conditions employed in the present investigation. The Stelmack and Mandelzys (1975) study measured pupil size under low-intensity diffuse white light conditions and cited differences in stimulus conditions which may account for this effect. It was speculated that perhaps the pupil is uniquely sensitive to differential psychosensory stimulation.

The study by Stelmack and Mandelyzs (1975) recorded average pupil size to neutral, affective, and taboo word stimuli, independent of the light reflex, during pre-stimulus (5 sec from the onset of the word stimuli), stimulus (5 sec after the onset of the word stimuli), and post-stimulus intervals (5 sec following stimulus interval) under diffuse lighting conditions of 2 ftC. (Harris, Thackray, & Schoenberger, 1966, Meyer, 1953, Mandelzys, 1973). Although no reliability data were reported, Stelmack and Mandelzys' (1975) observation that pupil constriction (de-dilation from baseline) (Harris, Thackray, & Schoenberger, 1966; Meyer, 1953; Mandelzys, 1973) occurred in over 20 per cent of the cases, in opposition to expected psychosensory pupil dilation, would attest to the instability of the pupil in diffuse lighting due to spontaneous oscillations and the effects of noise. Stark (1959) and Woodmansee (1966) have both reported extreme instability due to spontaneous oscillations and noise in the human pupil servomechanism. Also, the use of intervening words as "relax" during interstimulus intervals is questionable, as pupillary dilation has been shown to be a general component of the orienting response (Maltzman & Raskin, 1965; Sokolov, 1963). The simple removal of stimulus material does not guarantee that psysiological activity will return to a resting level (Peavler, 1975; Woodmansee, 1966). Yet, most designs have implicitly assumed this to be the case. Typically, pupil size has been reported to increase rapidly during the first few control-test pairs, and decrease as the experiment progresses and the subject adapts. Designs which obtain pupil size measurements for control trials both before and after a series of stimulus presentations, using the mean of the two as a control or baseline, might help reduce this problem.

The present results are similar to previous attempts which have failed to specify personality dimensions as relevant sources of variance in pupillometric studies. These results are in accordance with findings reported by Boddicker (1972), where no relationship between either the extraversion or neuroticism dimension of the EPI and the pupillary response, independent of the light reflex, were observed. Similarly, Francis & Kelly (1969) did not observe any significant relationship between the pupillary response and extraversion scores on the EPI.

The expectation that introverts would manifest greater baseline oculomotor muscle tension and exhibit a greater degree of peripheral defensive reaction, as inferred from the resting blink rate and frequency of eyeblinks during stimulation respectively, was also not supported. No significant differences were observed between extraversion groups either during dark-adaptation periods or under any of the hue or intensity levels employed. Thus, the significant inverse relationship between extraversion and blink rate reported by Franks (1963) and Holland (1960) was not supported. The present results are similar to those obtained by Mandelzys (1973), who failed to find any relationship between eyeblink frequency and extraversion. The present failure to relate eyeblinks with extraversion may be aligned with previous studies (Harris, Thackray, & Schoenberger, 1966; Meyer, 1953; Mandelzys, 1973) where the nature of the visual task of fixating on a single point, coupled with the restraining experimental instructions induced voluntary inhibition.

It would appear that under the present conditions, the components of the pupillary light reflex, the measures of tonic pupil size, blink rate, V- and W-waves, and trials-to-criterion-fatigue are inadequate to discern differences in corticoreticular arousability inferred from descriptive differences in extraversion on the basis of paper-and-pencil questionnaires. One possibility is that the pupillary light reflex is not an appropriate measure for testing individual differences in psychophysiological reactivity related to extraversion. Paradoxically, its resistance to extinction and the relative insensitivity of the reflex to extraneous influences such as thoughts or emotions may be its very disadvantages. It is possible that the pupillary light reflex is only minimally affected by psychological processes and the present results point to the conclusion that the pupillary light reflex is relatively independent of reticular activity as related to extraversion.

The significant effect of intensity on the magnitude of maximum constriction and redilation, as well as on the rate of redilation measures, is consistent with Lowenstein and Loewenfeld's (1961, 1969) observation that high-intensity light stimuli elicit pupillary reflexes characterized by faster and more extensive pupillary constriction and redilation. The present results are also in agreement with Reeves' (1920), Clynes' (1962), and ten Doesschate and Alpern's (1967) observations that the pupil becomes smaller as the amount of light reaching the retina is increased. These results are in agreement with the common observation of response magnitude increasing with an increase in stimulus intensity (Bouma, 1962; Hakerem & Sutton, 1966; Alpern, 1969). Denton (1956) and Campbell and Gregory (1960) have suggested that this decrease in pupil size with an increase in illumination might provide aperatures optimum for visual acuity at different light intensities. The pupillary light reflex also appears to clearly conform to Skinner's (1938) law of the magnitude of a response.

The significant main effect of hue on the measures of pupillary light reflex activity is consistent with the pattern of light reflex fatigue and inhibition resulting from heightened sympathetic activation as described by Rubin (1964) and Lowenstein and Loewenfeld (1950, 1952, 1969). The present results are also in agreement with the studies of Wilson (1966), Schaie (1966), Smets (1969), Nourse and Welch (1971), and Gerard (1958), who have contended that hues of long wavelengths are more sympathetically activating than hues of short wavelengths. Consistency is also indicated with the work of Allen and Schwartz (1940), Kravkov (1941), Kaplan (1960), Costello (1963), Goldstein (1963), Dixon (1966), Birren (1973), and Jacobs, Keith and Suess (1975), who have associated increased sympathetic activity with long wavelength hues.

In addition to the significantly decreased constriction and redilation, the slower rates of constriction and redilation, and the larger redilated pupil sizes following the red hue (adrenergic outflow?), the significantly greater number of V- and W-waves, and fewer trials-to-criterion-fatigue are congruent with the contention of Birren (1961), Goldstein (1963), Schaie (1966), and

Smets (1969) of the disruptive effect of red hues. These quantitative features of a relatively inhibited light reflex, coupled with larger redilated pupil sizes following presentation of the red hue, concur with Lowenstein and Loewenfeld's (1969) description of pupillary light reflex activity stemming possibly from sympathetic excitation of the reticular formation, resulting in supranuclear inhibition of the oculomotor nucleus. The greater redilated pupil sizes following the red hue presentations possibly reflect greater arousal due to increased peripheral sympathetic activity. The present results are similar to the description of the effects of physiological stress on the pupillary light reflex (Plouffe & Stelmack, in press).

Janisse (1974) has reported that the stronger a stimulus is rated in terms of affect, whether positive or negative, the larger the pupil size. Jasper and Cruikshank (1937) and Bernstein (1969) have suggested that the activating value of any stimulus may be the meaning which is associated iwth it. Similar to the OR studies of Sokolov (1963) bearing on patterns of response, and consistent with Klien's (1970) model of motivated perceiving, it is possible that subjects formed a greater wealth of affective associations to the red hue and focused on the chromatic illumination not only with respect to its observable characteristics, but also in terms of subjective salience. This interpretation is speculative, however, since a subjective report of stimulus affect were not obtained in this investigation.

The significant main effect of trials for all of the pupillary light reflex components, with the exception of the latency to maximum redilation, conforms to Lowenstein, Feinberg and Loewenfeld's (1969), and Plouffe and Stelmack's (in press) observations that the pupillary light reflex fatigues or habituates over repeated elicitations. Although the present study cannot distinguish whether habituation or fatigue are operating, the demonstration, that when exposed to repeated light stimulations at short intervals the light reflex is gradually reduced, has been understood in terms of supranuclear impulses inhibiting the oculomotor nucleus from sending efferent parasympathetic impulses to the pupillary sphincter (Lowenstein, Feinberg, & Loewenfeld, 1963). These results are also consistent with observations that pupil size shows a gradual arousal decrement effect (decrease in size) over time (Woodmansee, 1966).

Although the pupillary light reflex does not extinguish, the consistent and systematic decrease in latency to maximum constriction, magnitude of constriction and redilation, rate of redilation, and maximum redilated pupil size, the systematic increase in rate of constriction observed as a function of progressive trials, are similar to OR habituation phenomenon (Plouffe & Stelmack, in press; Sokolov, 1963).

The present results seem best interpreted in terms of an adaptation effect (Helson, 1963; Lowenstein & Loewenfeld, 1961), in which the repeated action of the chromatic light stimuli is to reduce the sensitivity of the pupillary light reflex for both wavelengths and intensity levels investigated in the present study. The significant interactions of hue and trials, with a faster decline and subsequent levelling off in pupillary responsivity for the blue hue, may be understood in terms of differences in the pupillary response due to chromatic adaptation, since this has already been shown to occur electrophysiologically (Armington & Biersdorf, 1956; De Valois, Jacobs, & Abramov, 1964; DeValois, Jacobs, & Jones, 1963; DeValois & Walraven, 1967), and in colour sensitivity studies (Stiles & Crawford, 1934; Wyszecki & Stiles, 1967).

The adaptation of the pupillary light reflex to the different intensities of light is further evidence for the familiar example of the eye's continued adjustment to illumination. Pupillary adaptation to verbal stimuli, independent of the light reflex, has also been shown to have rather dramatic effects possibly confounding studies utilizing the pupillary response (Lehr & Bergum, 1966). In view of these and the present observations, it might be that averaging pupil size across repeated trials, while increasing reliability, may be inappropriate. The response clearly changed during the course of the experiment.

