EYE COLOUR AS RELATED TO CRITICAL FLICKER FREQUENCY, PRESSURE AND VIBRATION THRESHOLDS

by

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THESIS

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ABSTRACT

This study investigated the relationship between eye colour and three sensory thresholds. Millodot (1975) measuring corneal touch thresholds, found that blue eyed individuals were more sensitive to touch than either green, hazel or brown. He suggested that a general relationship may exist between eye colour and tactile sensitivity. The generality of this relationship was examined in 65 female and 43 male undergraduate university students, using CFF, pressure and vibration thresholds. Eye colour was rated according to the chart proposed by Kent (1956).

Results indicated that the light eyed male was more sensitive to CFF and pressure than his dark eyed counterpart. Among females, vibration and CFF thresholds were significantly correlated, but no relationship was found between sensitivity and eye colour.

The present study supports a general relationship between eye colour and sensitivity. This result however, only appeared with males. It was suggested that the hormonal influence may have masked this relationship in the female. Further research needs to be done in areas concerning the possible role of melanin, and the influence of hormones.

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I'd like to dedicate this work to my family who didn't believe it could be done.

INTRODUCTION

Eye colour as a basic individual difference variable has recently begun to receive attention from psychologists. Eye colour has been found to be related to pain threshold (Sutton, 1959), motor behaviour (Landers, Obermeir, & Patterson, 1976; Markle, 1976; Worthy, 1974). perceptual reactance (Mahoney & Hartnett, 1976), critical flicker frequency (CFF) (Smith & Misiak, 1973) and corneal touch thresholds (Millodot, 1975).

These findings indicate that eye colour may be an important indicator of fundamental differences in central nervous system (CNS) organization. In particular, several of the findings indicate that light eyed individuals have greater perceptual sensitivity than dark eyed individuals. The present study was designed to further examine the extent of the relationship between eye colour and perceptual sensitivity.

Physiological and Genetic Basis of Eye Colour

Biologically, the eye is a very complex system, relying on the interaction of various components to accomplish what is known as vision. Basically, the eye is encased in a tough but elastic coat of connective tissue, the sclera. The anterior portion of this is known as the cornea, the first element in the light focusing system. Inside the sclera is the choroid, a structure providing blood supply to the eye and preventing internally reflected light from blurring the image. Between the main part of the sclera and the cornea, the choroid becomes thicker and is known as the ciliary body. Anterior to the ciliary body, the choroid extends into the eye cavity where it's known as the iris, which contains both circular and radially directed smooth muscles. The opening in the centre of the iris is the pupil, behind which is the lens, the second element in the light focusing system. Covering the inner surface of the choroid is the retina, which contains the rods and cones necessary for vision (from Keeton, 1967).

Eye colour varies between individuals, ranging from light blue to dark brown. Differences in eye colour are due to different distributions of melanin in the iris. Cross section of the iris shows that it consists of four layers. The outermost layer consists of flattened endothelial cells. The second layer consists of yellow or yellow and brown granules. The third layer consists of the circular and radial muscle fibres of the ciliary muscle. The innermost layer consists of two layers of pigmented epithelial cells, the pigment being retinal melanin (from Wasserman, 1974, p. 103).

The observed colour of the iris depends on the effect of incoming light on melanin granules. If melanin granules are large and densely packed in the layers of the iris, the eye appears brown or black. However, if the melanin granules in the outer layer are very small, an optical effect known as "Tyndall scattering" occurs, which makes the eye appear blue (Landers, Obermeier, & Patterson, 1976). Skinner (1955 in Wasserman, 1974) describes how eye colour is anatomically determined:

> "Blue eyes are due to the Tyndall effect or Rayleigh scattering when viewing the dark pigment of the posterior layer through the overlying layers. Different shades of blue are chiefly due to the structure, texture and colour of the overlying fibrous layers. Grey eyes are due to the effect of a thin, very superficial layer of melanin, usually appearing yellow rather than brown, on the blue iris as described above. Green and brown eyes with their various shades are due to the presence, localization and amount of melanin in the middle and anterior layers of the iris, depending to some extent on whether or not the pigment is more yellow or brown. Brown, dark brown and yellowish brown eyes are due to heavily pigmented superficial layers which obscure the posterior pigment. Black eyes are actually so intensely dark brown with such heavily pigmented superficial layers that the pupil cannot be distinguished from the iris." (p.104)

Although it is known that iris colour is dependent on the melanin concentration found in the iris during infancy (Duke-Elder & Wybar, 1961, in Smith & Misiak, 1973), the genetic basis of eye colour has yet to be explained. There is general acceptance that the major gene pairs responsible for skin colour also influence eye colour (Brues, 1975; Nicholls, 1973). The amount of iris pigmentation is a polygenic trait, with one of the genes found on the X chromosome. Thus eye colour as a genetically determined characteristic, is also partially sex linked.