With regard to the relationship between pupillary response measures, correlational analyses revealed a high positive relationship between the parasympathetic and sympathetic divisions of the light reflex, i. e., between extent and rate of constriction and redilation. These results confirmed Lowenstein and Loewenfeld's (1950, 1952, 1969) and Plouffe and Stelmack's (in press) observations with regards to autonomic nervous system balance as manifested in the dynamics of the pupillary light reflex. The parallel correlations between the pupillary components across both hue and intensity conditions indicated that the pupillary light reflex was a stable and internally consistent response.

Under the conditions of this experiment, the results indicate that the latency to maximum constriction measure was highly and reliably inversely related to the rate of constriction for both hue and intensity conditions. Similar to the findings of Plouffe and Stelmack (in press), the extent of constriction was positively associated with maximum redilated pupil size, rate of constriction, extent of redilation, and rate of redilation, across all conditions of the present investigation. A high association was found between the pupillary components within the parasympathetic divisions of the light reflex. As expected, faster rates of constriction were associated with shorter latencies and more extensive constriction. Within the sympathetic division of the reflex, the extent of redilation was positively associated with rate and maximum redilated pupil size. Latency to maximum redilation was not associated with any other aspects of the pupillary light reflex. Correlational analyses also revealed that constriction rate was more a function of extent than of latency.

A number of other observations emerged which are of interest to psychophysiology, particularly to the development of pupillometrics. In as much as tonic pupil size reflects corticoreticular activation (Stelmack & Mandelzys, 1975; Frith, 1977), the more highly aroused individuals fatigued significantly faster than the less aroused individuals, as indicated by the inverse association between maximum redilated pupil sizes and trials-to-criterion-fatigue. Latency to maximum constriction was also negatively correlated with both frequency of V- and W-waves. Observation of fatigue effects indicated that individuals consistently showed the same individual fatigue symptoms, i.e., subjects who displayed W-waves consistently, did not generally elicit V-waves, and vice versa. Frequency of V- and W-waves were not significantly related. In addition, although there were no group differences with respect to frequency of eyeblinks, the high positive relationship obtained between eyeblinks during stimulus presentation and resting blink rate, indicated that subjects consistently exhibited the same relative degree of oculomotor tension throughout the experiment.

The results of the correlational analyses suggest that the pupillary light reflex may be affected by the law of initial values (Heilizer, 1975; Loewenfeld & Newsome, 1969; Wilder, 1958). Both tonic resting dark-adapted pupil size and maximum redilated pupil size prior to stimulation correlated positively with magnitude and rate of constriction and redilation, frequency of W-waves, and were inversely related to trials-to-criterion-fatigue. Thus, from the direction of the correlations involving the pupillary response, it appears that these components may depend upon the initial conditions. The possibility exists that some of the pupil size findings have been confounded by variations in initial diameter. Goldwater (1972) has noted the difficulty of evaluating this effect, due to the paucity of explicit references to this variable. Finally, the positive correlation between tonic dark-adapted pupil size and maximum redilated pupil size would imply that subjects maintained the same relative levels of arousal throughout the experiment.

Hue Discrimination

This study also failed to demonstrate differential hue discriminatory ability between groups differing in degree of extraversion and inferred corticoreticular arousal. The expectation that introverts would show greater sensitivity to blue hues than extraverts, and that extraverts would show greater sensitivity to red hues, was not found. No significant differences were observed between groups differing in degree of extraversion for the indices of hue discrimination for either red or blue. The significant relationship between extraversion and hue sensitivity reported by Smith (1974) was therefore not supported utilizing measures of hue discrimination. The present results are similar to those obtained by Bourgeois (1972), who employed a signal detection analysis, which may have yielded a more sensitive estimate, less confounded by nonsensory or subject artifacts as motives, attitudes, or judgment-influencing sets. It would therefore appear that differences between introverts and extraverts observed with threshold and absolute sensitivity measures such as have been reported by Smith (1968) and Stelmack and Campbell (1974), are not mirrored by differences in differential sensitivity.

Correlational analyses revealed that, irrespective of extraversion or hue, hue discrimination was reliably consistent within individuals, i.e., subjects who showed superior hue discrimination for red also displayed superior hue discrimination for blue. Subjects with poor hue discrimination for red, reliably showed poor discrimination performance for blue hues. Hue discrimination for blue also varied consistently with frequency of W-waves.

Hypothesis Evaluation, Implications and Recommendations

The main hypothesis of this study was not supported. The present results indicate that, under the conditions of this investigation, differences in degree of extraversion are not reflected in either the components of the pupillary light reflex, basal pupil diameter, eyeblink frequency, fatigue of the light reflex, or hue discrimination measures. It may be that the relationship between extraversion and the pupillary light reflex is more complex than has been proposed, and differences may emerge only under specific conditions. The nature of the stimuli may itself have accounted to some extent for the relatively small amount of variation observed for the pupillary light reflex measures of the present study. Perhaps the levels of light intensity employed in the present study were too high to elicit differences in the pupillary light reflex characteristics. It was noted that the only differences in the pupillary light reflex between introverts and extraverts which emerged for the trials-to-criterion-fatigue measure, and the greatest variation in hue and over trials, were obtained with the low-intensity level.

An analysis of the electrodermal, electrocortical and psychosensory pupil response studies indicates that the most successful differentiation of extraverts and introverts emerges under low or moderate stimulus intensities. Both Glae (1973) and Stelmack (in press) have noted that the research which has confirmed Eysenck's (1967) hypothesis has been conducted under low to moderate intensity conditions. Indeed, Eysenck and Levy (1972) have outlined the same conditions as optical for the conditioning of introverts, and Stelmack, Achorn and Michaud (1977) have argued that low frequency auditory stimulation may have facilitated differentiation of extraverts and introverts with evoked potential measures. It is also to be noted that differences in absolute sensitivity have been observed only under low frequency conditions (Smith, 1968; Stelmack and Campbell, 1974). Unlike studies employing auditory stimuli of different frequencies, there appears to be no systematic investigation of the effects of intensity on the pupillary light reflex for individuals differing with respect to specific personality characteristics.

Although the research seems to point in another direction, Gray (1973) has conversely indicated that the most effective stimuli for differentiating introverts and extraverts on psychophysiological measures are those which have aversive characteristics. Some support for this contention may be gleaned from the study of Stelmack and Mandelzys (1975), where emotionally arousing taboo words most effectively differentiated extraversion groups with respect to pupillary OR measures. It is to be noted that the psychosensory pupillary response and eyeblink studies of Peavler and McLaughlin (1967), Francis (1969), Patrick (1969), Arima and Wilson (1972), Bernick, Altman, and Mintz (1972), and Janisse (1974), employed stimuli having aversive components (noise, stress, anxiety arousing words). The electrodermal study of Bartol and Martin (1974), which employed chromatic stimuli, also failed to differentiate introverts and extraverts. As well, the affective word stimuli employed in the studies of Stelmack, Bourgeois, Chian, and Pickard (1979) were more efficient than the chromatic stimuli in detecting differences in psychophysiological reactivity between introverts and extraverts. Perhaps the aversive component of such stimuli lent itself to producing larger between-subject variability.

The few studies which have employed pupillary measures in the investigation of individual differences in psychophysiological reactivity between introverts and extraverts differ greatly in methodology. Consequently, inferences from such studies should be cautiously entertained. Future research might concentrate on determining conditions under which consistent effects may be observed. Differentiation of introverts and extraverts with both tonic and phasic measures of the pupillary response may depend on the specific methodology employed, stimulus parameters, and measurements utilized.

A thorough evaluation of the pupillary light reflex as a psychophysiological measure should include attempts to relate personality variables as extraversion with the light reflex, paired with aversive or more highly arousing stimuli as noise or words having positive and negative value for the subject. A study assessing the effects of different states of awareness on the pupillary light reflex as induced by the effects of stimulant or depressant drugs for groups differing in degree of extraversion, might clarify much of the confusion stemming from Eysenck's (1967) proposal.

The often cited problem of response specificity has been frequently posited as contributing to between-subject variability, and is relevant to studies relating differences in extraversion with autonomic response (Duffy, 1957; Engel, 1972; Lacey, 1967; Lacey & Lacey, 1958). Various physiological measures typically employed in psychophysiological research do not always show high intercorrelations, and evidence has suggested that there appears to be a patterning in the individual's excitation which is dependent upon both organic within-individual factors as well as the specific stimulus situation (Duffy, 1957). As a demonstration, the studies conducted by Stelmack, Bourgeois, Chian, and Pickard (1979) found that no single index of the cardiac, electrodermal, or vasomotor OR components accounted for more than 24% of the variation due to extraversion. In contrast, the conjoint influence of all three of these components accounted for 54% of the variation due to extraversion. Although thirteen separate measures were employed, the present study utilized only one response system and did not assess reactivity manifested via other systems. The division of the pupillary light reflex into quantitative components is also more descriptive than functional, since the reflex is an autonomous autonomic response.

In view of reports which have noted associations between pupillary activity and amplitude and latency of the electrodermal response (Colman & Paivio, 1969; Kahneman, Tursky, Shapiro & Crider, 1969; Stelmack & Mandelzys, 1975), as well as directional fractionation of cardiac and pupillary responses (Libby, Lacey, & Lacey, 1973), it is recommended that the conjoint effect on several response systems be concurrently measured in future research. This might help increase prediction as well as to further assess the nature of individual response hierarchy. In addition, where possible, simultaneous recording of both psychophysiological and psychophysical measures is recommended in future research attempting to link personality variables with perceptual sensitivity and psychophysiological reactivity. The manipulation of stimulus parameters and sensory modalities is warranted, in order to investigate the level of generality of findings.

The adequacy of the EPI, by itself, as an objective measure of extraversion has also been questioned (Boddicker, 1972). The present investigation mirrors this query with the use of the EPQ since it was observed throughout the experimental sessions that many subjects scoring low in extraversion exhibited observable behaviours more attributable to extraverts, (i.e. sociable, talkative, outgoing), and many high scoring extraverted subjects manifested subdued, silent, and retiring behaviour typically ascribed to introverts. In addition to EPQ scores, the use of behavioural observation and/or peer ratings may increase accuracy in this regard in future research. The contention of trait over-generality (Averill & Opton, 1968) may also be relevant, since it is to be noted that Frith (1977) utilized a subscale of the extraversion dimension (the impulsivity scale) in his study. Separate examination of the subtraits of extraversion might improve prediction. With the exception of the Holmes' (1967) study, no investigation to date has observed differences in the pupillary light reflex between introverts and extraverts.

Confounding the picture even further, is the observation that the psychometric independence of extraversion and neuroticism might not be paralleled by physiological processes as Eysenck (1967) has proposed (Claridge, Wawman, Davis, 1963; Winter, Broadhurst,

& Glass, 1972). Mangan and O'Gorman (1969) have also demonstrated an interaction between neuroticism and extraversion for the electrodermal response, and Rodnight and Gooch (1963) have mirrored these results in the determination of susceptibility to a central nervous system depressant. The neurotics employed in the pupillary study of Rubin (1964) would appear to be classified as both neurotic and introverted on the basis of a classification scheme as the EPQ. To assess the conjoint effects of extraversion and neuroticism, future pupillometric studies attempting to differentiate individuals within the extraversion and neuroticism dimensions, might employ designs utilizing the four quadrants of the EPQ, classifying subjects into groups of high and low extraversion and high and low neuroticism. The specification of the physiological mechanisms and experimental conditions which differentiate individuals differing in terms of these personality dimensions, should however take precedent.

Conclusion

The hypothesis that introverted individuals manifest greater perceptual sensitivity, greater autonomic reactivity, and faster fatigue at lower levels of stimulus intensity than extraverts as a result of transmarginal inhibition (Eysenck, 1967; Gray, 1964, 1967) was not affirmed by the present study which employed measures of the pupillary light reflex. No relationship was found between extraversion and any of seven individual components of the pupillary light reflex or six additional pupillary response and fatigue indices under both hue and intensity conditions investigated in this study. Furthermore, hue discrimination for red and blue was not found to be related to extraversion. The present results question earlier studies (Holmes, 1967; Frith, 1977) which have specified individual differences in degree of extraversion as a relevant variance source in the pupillary light reflex. In addition, the contention of Holmes (1967), that introversion is associated with synaptic transmitter substances, as inferred from speed of pupillary constriction, is not supported. Pupillary constriction and redilation (parasympathetic and sympathetic innervation) were found to exhibit an almost perfect one-to-one correspondence, and no differences in the balance or interaction of sympathetic and parasympathetic mechanisms were observed for individuals differing in terms of inferred cortical excitability.

The results for tonic pupil size, blink rate and fatigue indices of the pupillary response did not provide evidence to support the position that individuals differing in degree of extraversion exhibit differential basal levels of arousal, or adopt different strategies for dealing with oculomotor tension and fatigue (Franks, 1963; Frith, 1977; Holland, 1960; Stelmack and Mandelzys, 1975). The contention that pupil size is a reliable indicator of arousal along Eysenckian (1967) dimensions is not supported, at least under the conditions of the present study.

Unlike earlier psychosensory pupil size studies which employed perhaps more "meaningful" affective stimuli more susceptible to cognitive influences (Stelmack & Mandelzys, 1975), the present findings point to a general interpretation that the possibility of observing differences in the pupillary light reflex may be explained by the nature of the stimulus itself. Furthermore, the speculation that introverts are more sensitive to hues of short wavelengths, indicating differences in autonomic nervous system dominance, failed to be supported under both the psychophysiological and psychophysical conditions of the present investigation.

In accordance with research which has related hues with psychophysiological reactivity, greater inhibition of the pupillary light reflex as characterized by slower and less extensive constriction and redilation, significantly more fatigue symptoms, and greater redilated pupil sizes, were observed for the red hue. Other tentative explanations to account for this phenomenon were also offered. The pupillary light reflex was also found to adapt to continued light stimulation and to exhibit similar effects due to intensity as has been reported in the literature.

In interpreting the present results obtained for both psychophysiological and psychophysical measures, individual response patterning, validity of the EPQ, over-generality of the extraversion dimension, stimulus conditions, and methodological problems, questionable pupillometric scoring procedures, and controls not exercised in previous studies were suggested as possible explanations. Despite the observation that the components of the pupillary light reflex exhibited characteristics consistent with previous descriptions, the light reflex, as an appropriate index of individual differences in corticoreticular reactivity was also questioned. It appears that the pupillary light reflex is independent of reticular activity as related to extraversion, at the light intensity levels employed in the present research. The question which must be considered is whether, given the possibility that specific autonomic system between-subject variability may be to some extent idiosyncratic, the pupillary light reflex, by itself, possibly is not an adequate index of level of activity in the corticoreticular system as it applies to individual differences in extraversion.

Several research implications were suggested. It would appear worthwhile to more thoroughly explore the relationship between the pupillary light reflex and other personality variables in conjunction with a more extensive battery of autonomic indices. In addition to utilizing varying response modalities, future research investigating the biological basis of extraversion should further explore the problem of individual response specificity by employing a more thorough range of stimulus conditions. Since no studies to date have attempted to relate the pupillary light reflex along with other autonomic indices to personality factors, and several studies have observed directional fractionation of the cardiac and pupillary responses independent of illumination, (Libby, Lacey, & Lacey, 1973), heart rate might offer a promising concomitant autonomic index. Related research in this area may help clarify the nature of individual perceptual differences.

One possibility would be to investigate the role of the pupillary light reflex paired with neutral, affective, and taboo words. The quantitative and pattern changes occurring in the pupillary components with stronger, more meaningful affective stimuli presented in temporal proximity with the light reflex~~,~~ might offer a promising avenue for research on individual differences. Since it is not clear that the dimensions of extraversion and neuroticism do not interact on the physiological level, future investigations might also include both variables.

Further refinements in pupillary measurement, such as employing time locked or out-of-phase measures, as well as appropriate transformations of the data may be necessary. The investigation of pupillary dynamics in conjunction with other personality dimensions also warrants consideration. The paucity of research employing the pupillary light reflex as an autonomic index attests to the need for further refinements. It seems clear that the pupil has begun to show potential as a valuable tool in psychophysiological research. If the pupil is to be "a new tool with which to probe the mind... and to establish personality differences" (Hess and Polt, 1965, p. 54), then it merits a more systematic experimental investigation. Finally, the use of a scoring procedure as was employed in the present research might contribute to the measurement of other psychophysiological measures since it was found to aid in economy of time and accuracy in the scoring of pupillographic data.

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IN APPENDIX A AND APPENDIX D,

LEAVES 185 to 188, 195 to 196

NOT MICROFILMED

185-188 Eysenck Personality Questionnaire

MAY BE OBTAINED FROM

Educational and Industrial Testing Service
Box 7234
San Diego, California 92107

195-196 Farnsworth-Munsell 100 Hue Test Scoring Diagram

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APPENDIX B

EPQ SCORES AND AGES FOR GROUPS OF INTROVERTED, MIDDLE, AND EXTRAVERTED SUBJECTS

APPENDIX B

EPQ SCORES FOR EXTRAVERSION (E), NEUROTICISM (N), PSYCHOTICISM (P), LIE SCALE (L), AND AGE FOR INTROVERTED GROUP

Subject	E	N	P	L	Age
1	7	6	1	1	19
2	6	8	2	1	23
3	6	9	1	10	20
4	1	11	2	0	27
5	6	8	3	1	38
6	7	7	3	3	31
7	8	16	3	5	28
8	4	11	6	8	23
9	2	9	6	2	22
10	6	10	2	10	20
11	4	9	2	8	28
12	5	8	6	3	19
13	5	12	2	9	19
14	7	10	4	8	21
15	6	5	8	6	22
16	8	2	7	3	20
17	3	8	3	2	22

APPENDIX B

EPQ SCORES FOR EXTRAVERSION (E), NEUROTICISM (N), PSYCHOTICISM (P), LIE SCALE (L), AND AGE FOR MIDDLE GROUP

Subject	E	N	P	L	Age
1	14	8	0	11	18
2	16	8	2	4	20
3	13	12	0	12	26
4	17	9	1	9	20
5	15	8	5	1	22
6	12	3	2	8	26
7	13	16	4	2	20
8	17	1	2	8	21
9	11	5	5	8	20
10	11	15	4	4	25
11	14	4	2	5	19
12	11	9	4	7	19
13	10	12	2	5	19
14	15	10	2	7	20
15	17	7	5	1	18
16	16	13	4	5	19
17	12	7	0	6	19