Although the evolutionary implications of skin colour have been extensively examined, the combination of skin and eye colour is less frequently considered. One such study looked at the relationship between melanin deposition in the eye and that in the skin (Robins, 1973). Using reflectance spectrophotometry, (high reflectance - low melanin - light skin), he failed to find a correlation between skin and eye colour in males. However, in females, the two variables, skin and eye colour, were correlated, eg, blue eyes had higher skin reflectances (light skin) and brown had low reflectances (dark skin). The observed sexual difference was explained in terms of genetic differences in skin pigmentation between blue and brown eyed individuals, which expressed itself under the influence of female oestrogenic hormones. It was also noted that melasma, a darkening of the skin, is a known complication of oral contraception (Jelinek, 1970, in Robins, 1973).

A known function of melanin is that of protection against solar radiation. Melanin's protective capacity in the skin can be seen through, 1) it's action as an optical filter with absorption of ultraviolet (UV) and visible spectrum, 2) as a repository for free radicals generated by UV radiation, 3) through arrangement in nuclear caps, so that it affords protection to vulnerable oranelles and macromolecules, i.e. DNA, where it again acts as a repository for free radicals (Wasserman, 1974).

While melanin may have a protective function in the skin, what if any is it's function in the eye? Cota (1940, in Short, 1975) gave two adaptive functions in the animal kingdom, "that of concealing the eye and that of increasing it's conspicuousness" (p. 425). Walls (1942, in Short, 1975) doubted the efficacy of concealment, since the eye tended to glisten in the light, betraying it's owner. Conspicuousness of the eye appeared to have been adopted by many smaller species, since eyes clearly larger than one's relative body size presented a shocking appearance to predators. However, it is doubtful if either of these functions are particularly important in man. The evolutionary model proposed to account for the distribution of the iris colour in man, was that it was a pleiotropic carryover from the general integumental pattern, and indirectly influenced by the same kinds of evolutionary forces that control for the selection of skin colour (in Short, 1975).

Walls stated that light iris colour in it's ability to reflect light, endowed the iris with the same qualities as dark colour did by it's absorption. Further, iris pigmentation served to filter light entering the eye, preventing overstimulation of the retina and reducing ocular glare. Without any pigment, the value of the iris would be negligible, since pupil constriction couldn't control either the intersity of the light beam, or it's geometry (Short, 1975). However, Hoffman (1975) pointed out that the pupil had an absolute minimum below which it could contract no further. Once this limit was reached, melanin was invaluable in maintaining visual acuity.

Eye Colour and Sensitivity

One of the proposed functions of melanin in the eye is that of maintaining visual acuity in optically stressful environments. Visible pigmentation of the eye occurs in three areas, the cornea, the iris and the sclera. Functionally, the most important is that found in the retina, pigmentation here not being directly observable. However, it is assumed that the relationship between melanin in the iris and the retina is on a 1 to 1 ratio (Helson & Guilford, 1933). It is the melanin in the pigment layer of the retina and that in the choroid, which prevents light reflection throughout the globe (Helson & Guilford, 1933), thus maintaining acute vision. Lack of melanin in both areas is seen in albinos. Typically, they have difficulty in maintaining visual acuity due to excess stimulation of rods and cones.

Two techniques used in the study of visual sensitivity are light adaptation and dark adaptation. In an early study, Helson and Guilford (1933) used the latter to investigate the relationship between visual sensitivity and retinal pigmentation. They found that, as pigmentation increased so did sensitivity, or in their case, a minimum amount of light required to evoke a sensation of light. This was especially true for Negroes, who were more sensitive than even the dark eyed Whites. Karpinos (1944) also found visual acuity to be a function of iris pigmentation. Using WW II soldiers, the Coloureds (his term) had better vision in their weaker eye than did Whites in their stronger eye. Even when age was taken into account, diminution in visual acuity was slower amoung Coloureds than Whites. Thus it was concluded that melanin pigment in the eye may have evolved as an adaptive feature in maintaining visual acuity. Hoffman (1975) however, did not find iris pigmentation to influence acuity in environmentally stressful conditions, eg. environments in which there are high or low intensitities of sunlight. In his study, Hoffman examined both males and females, classifying the degree of retinal pigmentation as light, medium or dark. Each subject was asked to read from a Landolt C recognition test pattern at 20 feet, under 10 different intensities of light. He failed to find that the degree of retinal pigmentation was associated with the visual acuity or pupil size under the limits of brightness used. In another study iris pigmentation had no significant effect on visual acuity under conditions of bright light. Short (1975) tested 4 different populations on stimuli of 2 parallel light bars whose interspace and brightness were varied.

He found no difference between males and females for fine discrimination, while on gross discrimination, males maintained visual acuity under higher levels of stress than did females.

Eye colour has also been viewed to be a function of environmental adaptation. Bornstein (1973) found that, 1) exposure to UV radiation due to altitude or proximity to the equator and 2) ocular deposits of xanothophyll resulting from ingestion of carotenoids (a lipochrome capable of conversion into vitamin A), promoted increased density of yellow pigmentation of the cornea, lens and pigment epithelium. The yellow pigment absorbs the short wavelengths (blue-green) before it excites the blue-green receptor pigments. This results in a depression of spectral sensitivity to short wave lengths, confusion of the blue-green in colour matching and colour naming and an increase in visual acuity in the darkly pigmented races.

Bornstein's work on possible physiological differences between races in colour vision and colour naming gives the most plausible answer to the acuity question. His results support earlier work finding Negroes to have better acuity than most Whites. Hoffman's and Short's work on eye colour in bright environments, however, does not fit into the pattern, which leaves the biological function of eye colour unresolved.

Perceptual and Behavioural Correlates of Eye Colour

Very few studies have investigated the possible relationship between eye colour and perceptual and behavioural measures. However, several have found systematic relationships in which measures vary directly with the degree of iris pigmentation. Specifically, these studies raise the possibility that the degree of iris pigmentation, from little (blue) to greater amounts (dark brown) is a reflection of underlying differences in CNS function.

One of the earlier studies in this area was on the relationship between eye colour and reaction to dental pain. Sutton (1959) recorded the patient's reactivity to dental drilling on a four point scale, the lowest being no pain reaction, the highest, the need for anaesthetic. He also recorded eye colour using a nine point scale. His results indicated that the darker the eye colour, the greater was the reaction to dental pain.

Mahoney and Hartnett (1976) studied the relationship between Petrie's 1967 concept of perceptual reactance and eye colour. The subjects were classified as perceptual augmenters, moderates or reducers, according to their overestimation, accurate estimation or underestimation of 25.4 mm and 33 mm block sizes. Their results indicated that augmenting males were the most dark eyed, while augmenting females were the most light eyed.

Corneal touch threshold measures have also given eye colour sensitivity differences. Millodot (1975) found by stimulating the inferior point of the cornea, that blue eyed people were more sensitive to touch than green, hazel or brown. Although sex differences were noted, males being more sensitive than females, they were not statistically significant. He later showed (1976) that individuals with different coloured irises (heterochromia) had uniform sensitivity in both eyes. His interpretation of these findings was that eye colour was related to corneal sensitivity through some central nervous system (CNS) factor which was correlated with eye colour (or melanin concentration). He further speculated that this difference may reflect a general difference in tactile sensitivity, ie., somatorsensory rather than corneal. Earlier, Millodot and Lamont (1974) had shown that corneal sensitivity was influenced by the menstrual cycle. The results showed that corneal touch thresholds dramatically increased with the onset of menstruation. However, thresholds did not vary for men, or women on oral contraceptives. This then raises the question of a gender specific hormone affecting sensitivity.