APPENDIX B

EPQ SCORES FOR EXTRAVERSION (E), NEUROTICISM (N), PSYCHOTICISM (P), LIE SCALE (L), AND AGE FOR EXTRAVERTED GROUP

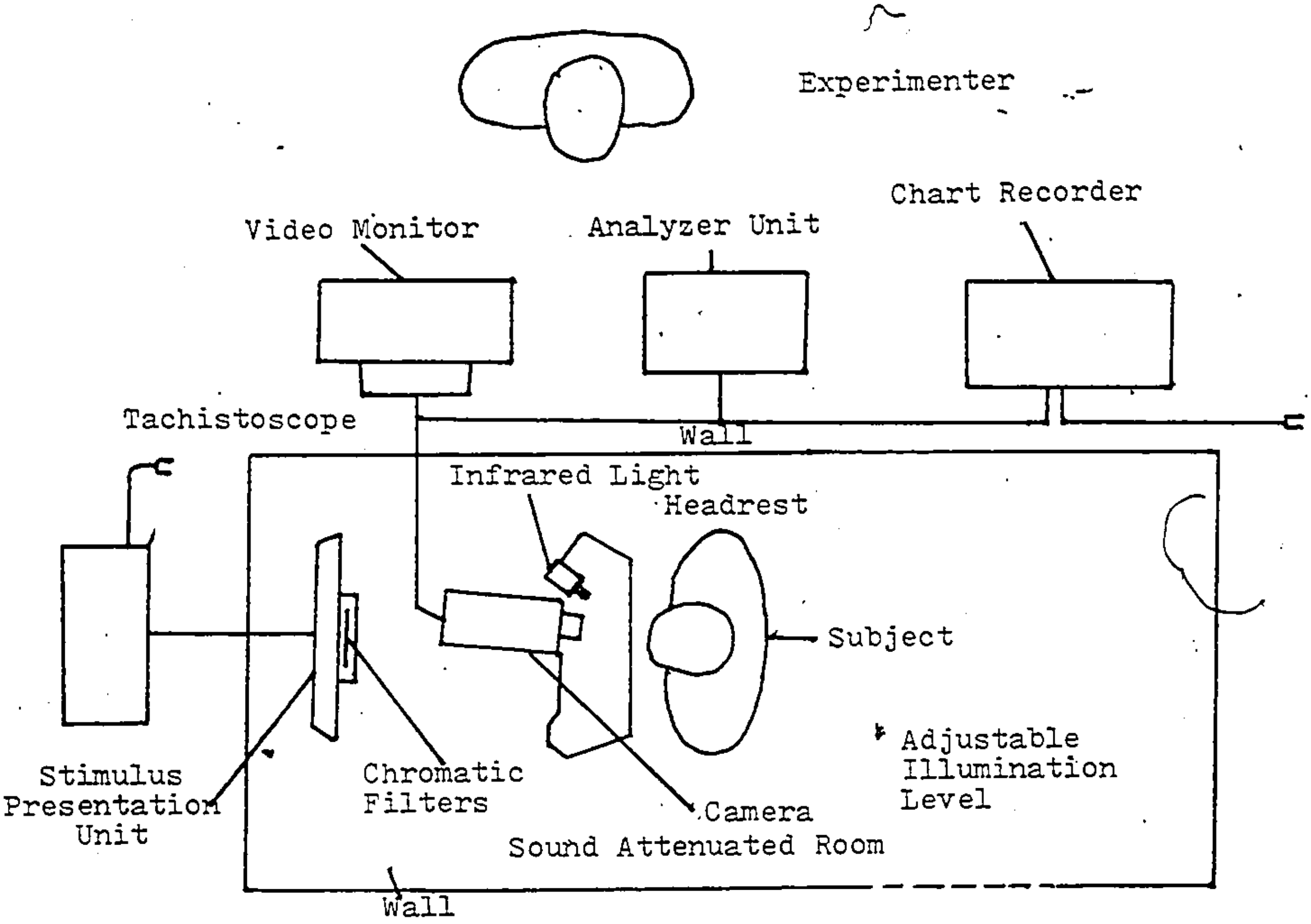
Subject	E	N	P	L	Age
1	18	8	2	8	19
2	20	8	5	1	20
3	20	7	2	1	19
4	18	8	7	7	20
5	19	4	3	9	21
6	20	1	6	3	23
7	20	13	2	3	20
8	20	6	5	3	20
9	20	10	2	8	22
10	18	5	6	3	19
11	21	4	8	0	19
12	18	2	1	6	19
13	20	11	1	9	21
14	19	14	2	4	20
15	20	12	6	1	20
16	18	15	2	5	18
17	19	12	5	5	24

APPENDIX C

DIAGRAMMATIC ILLUSTRATION OF PUPILLOMETER SYSTEM

APPENDIX C

Diagrammatic Illustration of Polymetric Pupillometer System, Model V-116R-IR, Employed to Present Chromatic Light Stimuli and Record Pupillary Measures



APPENDIX E

FARNSWORTH-MUNSELL 100 HUE TEST ERROR SCORES FOR INTROVERTED, MIDDLE, AND EXTRAVERTED SUBJECTS

APPENDIX E

Farnsworth-Munsell 100 Hue Test Error Scores for the Red and Blue Hues

Subject	Error Score					
	Introvert Group		Middle Group		Extravert Group	
	red	blue	red	blue	red	blue
1	8	10	10	8	10	18
2	7	8	15	34	0	1
3	10	8	10	11	4	0
4	8	6	0	4	10	10
5	23	18	0	0	0	2
6	11	6	0	4	2	12
7	0	12	8	1	18	12
8	2	11	10	9	7	17
9	6	6	20	6	12	9
10	3	0	7	20	2	18
11	14	12	6	12	13	26
12	9	17	0	0	10	22
13	5	17	17	2	2	8
14	24	12	4	8	29	8
15	1	8	10	0	0	2
16	4	0	7	6	1	0
17	0	2	0	0	9	11

APPENDIX F

PRINCIPAL STATISTICS FOR PUPILLARY RESPONSE MEASURES

APPENDIX F

Legend for Mean Values of Pupillary Light Reflex Measures for Extraversion Groups During the High- and Low-Intensity and Red and Blue Conditions to the 15 Trials:

Hue

1 - Blue

2 - Red

Intensity

1 - Low

2 - High

APPENDIX F

Mean Magnitude of Maximum Constriction

Hue	Intensity	Trials	Introverts	Middle	Extraverts	Average
1	1	1	4.07046	[illegible]	4.14[illegible]	4.[illegible]
1	1	2	3.57170	[illegible]	3.73[illegible]	[illegible]
1	1	3	3.54857	3.52717	3.66352	3.5[illegible]
1	1	4	3.61143	3.47694	3.61464	3.5[illegible]
1	1	5	3.43805	3.52952	3.55776	3.52[illegible]11
1	1	6	3.48629	3.45323	3.57752	3.50[illegible]
1	1	7	3.48552	3.55576	3.54054	3.5[illegible]
1	1	8	3.36647	3.56564	3.51746	3.4[illegible]
1	1	9	3.43588	3.39729	3.61382	3.44[illegible]
1	1	10	3.27505	3.55023	3.47570	3.43[illegible]
1	1	11	3.39176	3.56605	3.46482	3.40[illegible]
1	1	12	3.33446	3.39494	3.49423	3.42797
1	1	13	3.44434	3.45629	3.46111	3.45[illegible]
1	1	14	3.51805	3.45217	3.36035	3.443[illegible]
1	1	15	3.39905	3.51429	3.45640	3.46[illegible]
2	1	1	3.54805	3.56905	3.36745	3.45[illegible]
2	1	2	3.21482	3.19341	3.11770	3.17[illegible]
2	1	3	3.19664	3.12935	2.98211	3.08[illegible]
2	1	4	3.03064	3.14835	2.93163	3.03[illegible]
2	1	5	2.78923	3.12706	2.73864	2.88[illegible]
2	1	6	2.93270	2.80817	2.73834	2.84[illegible]
2	1	7	2.81868	2.93441	2.87770	2.87[illegible]
2	1	8	2.83499	2.88676	2.77011	2.83[illegible]
2	1	9	2.92793	2.97711	2.65559	2.8[illegible]
2	1	10	2.86329	2.84117	2.80776	2.87[illegible]
2	1	11	2.96288	2.87464	2.68329	2.77[illegible]
2	1	12	2.86529	2.85817	2.70639	2.8[illegible]
2	1	13	2.90699	2.93617	2.70753	2.8[illegible]
2	1	14	2.87994	2.76395	2.73417	2.79[illegible]
2	1	15	2.82198	2.64257	2.64294	2.70944
1	2	1	4.22955	4.11364	4.30355	4.21760
1	2	2	3.88993	3.97349	3.76408	3.877[illegible]
1	2	3	3.84535	3.69446	3.80570	3.78[illegible]
1	2	4	3.74105	3.56929	3.70985	3.70597
1	2	5	3.73599	3.78854	3.71764	3.74842
1	2	6	3.66335	3.76241	3.65099	3.69225
1	2	7	3.64611	3.57423	3.57033	3.59[illegible]
1	2	8	3.62455	3.77123	3.57294	3.65[illegible]1
1	2	9	3.53164	3.64834	3.49532	3.55537
1	2	10	3.55841	3.63276	3.56440	3.591[illegible]
1	2	11	3.53611	3.63405	3.54070	3.59[illegible]
1	2	12	3.61541	3.67270	3.52717	3.60[illegible]
1	2	13	3.50335	3.70955	3.47129	3.56[illegible]7
1	2	14	3.56523	3.57697	3.41217	3.51[illegible]
1	2	15	3.55999	3.57870	3.40911	3.51[illegible]
2	2	1	3.84088	3.57411	3.64223	3.55[illegible]
2	2	2	3.36417	3.59699	3.36145	3.43[illegible]
2	2	3	3.37011	3.46740	3.31543	3.38[illegible]
2	2	4	3.32335	3.21111	3.23142	3.25[illegible]
2	2	5	3.20464	3.26440	3.04388	3.18704
2	2	6	3.16882	3.34032	3.11758	3.20[illegible]7
2	2	7	3.12417	3.43170	3.10717	3.22101
2	2	8	3.11023	3.28035	3.24905	3.21391
2	2	9	3.17105	3.15782	3.12111	3.14[illegible]
2	2	10	3.11294	3.26217	3.17623	3.14311
2	2	11	3.13741	3.09235	3.15970	3.13[illegible]
2	2	12	3.16858	3.22392	3.09666	3.16[illegible]
2	2	13	3.12517	3.25364	3.07917	3.18[illegible]
2	2	14	3.07356	3.56047	3.13879	3.19[illegible]
2	2	15	3.08970	3.41782	3.124[illegible]	3.17[illegible]
Average			3.34770	[illegible]	[illegible]	3.34[illegible]