Markle (1976) investigated the relationship between eye colour and motor behaviour. Eye colour was found to be a significant predictor of individual differences, particularly along the self paced - reactive dimension. Self paced behaviour includes activities where the individual initiates responses at his own pace, eg., bowling or golf. Reactive activities are those that require quick responses to a rapidly changing stimulus, eg., boxing. Markle found that light eyed individuals performed better at the self paced tasks, while dark eyed individuals performed better at reactive ones. In various professional sports, such as baseball and basketball, it was found that Blacks performed significantly better at reactive types of activities, eg., batting and field goals shooting. In professional football, as the proportion of Blacks playing a particular position increased, the mean eye darkness of Whites playing that position also increased. In nonathletic situations, dark eyed subjects performed better than light eyed subjects on tasks involving speed of response, but not on tasks involving inhibition of response. Thus it would appear that speed of locomotion was related to eye colour. This was demonstrated by Kane (1971 in Markle, 1976) who found Blacks able to run faster than Whites. Worthy (1974, in Markle, 1976) offered evidence from his research on birds, snakes, and insects, that dark eyed animals were faster than their light eyed counterparts. Worthy (1974) proposed the generalization that, "dark eyed organisms tend to specialize in tasks that require hesitation, inhibition and self paced responses", (p. 2), and presents a variety of examples in support of this position.

There are, however, several critics of Worthy's hypothesis. When Jones and Hochner (1973) examined the 1971 baseball and basketball statistics, the results were not consistent with the Worthy theory. Black pitchers performed better than White, while White basketball players were better on the self paced (free throw) task, but failed to show the racial differences in field goal shooting. They proposed that Worthy's typology was too simple and suggested instead a 3 dimensional sports personality model, consisting of 3 dominant motives, approval, achievement, and power, which may be further broken down into, team - individual, success - style, and, competition - play.

Landers, Obermeirer and Patterson (1976) further looked into Worthy's theory, that dark eyed individuals were faster than light eyed individuals on reactive motor tasks. They found that when rotary pursuit and choice response time tasks were examined, there was the predicted effect of brown being faster than blue. However, this relationship held only when speed was the criterion. When measures of response time, reaction time (RT) and movement, or response - RT, were examined, iris pigmentation effects were limited to reaction time. It would appear from this study that eye colour only becomes a factor when reactions involving speed, rather than accuracy, are required.

Although a variety of studies have found significant relationship between various behaviours and eye colour, there has been little systematic research.

Of interest to the present study is Millodot's recent report that perceptual sensitivity decreases as eye colour darkens (Millodot, 1975). In particular Millodot's hypothesis that this relationship reflects general differences in tactile sensitivity appears worthy of further investigation.

Experimental Techniques

As this investigation centers on the generalizability of somatosensory processes, three were identified for testing: pressure, vibration and critical flicker frequency (CFF). These were selected through 1) practical considerations, e.g., availability and cost of equipment, 2) replication of existing studies, specifically, CFF.

Vibration and Pressure Sensitivity

Historically, a debate has centered on whether pressure and vibration represent the same senses. This debate continued until recently when researchers agreed that pressure and vibration were two variants of the same sense. Not only are the two histologically similar but probably involve the same innervators - Pacinan corpuscles in hairless skin and mucocutanious organs, Krause end bulbs in areas verging on mucous tissue (Geldard, 1972). The correspondence between vibratory and sensory thresholds is further evidenced by: 1) similar temperature sensitivities, that is, that pressure thresholds are related to skin temperatures in a concave function, just as are vibration thresholds, 2) spots sensitive to vibration coincide with spots sensitive to touch, 3) pressure sensitive spots have low vibration thresholds while pressure insensitive spots are also relatively insensitive to vibration. Typically, pressure sensitivities have been investigated using von Frey hairs in graduated series. More recently, aesthesiometers have also been used to measure thresholds.

It was noted that pressure thresholds vary according to the area stimulated. Sensitive areas typically stimulated include the ball of the thumb, tips and balls of other fingers and various positions on the underside of the forearm.

It is clear that the vibratory sense is based on the operation of pressure receptors. It can be shown that a vibratory stimulus placed on the skin travels great distances with little loss in intensity. It is the widespread transmissions of vibratory disturbances that makes the exact location of the stimulus difficult to locate. Spots isolated as being sensitive to vibration include fingertips, palm, sole of the foot, and skin over the sternum. All areas sensitive to vibration are also areas in close association with bony tissue, a known good conductor.

It would appear that there are a number of variables influencing vibration and pressure sensitivities. There is, however, discrepancy between researchers as to the influence of these. One variable in this category is age. Goodenough and Anderson (1931, in Mouessen & Reuder, 1969) claimed that the young child had a smaller body surface than the adult, consequently, the touch receptors were closer together (more receptors per unit area), hence greater sensitivity. This is not in agreement with Semmes, Weinstein, Ghent, and Teuber (1960 in Weinsteine and Sersen, 1961) who failed to find any significant age difference when measuring pressure sensitivities. Yet, Ghent (1961, in Weinstein, 1962) and Mouessen et al (1969) did find older children to have lower absolute thresholds than the younger ones. Mouessen et al claim that familiarity with the experimenter influenced reports of sensitivity more in the younger child than in the older one, and perhaps remains as a criticsm for the other earlier studies.