APPENDIX F

Mean Latency to Maximum Constriction

Hue	Intensity	Trials	Introverts	Middle	Extraverts	Average
1	1	1	3.34575	[illegible]	[illegible]	[illegible]
1	1	2	2.62829	2.73140	2.77570	[illegible]
1	1	3	2.66623	2.50835	2.50470	[illegible]
1	1	4	2.61017	2.46164	2.94804	[illegible]
1	1	5	2.57734	2.30799	2.48594	2.40719
1	1	6	2.64899	2.73264	2.67070	2.68011
1	1	7	2.56632	2.39411	2.69282	2.51752
1	1	8	2.60058	2.56164	2.46905	2.54419
1	1	9	2.44495	2.44470	2.60658	2.49084
1	1	10	2.60735	2.70905	2.70982	2.60540
1	1	11	2.48711	2.51841	2.72211	2.57488
1	1	12	2.27447	2.35682	2.84593	2.39240
1	1	13	2.45038	2.72711	2.36533	2.38039
1	1	14	2.84017	2.43158	2.40993	2.54056
1	1	15	2.61258	2.51464	2.62117	2.58250
2	1	1	2.92923	2.84170	2.96176	2.91089
2	1	2	2.62435	2.53617	2.93495	2.69017
2	1	3	2.71705	2.59117	2.47417	2.59417
2	1	4	2.65817	2.52164	2.72170	2.60234
2	1	5	2.32411	2.29511	2.29475	2.30466
2	1	6	2.01632	2.40456	2.11547	2.34629
2	1	7	1.95670	2.27917	2.51070	2.25866
2	1	8	1.89352	2.35185	2.08235	2.10592
2	1	9	2.62882	2.31958	2.20876	2.35539
2	1	10	2.34088	2.19488	2.14223	2.29266
2	1	11	2.38682	1.92546	2.01117	2.10892
2	1	12	2.23794	2.50052	2.15317	2.29721
2	1	13	2.29029	2.47570	2.47641	2.41413
2	1	14	2.61764	2.33241	2.23964	2.39058
2	1	15	2.15617	2.17641	1.95335	2.59864
1	2	1	3.29535	3.11864	3.30235	2.23911
1	2	2	3.01640	2.76279	3.05688	2.94544
1	2	3	2.67347	2.33276	2.72782	2.71135
1	2	4	2.79958	2.72458	2.96111	2.82842
1	2	5	2.69317	2.49152	2.75711	2.64727
1	2	6	2.63582	2.60652	2.80764	2.70399
1	2	7	2.26517	2.72994	2.61423	2.53511
1	2	8	2.83593	2.73405	2.92585	2.79862
1	2	9	2.48200	2.84617	2.57705	2.83507
1	2	10	2.68276	2.88864	2.84147	2.75429
1	2	11	2.40670	2.53676	2.73164	2.55536
1	2	12	2.31858	2.48455	2.80176	2.55490
1	2	13	2.83752	2.67623	2.70276	2.75894
1	2	14	2.85546	2.51493	2.61182	2.72739
1	2	15	2.82770	2.47664	2.58305	2.72913
2	2	1	3.14146	3.14746	3.06842	3.12531
2	2	2	2.77064	2.97311	2.85123	2.87409
2	2	3	2.72946	2.74105	3.08594	2.88215
2	2	4	2.72005	2.47056	2.51694	2.56919
2	2	5	2.72935	2.79641	2.70629	2.76201
2	2	6	2.58858	2.51376	2.77441	2.67538
2	2	7	2.76158	2.76258	2.78235	2.76553
2	2	8	2.36411	2.52440	2.51035	2.56871
2	2	9	2.54982	2.59541	2.81240	2.65256
2	2	10	2.55529	2.77652	2.64823	2.65662
2	2	11	2.52476	2.24717	2.56270	2.45194
2	2	12	2.62452	2.31129	2.54558	2.56048
2	2	13	2.65546	2.34341	2.50999	2.51805
2	2	14	2.69842	2.47364	2.55040	2.57629
2	2	15	2.31257	2.68192	2.30799	2.46411
	Average		2.59500	2.55446	2.64841	2.59665

APPENDIX F

Mean Rate of Constriction

Hue	Intensity	Trials	Introverts	Middle	Extraverts	Average
1	1	1	1.36433	[illegible]	[illegible]	[illegible]
1	1	2	1.[illegible]3712	[illegible]	[illegible]	[illegible]
1	1	3	1.37735	[illegible]	[illegible]	[illegible]
1	1	4	1.41141	1.50447	[illegible]	[illegible]
1	1	5	1.43353	1.49963	1.47065	[illegible]
1	1	6	1.41364	1.71394	[illegible]	[illegible]
1	1	7	1.44164	1.54641	1.42170	[illegible]
1	1	8	1.36053	1.47311	1.47464	[illegible]
1	1	9	1.51023	1.47468	1.45194	[illegible]
1	1	10	1.48659	1.34047	1.33424	[illegible]
1	1	11	1.44429	1.41753	1.36305	1.41013
1	1	12	1.54611	1.57870	1.42565	1.51611
1	1	13	1.48724	1.59449	1.63927	1.57013
1	1	14	1.28188	1.51594	1.50794	1.43025
1	1	15	1.37405	1.30683	1.43299	1.43443
2	1	1	1.24606	1.27685	1.15900	1.22713
2	1	2	1.25200	1.33459	1.10545	1.24032
2	1	3	1.27947	1.26900	[illegible]	1.26723
2	1	4	1.35664	1.39074	[illegible]	1.31712
2	1	5	1.35532	1.55295	1.24605	1.40276
2	1	6	1.29411	1.34706	1.40217	1.36544
2	1	7	1.37641	1.46447	1.20623	1.41572
2	1	8	1.70811	1.47747	1.46176	1.54111
2	1	9	1.35212	1.46329	1.35106	1.54442
2	1	10	1.37323	1.49678	[illegible]	[illegible]
2	1	11	1.42629	1.69170	[illegible]	[illegible]
2	1	12	1.50106	1.23647	1.35783	[illegible]
2	1	13	1.41882	1.40562	1.19494	[illegible]
2	1	14	1.20670	1.34664	1.40664	[illegible]
2	1	15	1.56711	1.42600	1.47394	1.44901
1	2	1	1.32723	1.32529	1.34347	1.33200
1	2	2	1.34388	1.47417	1.25088	[illegible]
1	2	3	1.42982	1.47094	1.44535	1.44470
1	2	4	1.37935	1.38270	1.32176	1.36127
1	2	5	1.45482	1.59641	1.42599	1.49240
1	2	6	1.44976	1.56153	1.33952	1.45037
1	2	7	1.71058	1.45094	1.41552	1.51711
1	2	8	1.33411	1.43136	1.29870	1.35372
1	2	9	1.51541	1.31264	1.42970	1.41935
1	2	10	1.36994	1.52005	1.30335	1.39752
1	2	11	1.58088	1.53611	1.49744	1.53821
1	2	12	1.75053	1.66747	1.29176	1.56325
1	2	13	1.28223	1.46217	1.30417	1.34952
1	2	14	1.29529	1.64800	1.46744	1.47141
1	2	15	1.31176	1.62333	1.22200	1.38566
2	2	1	1.24417	1.34709	1.29305	1.26317
2	2	2	1.24806	1.23142	1.21368	1.23117
2	2	3	1.31429	1.30658	1.13723	1.25137
2	2	4	1.27923	1.34447	1.33017	1.31795
2	2	5	1.24482	1.21062	1.16000	1.20521
2	2	6	1.27170	1.40970	[illegible]	1.29144
2	2	7	1.17082	1.27935	[illegible]	1.21425
2	2	8	1.50423	1.47276	1.22342	1.40027
2	2	9	1.36094	1.29764	1.20776	1.26378
2	2	10	1.30341	1.20741	1.27400	1.26160
2	2	11	1.34782	1.44329	1.39141	1.39417
2	2	12	1.28494	1.47529	1.32470	1.36164
2	2	13	1.33829	1.55917	1.29888	1.39576
2	2	14	1.21747	1.48088	[illegible]	1.33462
2	2	15	1.45641	[illegible]	[illegible]	[illegible]
Average			1.38672	1.42644	1.34158	[illegible]