Handedness is another variable influencing vibration and pressure sensitivities. Discussion has centered on use of the preferred hand where the distribution of nerve endings and callouses may influence thresholds. Most researchers agree to the superiority of the left side of the body for sensation of pressure (Ghent, 1961, Semmes et al, 1960, Weinstein & Sersen, 1961) or electrical stimuli (Green, Reese, Peques & Elliot, 1961 (in Weinstein, 1962) in detrals. Whether the right side is more sensitive in sinistrals was not mentioned.

From the literature it would appear that pressure and vibration involve the same sense. This was demonstrated through similar temperature sensitivities as well as similar thresholds. Variables influencing these sensitivities were handedness, the nonpreferred being the more sensitive in dextrals and age.

Critical Flicker Frequency (CFF)

Another measure in this study was that of critical flicker frequency. CFF is defined as the number of light dark cycles per second, at which a physically intermittent light is perceived as steady (Woodworth & Schlosberg, 1954). CFF has been used extensively to examine drug effects on the central nervous system (CNS) (Smith & Misiak, 1976). It has also become an instrument in measuring CNS degeneration in psychiatric and geriatric cases (Dillon, 1959). CFF thresholds were found to be influenced by age (Misiak, 1947, Fisher, 1955) sex (Hartmann, 1934), time of day

(Walsh & Misiak, 1966), and eye colour (Smith & Misiak, 1973).

As was mentioned, Hartmann (1934) found sex to be a determining factor in establishing CFF thresholds. He found males to have higher sensitivity than females in CFF independent of their age. Later Misiak (1947) found significant age differences in CFF sensitivity, but no sex differences. He assumed from this, that findings of lower CFF with older people was due to degeneration of the optic nerve and cerebrum. In his 1951 study, he found interindividual variability to increase with age, a tendency characteristic of many mental and physical capabilities. Misiak attributed the decrease in CFF values to any of three factors: 1) peripheral (retina) or central (subcortical) factors or both, 2) with age one gets a smaller pupil diameter and the decrease in mobility may be reflected in a lower CFF score, 3) an interaction of the parasympathetic and sympathetic nervous system with the pupil. It was suggested that if the parasympathetic becomes dominant with age, the light reflex is more pronounced and the pupil diameter becomes smaller with a consequent decrease in CFF value.

Recently, CFF was also investigated with eye colour (Smith & Misiak, 1973). Using only males, they found an inverse relationship between CFF and iris melanin concentration. In other words, blue eyed males were more sensitive to CFF than their brown eyed counterparts.

It has been shown that CFF may reflect CNS sensitivities. That these thresholds are influenced by age and recently, eye colour was mentioned. However, the fact that sex differences from an earlier study were not replicated in later studies leads one to either suspect the original findings, or to speculate on other intervening variables.

Present Study

Far from being just the subject of songwriters and lovers, eye colour does appear to be a variable influencing perception and reactions to the environment. Eye colour has been shown to be related to sensitivity, but the direction of the relationship has varied.

Helson and Guilford (1933) and Karpinos (1944) who examined eye colour and acuity, found the darker eye colour (brown) to be better at perceiving two stimuli as distinct. This suggests that eye colour may have a causal effect on resolving power, being peripherally rather than centrally mediated. Sutton (1959) adds another dimension to the eye colour sensitivity question by finding brown eyes to be more sensitive to pain (lower threshold) than light eyes.

This raises questions on the difference between pain and the detection of touch and how melanin is involved. This finding may well reflect cultural differences in the reporting of pain.

On the other hand two findings have reported light eyed to be more sensitive (Millodot, 1973, Smith and Misiak, 1973).

Particularly intriguing is Millodot's (1975) suggestion that eye colour is related to overall tactile sensitivity. Since no empirical data bearing on his hypothesis could be found, the purpose of the present study is to look at two somomatosensory measures, pressure and vibration and their relationship to eye colour. In addition, the present study sought to replicate the relationship between eye colour and CFF reported by Smith and Misiak (1973). It is hypothesized that the relationship, if any between eye colour and the three measures of sensitivity used in the present study will be in the same direction of the Millodot's, and Smith and Misiak's studies, that is a decrease in sensitivity with an increase in eye colour.