APPENDIX F

Mean Magnitude of Redilation

Hue	Intensity	Trials	Introverts	Middle	Extraverts	Average
1	1	1	[illegible]	[illegible]	3.65754	[illegible]
1	1	2	3.45176	[illegible]	3.37864	[illegible]
1	1	3	3.51499	[illegible]	3.63240	[illegible]
1	1	4	3.38488	[illegible]	3.26693	3.32544
1	1	5	3.33435	3.29105	3.50355	3.37293
1	1	6	3.41398	3.30198	3.40599	3.37362
1	1	7	3.26646	3.30970	3.53476	3.43697
1	1	8	3.48723	3.39846	3.45117	3.44562
1	1	9	3.29517	3.39594	3.37546	3.35576
1	1	10	3.35523	3.38739	3.37094	3.37140
1	1	11	3.27152	3.25794	3.40722	3.31576
1	1	12	3.47792	3.35952	3.42805	3.42180
1	1	13	3.34170	3.28574	3.39094	3.33952
1	1	14	3.39029	3.33623	3.26717	3.32923
1	1	15	3.16788	3.46155	3.36335	3.32770
2	1	1	3.12270	3.02782	2.88499	3.01184
2	1	2	2.97794	3.08435	2.86082	2.97437
2	1	3	3.05105	2.85582	2.76417	2.89035
2	1	4	2.79947	3.06570	2.73576	2.87364
2	1	5	2.82335	2.76957	2.55123	2.72470
2	1	6	2.79046	2.69670	2.47499	2.65405
2	1	7	2.77976	2.83017	2.65147	2.75380
2	1	8	2.73670	2.94058	2.66611	2.78123
2	1	9	2.68317	2.78564	2.45405	2.65095
2	1	10	2.57776	2.58176	2.63055	2.59670
2	1	11	2.79576	2.57911	2.47865	2.61784
2	1	12	2.85417	2.64205	2.47546	2.65723
2	1	13	2.99023	2.66552	2.51099	2.72225
2	1	14	2.64064	2.54929	2.50399	2.56464
2	1	15	2.75664	2.55176	2.43323	2.58221
1	2	1	3.49052	3.51252	3.66246	3.55184
1	2	2	3.64558	3.67229	3.53459	3.61749
1	2	3	3.75229	3.63764	3.66470	3.68487
1	2	4	3.67405	3.55123	3.74782	3.65770
1	2	5	3.63246	3.39435	3.63135	3.55605
1	2	6	3.51794	3.55452	3.60056	3.5910[illegible]
1	2	7	3.60405	3.65887	3.50970	3.59087
1	2	8	3.59576	3.58782	3.56623	3.58327
1	2	9	3.32005	3.41482	3.50370	3.41286
1	2	10	3.59841	3.57094	3.54064	3.56999
1	2	11	3.64029	3.63499	3.46947	3.58158
1	2	12	3.44946	3.54341	3.35029	3.44772
1	2	13	3.47593	3.53676	3.46470	3.49913
1	2	14	3.46023	3.36764	3.31176	3.37987
1	2	15	3.57476	3.46052	3.39276	3.47601
2	2	1	3.32547	3.37588	3.29817	3.33317
2	2	2	3.25511	3.35523	3.15252	3.25429
2	2	3	3.23358	3.20629	3.09052	3.17680
2	2	4	3.11194	3.17229	2.92929	3.07117
2	2	5	3.13752	3.12440	2.95305	3.07166
2	2	6	3.07599	3.16035	2.93034	3.05556
2	2	7	3.14929	3.28358	2.98558	3.13948
2	2	8	3.02476	2.99399	3.04746	3.02207
2	2	9	3.00211	3.14623	3.00888	3.05240
2	2	10	3.10664	3.17335	3.05394	3.11131
2	2	11	3.05505	3.00476	2.96953	3.00978
2	2	12	2.91658	3.25152	3.00334	3.05715
2	2	13	3.07670	3.12541	2.97170	3.05793
2	2	14	3.02741	3.26070	3.02435	3.10415
2	2	15	2.94638	3.09968	2.71276	2.91631
	Average		3.22569	3.222[illegible]9	3.14603	3.19640

APPENDIX F

Mean Latency to Maximum Redilation

Hue	Intensity	Trials	Introverts	Middle	Extraverts	Average
1	1	1	[illegible]	[illegible]	[illegible]	[illegible]
1	1	2	9.39152	[illegible]	[illegible]	[illegible]
1	1	3	10.23035	[illegible]	[illegible]	[illegible]
1	1	4	[illegible]	9.34157	[illegible]	[illegible]
1	1	5	10.02505	9.86749	9.75446	[illegible]
1	1	6	9.94364	9.36152	[illegible]	[illegible]
1	1	7	9.85755	9.93205	9.67340	[illegible]
1	1	8	10.20529	10.05840	[illegible]	[illegible]
1	1	9	9.76552	9.74711	[illegible]	9.81121
1	1	10	10.03134	10.29011	10.24043	[illegible]
1	1	11	9.43455	9.43943	9.40954	[illegible]
1	1	12	9.63854	10.35217	9.97376	10.00574
1	1	13	10.10299	9.94659	9.92733	[illegible]
1	1	14	10.00041	9.55446	9.47070	9.78513
1	1	15	9.95734	9.25311	9.66570	9.65552
2	1	1	9.71194	9.87232	9.44775	[illegible]
2	1	2	9.92346	9.67123	9.66917	9.76176
2	1	3	10.10199	9.37717	10.11044	9.86332
2	1	4	9.25929	10.06038	9.44246	9.75405
2	1	5	10.09264	9.03957	9.62889	9.58700
2	1	6	10.05605	9.41067	9.52564	9.66413
2	1	7	9.92405	10.02235	9.43511	[illegible]
2	1	8	10.06840	9.74311	9.95204	9.93151
2	1	9	9.87652	9.56923	9.47072	9.63430
2	1	10	10.04534	9.40517	9.62982	[illegible]
2	1	11	9.83340	10.22511	10.12004	10.06066
2	1	12	9.56358	9.40305	9.45699	9.64115
2	1	13	10.06299	9.26352	10.12655	9.31774
2	1	14	9.74305	9.88711	10.05076	9.56094
2	1	15	9.96952	9.57017	9.96129	9.86352
1	2	1	10.03599	10.14805	10.11964	10.09034
1	2	2	9.82023	10.32029	9.57011	9.91016
1	2	3	9.94464	10.27040	9.66241	9.95910
1	2	4	10.51511	10.31425	10.06123	10.29041
1	2	5	10.30682	9.93840	9.94655	10.09357
1	2	6	10.15234	10.04020	10.06329	10.08592
1	2	7	10.15299	9.97952	10.07593	10.06919
1	2	8	10.08364	9.78211	9.99640	9.95359
1	2	9	10.38152	9.76370	10.27752	10.14094
1	2	10	10.33423	9.76564	9.72370	9.94146
1	2	11	10.07993	10.06840	9.91576	10.02129
1	2	12	9.48946	10.21740	9.96435	9.89074
1	2	13	9.86747	9.37587	9.33499	9.52604
1	2	14	9.75258	9.73899	10.06848	9.85276
1	2	15	9.85841	9.89735	10.05929	[illegible]
2	2	1	9.85534	9.95917	9.65929	[illegible]
2	2	2	10.09387	9.55193	10.25181	[illegible]
2	2	3	9.86893	9.85270	10.02576	9.91573
2	2	4	9.74623	9.92046	9.49036	9.72132
2	2	5	9.74852	9.91335	9.63317	9.76435
2	2	6	9.25011	9.90052	10.00423	9.71529
2	2	7	9.62593	9.86954	10.16993	9.88845
2	2	8	10.20758	9.53456	9.51423	9.75213
2	2	9	9.78481	10.23746	10.40911	10.14346
2	2	10	9.49564	9.38540	9.69623	9.52576
2	2	11	9.70870	9.89406	10.00952	9.89421
2	2	12	10.25440	10.32322	9.83962	10.07444
2	2	13	10.11040	10.02305	10.04327	10.05897
2	2	14	10.04976	9.84033	9.79323	9.89410
2	2	15	10.43052	9.32445	9.91470	[illegible]
	Average		9.94222	[illegible]	9.86903	[illegible]

APPENDIX F

Mean Rate of Redilation

Hue	Intensity	Trials	Introverts	Middle	Extraverts	Average
1	1	1	0.63576	[illegible]	[illegible]	[illegible]
1	1	2	1.04883	[illegible]	[illegible]	[illegible]
1	1	3	0.57506	[illegible]	0.66470	[illegible]
1	1	4	0.55476	0.59429	0.60759	[illegible]
1	1	5	0.53035	0.58906	0.64447	[illegible]
1	1	6	0.59418	0.59541	0.60606	0.59965
1	1	7	0.56918	0.60642	0.64541	0.60713
1	1	8	0.57341	0.59500	0.61959	0.59600
1	1	9	0.55835	0.58018	0.64065	0.59305
1	1	10	0.56506	0.55459	0.55212	0.55728
1	1	11	0.55329	0.61484	0.61518	0.59445
1	1	12	0.56994	0.58844	0.63618	0.59635
1	1	13	0.52706	0.74265	0.59682	0.62217
1	1	14	0.51794	0.56441	0.56941	0.55725
1	1	15	0.54132	0.61376	0.57706	0.57758
2	1	1	0.57541	0.62541	0.57476	0.59166
2	1	2	0.51418	0.55965	0.51965	0.53115
2	1	3	0.45294	0.55300	0.50735	0.50443
2	1	4	0.49200	0.56192	0.45318	0.49900
2	1	5	0.41294	0.50341	0.44018	0.45217
2	1	6	0.48941	0.45335	0.43059	0.45779
2	1	7	0.47706	0.51182	0.41700	0.46852
2	1	8	0.46706	0.53994	0.44923	0.48541
2	1	9	0.45323	0.49053	0.44394	0.46257
2	1	10	0.45412	0.46573	0.44935	0.45623
2	1	11	0.47418	0.39959	0.39794	0.42390
2	1	12	0.49476	0.43529	0.40735	0.44590
2	1	13	0.45235	0.48212	0.40823	0.44757
2	1	14	0.43353	0.43371	0.43053	0.43259
2	1	15	0.42653	0.44559	0.42012	0.43074
1	2	1	0.64947	0.52712	0.59329	0.62329
1	2	2	0.63771	0.66992	0.63012	0.64598
1	2	3	0.63247	0.66129	0.63171	0.64182
1	2	4	0.59623	0.58848	0.61729	0.60050
1	2	5	0.82488	0.59706	0.71506	0.71233
1	2	6	0.64447	0.64312	0.61076	0.63278
1	2	7	0.58029	0.63559	0.57598	0.59725
1	2	8	0.58906	0.62529	0.64735	0.62056
1	2	9	0.53806	0.58562	0.57412	0.58600
1	2	10	0.60406	0.62059	0.64671	0.62378
1	2	11	0.55598	0.64629	0.56971	0.59129
1	2	12	0.56871	0.56241	0.60759	0.57956
1	2	13	0.54506	0.64847	0.59365	0.59572
1	2	14	0.57712	0.56600	0.54206	0.56172
1	2	15	0.60900	0.69794	0.55518	0.59070
2	2	1	0.59798	0.72200	0.57453	0.63147
2	2	2	0.59194	0.64335	0.54076	0.59202
2	2	3	0.53823	0.54429	0.55771	0.54674
2	2	4	0.53247	1.00000	0.49765	0.67670
2	2	5	0.52688	0.52271	0.46512	0.50490
2	2	6	0.51418	0.53682	0.48194	0.51164
2	2	7	0.47559	0.58271	0.48575	0.51458
2	2	8	0.46223	0.51988	0.49547	0.49253
2	2	9	0.46506	0.50718	0.48965	0.48729
2	2	10	0.50259	0.58023	0.50676	0.52986
2	2	11	0.48294	0.50488	0.50276	0.49636
2	2	12	0.47576	0.50259	0.49253	0.49029
2	2	13	0.46900	0.57335	0.45676	0.49970
2	2	14	0.46241	0.58294	0.49253	0.51252
2	2	15	0.48829	0.57159	0.52282	0.52757
Average			0.54514	[illegible]	0.54617	0.55538

APPENDIX F

Mean Maximum Redilated Pupil Size

Hue	Intensity	Trials	Introverts	Middle	Extraverts	Average
1	1	1	6.72084	[illegible]	[illegible]	[illegible]
1	1	2	6.56029	[illegible]	[illegible]	[illegible]
1	1	3	6.67382	[illegible]	[illegible]	[illegible]
1	1	4	6.55511	6.60911	[illegible]	6.51547
1	1	5	6.48704	6.57217	[illegible]	[illegible]
1	1	6	6.48005	[illegible]	[illegible]	[illegible]
1	1	7	6.37352	6.60133	[illegible]	[illegible]
1	1	8	6.44793	6.50746	6.33670	[illegible]
1	1	9	6.31535	6.56547	6.20047	[illegible]
1	1	10	6.45170	6.45040	6.21470	[illegible]
1	1	11	6.40776	6.51411	6.20748	[illegible]
1	1	12	6.51005	6.54376	6.24364	6.43313
1	1	13	6.50493	6.53817	6.19117	6.43041
1	1	14	6.48052	6.53105	6.22017	[illegible]
1	1	15	6.39535	6.53505	6.15392	[illegible]
2	1	1	6.97370	7.02137	6.75170	6.81572
2	1	2	6.85182	6.95555	6.57259	6.79529
2	1	3	6.79552	6.82729	[illegible]	6.71406
2	1	4	6.67076	6.84752	6.50464	6.67548
2	1	5	6.68227	6.71375	6.46447	6.62014
2	1	6	6.54740	6.65055	6.43008	6.54544
2	1	7	6.57946	6.53799	6.35411	[illegible]
2	1	8	6.69270	6.76674	6.40938	6.61970
2	1	9	6.61552	6.67241	[illegible]	[illegible]
2	1	10	6.55752	6.58893	[illegible]	6.49470
2	1	11	6.50640	6.64029	6.30704	6.50042
2	1	12	6.54376	6.56905	[illegible]	6.47040
2	1	13	6.61623	6.49940	6.32141	6.47955
2	1	14	6.51929	6.48011	6.31048	6.43960
2	1	15	6.51970	6.52652	6.30070	6.49045
1	2	1	6.65805	6.56935	6.54117	6.70223
1	2	2	6.62611	6.66041	6.47740	[illegible]
1	2	3	6.56458	6.59342	6.45246	6.50330
1	2	4	6.48067	6.59039	6.33117	6.46755
1	2	5	6.41638	6.58608	6.24276	6.41547
1	2	6	6.38540	6.46629	6.20429	6.35137
1	2	7	6.40593	6.55740	6.15070	[illegible]
1	2	8	6.42148	6.45466	[illegible]	6.35523
1	2	9	6.34458	6.45732	[illegible]	6.32746
1	2	10	6.34270	6.46976	[illegible]	6.32125
1	2	11	6.45329	6.45473	[illegible]	6.34057
1	2	12	6.33252	6.49723	6.07070	6.30161
1	2	13	6.34527	6.47459	[illegible]	6.30540
1	2	14	6.32629	6.43629	6.05011	6.27087
1	2	15	6.38005	6.34394	6.06473	6.26957
2	2	1	6.72776	6.32911	[illegible]	6.76238
2	2	2	6.67952	6.77023	6.50245	6.65072
2	2	3	6.62005	6.67199	6.44470	6.57535
2	2	4	6.56440	6.67958	6.37052	6.53812
2	2	5	6.49032	6.55292	[illegible]	6.50551
2	2	6	6.44105	6.59223	6.40082	6.47402
2	2	7	6.46099	6.44682	6.37534	[illegible]
2	2	8	6.42505	6.54066	6.29962	[illegible]
2	2	9	6.37170	6.42529	6.48446	7.42709
2	2	10	6.42517	6.37405	[illegible]	6.37512
2	2	11	6.42999	6.41006	6.25241	6.36413
2	2	12	6.32440	6.51535	6.30040	6.38003
2	2	13	6.41105	6.50604	6.27220	6.39004
2	2	14	6.37099	6.58317	6.26170	6.35559
2	2	15	6.33305	6.42705	[illegible]	[illegible]
Average			6.50899	6.59581	6.37411	6.49284

APPENDIX F

Frequency of V-Waves During the High- and Low-Intensity and Red and Blue Hue Conditions

Subject		HR	HB	LR	LB
Introverts	1	04	03	07	01
	2	02	01	02	05
	3	00	02	05	01
	4	00	00	01	01
	5	00	02	04	01
	6	05	01	02	02
	7	04	04	01	00
	8	01	00	03	01
	9	00	01	00	03
	10	01	01	01	03
	11	02	02	05	05
	12	05	02	06	06
	13	00	03	00	00
	14	00	00	02	03
	15	02	02	02	04
	16	01	00	02	02
	17	06	00	04	01

Subject		HR	HB	LR	LB
Extraverts	35	00	00	07	01
	36	03	04	02	03
	37	03	00	02	02
	38	03	05	03	07
	39	04	04	03	01
	40	01	03	06	02
	41	04	01	09	04
	42	03	03	01	02
	43	03	02	01	00
	44	04	00	05	01
	45	05	03	03	00
	46	03	01	03	00
	47	04	01	05	00
	48	04	01	03	02
	49	01	00	00	00
	50	03	00	01	00
	51	07	02	04	00

Subject		HR	HB	LR	LB
Middle	18	00	00	00	04
	19	04	02	03	01
	20	02	01	06	05
	21	00	00	00	02
	22	07	14	04	02
	23	04	00	05	06
	24	00	00	02	00
	25	05	01	02	04
	26	01	07	04	00
	27	00	04	03	02
	28	01	00	02	01
	29	03	01	02	01
	30	00	00	05	02
	31	00	01	02	01
	32	02	00	00	01
	33	04	00	06	00
	34	02	01	01	01

Legend:

Intensity

H - High
L - Low

Hue

R - Red
B - Blue

APPENDIX F

Principal Statistics for Frequency of V-Waves

Group	Intensity	Hue	M	SD
Introvert	Low	Red	2.76	2.07
		Blue	2.29	1.82
	High	Red	1.94	2.07
		Blue	1.41	1.22
Middle	Low	Red	2.76	1.99
		Blue	1.94	1.78
	High	Red	2.06	2.13
		Blue	1.88	3.62
Extravert	Low	Red	3.41	2.37
		Blue	1.47	1.87
	High	Red	2.41	1.60
		Blue	1.71	1.64

APPENDIX F

Frequency of W-Waves During the High- and Low-Intensity and Red and Blue Hue Conditions

Subject		HR	HB	LR	LB
Introverts	1	11	06	10	09
	2	11	07	07	09
	3	18	11	18	15
	4	07	01	09	08
	5	09	08	09	08
	6	09	10	14	12
	7	05	02	07	06
	8	11	03	13	04
	9	12	03	13	01
	10	08	06	04	08
	11	08	01	07	08
	12	06	02	05	06
	13	09	09	13	10
	14	16	10	13	11
	15	07	10	12	09
	16	09	14	06	12
	17	12	06	13	09

Subject		HR	HB	LR	LB
Extraverts	35	08	05	08	10
	36	12	05	15	06
	37	10	02	11	08
	38	08	07	12	06
	39	04	04	09	08
	40	14	07	16	07
	41	13	09	15	09
	42	08	10	10	08
	43	05	12	13	09
	44	14	08	15	12
	45	14	05	12	06
	46	16	11	18	13
	47	13	09	08	11
	48	04	00	07	04
	49	02	00	06	01
	50	04	01	10	04
	51	13	09	15	16

Middle	18	07	04	07	06
	19	11	02	14	05
	20	07	07	06	07
	21	01	00	00	00
	22	03	01	09	04
	23	10	06	14	07
	24	02	00	02	02
	25	15	04	11	07
	26	16	07	11	10
	27	11	10	13	14
	28	17	04	10	04
	29	12	10	13	07
	30	11	15	11	10
	31	11	12	15	09
	32	07	05	10	01
	33	04	06	08	02
	34	08	10	16	10