METHOD

Subjects

There were 108 subjects (65 female and 43 male), ranging in age from 16 to 54, recruited from the Lakehead University student community in Thunder Bay, Ontario. All subjects received course credit for participation in the experiment.

Apparatus

1. Pressure Gauge

An Halda aesthesiometer was embedded in a U-shaped 6 X 7 cm block of wood. This device was attached to an extension from a 1 rpm motor, housed in a separate metal box. The motor rotated the aesthesiometer from a position 2 cm above the subject's dominant hand to one where it touched the back of the hand, at a point 4 cm proximal to the base of the index finger. The rate of change in pressure of the aesthesiometer was .4 grams per second. Each trial took approximately 3 seconds once the aesthesiometer was started by the experimenter to when the subject pressed the button indicating a touch (refer to figure 1.).

2. Vibration Threshold

A 3.8 cm split ping pong ball glued to the centre of a 10.2 cm speaker, was adjusted to rest lightly on the ball of the subject's third finger of the dominant hand. The speaker apparatus was further attached to a 75 cm lever system with an adjustable weight in order to control the weight of the speaker on the finger. The 4 ohm speaker was connected to an Eico 378 audio generator with the frequency set at 100 cps and a range of 0 - 300 uV. The intensity read as the actual value in uV fed to the speaker, was controlled by a 6 rpm motor, housed in a separate metal box. The linear rate of change, from 0 - 300 uV, was 50 uV per second. The subject's switch was situated so it could be easily reached with the other hand. The experimenter's switch was situated at the bottom of the motor box (refer to figure 2).

3. Critical Flicker Frequency (CFF)

The instrument used to measure CFF was a Lafayette 1202a flicker fusion apparatus, capable of generating from 2 to 128 cps of light. The light source was a Sylvania R1166 bulb, which was located 13 cm from a diffusing glass, which in turn was positioned 4 cm from the board. A 9 rpm motor housed in a separate metal box controlled the rate of change of intermittency of the flicker. The rate of change for the full cycle (32-128 cps) was 12 seconds. The period changed linearly with time. The luminance was established at 30.3 foot - Lambert, as measured by a MacBeth illuminometer. The stimuli were viewed through a hole, 2.5 cm in diameter, located in a 70.6 X 63.1 cm board, positioned 85.7 cm away from the subject. The subject controlled the trial with a telegraph type switch located near his chair.

4. Eye Colour Determination

Eye colour was assessed from the chart given by Kent (1956). This chart was composed of a range of nine eye colours from light blue (1) to dark brown (9).

Procedure

As the generalizability of somatosensory senses was the prime objective of this investigation, it was decided to vary the spot stimulated as well as the test used. The dominant hand was selected for both pressure and vibration tests, with the back of the hand and the ball of the third finger selected as stimulus areas. In this manner it was hoped to compare sensitivities from an area with a high density of nerve endings (ball of the finger) and one with less (back of the hand).

1. Pressure Gauge

The subject was seated and the data sheet answered. The task was then explained to the subject (refer to subject's instructions for all tasks in appendix A) and any questions answered. The subject's switch was adjusted so it could be pressed with one hand, once a light touch was felt on the back of the dominant hand. The subject then put on the darkened goggles and practiced the task during the familiarization trial, which was followed by the five test trials. Once the switch was pressed, the pressure reading, in grams, was recorded from the gauge. The mean pressure value from the five trials was then taken as the measure of sensitivity.

2. Vibration Threshold

The dominant hand was placed, palm up, on the table. The speaker apparatus was then adjusted so the ping pong ball rested lightly on the ball of the third finger. A series of two familiarization trials, one ascending and one descending, was followed by six test trials, three of each method. The subject was instructed to press the switch when the ping pong ball started to vibrate (ascending) or when it ceased to vibrate (descending). An ascending median and a descending median were calculated. The threshold was defined as the mean of the two medians.

3. Critical Flicker Frequency (CFF)

The subject was seated .85m infront of the board in a partially lit room (light source, 25 W bulb). A series of two practice trials using the ascending and descending method of limits was given. The subjects were instructed to report the appearance or disappearance of the flicker by pressing the telegraph key. This was followed by 10 actual trials, five of each method. The median values from each method were then averaged to determine the final sensitivity value.