APPENDIX F

Principal Statistics for Frequency of W-Waves

Group	Intensity	Hue	*M*	*SD*
Introvert	Low	Red	10.17	3.83
		Blue	8.53	3.22
	High	Red	9.88	3.37
		Blue	6.41	3.94
Middle	Low	Red	10.00	4.39
		Blue	6.17	3.76
	High	Red	9.00	4.76
		Blue	6.06	4.28
Extravert	Low	Red	11.76	3.53
		Blue	8.12	3.66
	High	Red	9.53	4.47
		Blue	8.12	3.79

APPENDIX F

Trials-to-Criterion-Fatigue During the High- and Low-Intensity and Red and Blue Hue Conditions

Subject		HR	HB	LR	LB
Introverts	1	01	01	01	04
	2	02	07	01	08
	3	03	02	02	04
	4	11	00	00	13
	5	02	01	01	02
	6	02	03	01	02
	7	01	00	02	05
	8	01	00	02	01
	9	02	01	03	02
	10	03	01	01	01
	11	06	09	01	05
	12	02	02	01	01
	13	01	01	01	02
	14	02	02	01	02
	15	02	01	03	10
	16	01	03	01	13
	17	02	01	01	01
Extraverts	35	02	03	01	03
	36	01	02	02	01
	37	01	02	01	02
	38	07	07	05	03
	39	01	03	04	04
	40	02	03	01	03
	41	03	04	04	01
	42	02	05	01	05
	43	01	05	03	02
	44	04	03	02	03
	45	03	06	02	02
	46	01	01	02	02
	47	03	02	03	03
	48	01	05	02	03
	49	01	01	01	01
	50	03	01	03	01
	51	02	06	01	04
Middle	18	01	02	03	05
	19	01	03	03	01
	20	03	11	01	06
	21	02	03	02	01
	22	04	03	03	02
	23	02	02	01	03
	24	01	02	01	03
	25	03	01	04	02
	26	02	01	01	01
	27	01	02	01	03
	28	01	07	01	05
	29	01	04	01	01
	30	01	02	01	05
	31	06	13	02	05
	32	04	00	03	14
	33	07	06	01	09
	34	01	03	01	02

APPENDIX F

Principal Statistics for Trials-to-Criterion-Fatigue

Group	Intensity	Hue	M	SD
Introvert	Low	Red	2.24	1.25
		Blue	2.53	1.18
	High	Red	2.24	1.56
		Blue	3.47	1.90
Middle	Low	Red	1.35	0.79
		Blue	4.47	4.09
	High	Red	2.59	2.47
		Blue	2.06	2.44
Extravert	Low	Red	1.76	1.03
		Blue	4.00	3.39
	High	Red	2.41	1.87
		Blue	3.82	3.54

APPENDIX F

Frequency of Eyeblinks During Stimulation During the High- and Low-Intensity and Red and Blue Hue Conditions

	Subject	HR	HB	LR	LB
Introverts	1	05	02	05	09
	2	03	03	03	05
	3	14	12	15	08
	4	08	09	09	09
	5	27	26	20	30
	6	20	03	32	16
	7	01	13	03	08
	8	15	14	17	17
	9	10	10	26	34
	10	08	06	07	06
	11	11	08	18	11
	12	16	09	13	14
	13	03	01	03	01
	14	08	10	12	13
	15	13	15	20	20
	16	08	11	09	12
	17	13	24	14	19
Extraverts	35	10	20	16	18
	36	24	09	13	21
	37	11	23	14	24
	38	12	22	31	16
	39	04	07	07	04
	40	08	10	05	22
	41	09	11	05	01
	42	03	04	08	07
	43	02	03	00	03
	44	44	35	21	35
	45	11	15	06	04
	46	43	27	39	34
	47	04	05	06	11
	48	11	10	03	07
	49	19	03	03	10
	50	18	32	26	18
	51	00	05	04	04
Middle	18	13	16	16	19
	19	10	10	13	11
	20	00	09	07	03
	21	13	16	16	20
	22	09	11	01	08
	23	08	03	21	10
	24	25	03	08	10
	25	05	19	11	28
	26	05	08	16	04
	27	24	27	19	19
	28	06	01	34	11
	29	01	05	03	05
	30	14	05	05	05
	31	00	03	03	00
	32	29	18	27	27
	33	19	31	45	39
	34	08	07	04	05

APPENDIX F

Principal Statistics for Frequency of Eyeblinks During Stimulation

Group	Intensity	Hue	*M*	*SD*
Introvert	Low	Red	31.53	27.23
		Blue	31.71	24.95
	High	Red	30.18	28.75
		Blue	34.35	31.78
Middle	Low	Red	38.18	23.29
		Blue	36.58	27.90
	High	Red	33.24	32.21
		Blue	32.59	27.43
Extravert	Low	Red	36.53	30.02
		Blue	30.76	20.40
	High	Red	31.71	17.66
		Blue	28.71	15.02

APPENDIX F

Mean Dark-Adapted Pupil Size Between the High- and Low-Intensity and Red and Blue Hue Conditions

Subject

		HR	HB	LR	LB			HR	HB	LR	LB
Introverts	1	8.114	8.260	8.535	7.949	Extraverts	35	6.363	6.061	5.887	5.904
	2	7.088	7.195	7.225	7.472		36	8.223	8.577	9.045	8.788
	3	8.725	9.049	7.909	8.140		37	6.041	6.249	6.405	6.096
	4	6.176	6.195	6.332	6.019		38	6.171	6.423	6.375	6.462
	5	7.518	7.347	7.625	7.604		39	6.716	6.852	6.595	6.607
	6	6.543	6.740	6.657	6.469		40	6.830	6.875	6.964	7.122
	7	6.757	6.598	6.954	6.972		41	6.678	6.656	6.714	6.497
	8	6.966	7.142	7.110	7.013		42	7.755	7.627	7.537	7.728
	9	5.841	5.900	5.475	5.536		43	8.800	8.748	8.574	8.336
	10	6.628	6.650	6.770	6.765		44	5.863	6.079	6.665	5.709
	11	6.864	6.828	6.843	6.799		45	7.359	7.162	7.509	7.299
	12	7.523	7.504	7.639	7.597		46	7.785	8.762	7.943	8.100
	13	7.195	7.272	6.756	7.070		47	8.230	7.650	7.120	7.310
	14	7.453	7.609	7.476	7.420		48	4.862	5.026	4.920	4.801
	15	6.241	6.727	7.843	6.272		49	7.471	6.905	7.316	6.870
	16	6.778	6.998	6.982	6.843		50	6.870	6.670	6.603	6.896
	17	6.881	6.829	7.056	6.579		51	5.592	5.560	5.825	5.463

Middle	18	6.818	6.630	6.559	6.512
	19	7.370	7.555	7.521	7.465
	20	6.467	6.693	6.553	6.590
	21	6.140	5.659	5.641	6.011
	22	5.377	5.659	5.615	5.513
	23	7.414	7.541	7.648	7.439
	24	8.025	7.889	7.897	7.392
	25	8.908	8.727	8.524	8.640
	26	5.848	6.106	6.448	6.511
	27	8.060	7.890	7.840	7.764
	28	7.071	7.223	6.764	6.868
	29	8.205	7.818	8.280	7.450
	30	7.290	7.090	6.630	7.003
	31	6.970	7.358	7.15[illegible]	7.076
	32	8.550	8.607	9.203	8.702
	33	8.181	7.726	7.875	7.800
	34	7.741	7.943	7.628	7.765

APPENDIX F

Resting Blink Rate Between the High- and Low-Intensity and Red and Blue Hue Conditions

Subject		HR	HB	LR	LB
Introverts	1	10	19	15	17
	2	04	02	02	07
	3	49	62	81	72
	4	17	27	11	19
	5	04	80	83	77
	6	16	20	14	23
	7	03	19	12	1
	8	52	25	63	62
	9	76	129	65	64
	10	07	17	07	08
	11	06	23	26	22
	12	43	37	38	36
	13	07	05	15	10
	14	23	23	13	18
	15	47	58	53	46
	16	39	23	32	48
	17	10	15	06	09

		HR	HB	LR	LB
Extraverts	35	31	43	51	50
	36	32	41	54	24
	37	37	26	56	70
	38	62	37	35	49
	39	10	07	09	07
	40	17	12	14	22
	41	25	24	09	17
	42	28	32	40	23
	43	20	19	16	13
	44	34	27	130	39
	45	49	44	38	42
	46	72	59	46	72
	47	16	21	12	15
	48	28	14	15	15
	49	36	34	52	32
	50	40	44	38	30
	51	02	04	06	03

Middle	18	58	72	61	64
	19	08	26	18	28
	20	06	03	06	01
	21	50	69	54	66
	22	36	34	43	26
	23	09	04	18	18
	24	34	29	28	28
	25	11	18	44	33
	26	04	25	26	32
	27	02	99	70	86
	28	07	15	60	20
	29	05	04	10	12
	30	24	17	13	15
	31	15	16	15	14
	32	96	65	70	72
	33	75	30	74	91
	34	25	28	39	16

APPENDIX F

Principal Statistics for Mean Dark-Adapted Pupil Size and Resting Blink Rate

	Mean Dark-Adapted Pupil Size		Resting Blink Rate	
Group	M	SD	M	SD
Introvert	7.06	0.73	12.01	7.57
Middle	7.28	0.93	12.56	10.02
Extravert	6.90	1.05	13.53	11.22