5. Eye Colour Determination

Interexperimenter reliability to match eye colour was tested in a pilot study. With 15 subjects, there was perfect agreement in 13 cases and a small discrepancy in 2 cases. In the test trial, the subject's eye colour was noted by direct observation by the experimenter and compared to those on the chart. The subject was then assigned a score between 1 and 9 from the chart.

Figure 1 Pressure Apparatus

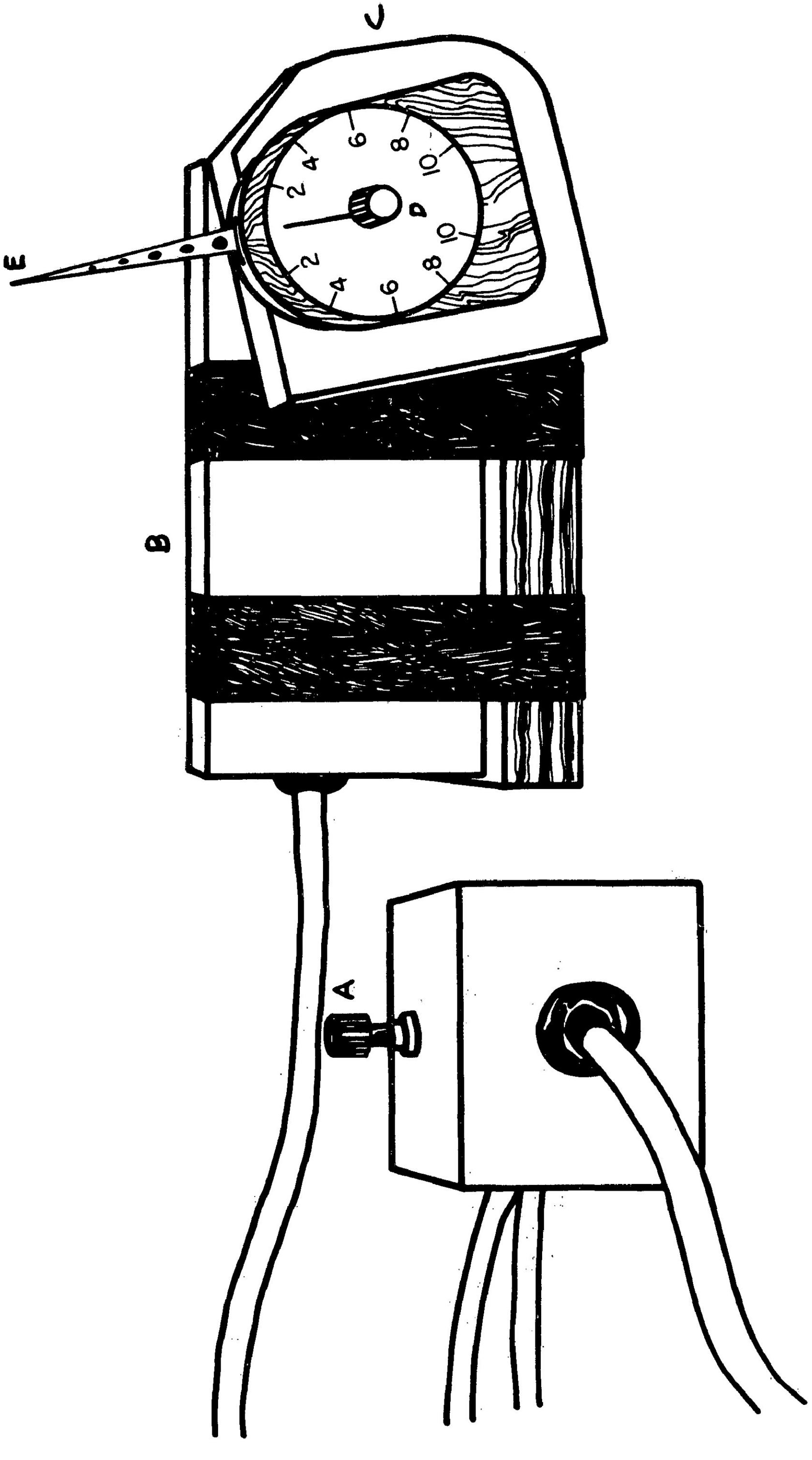
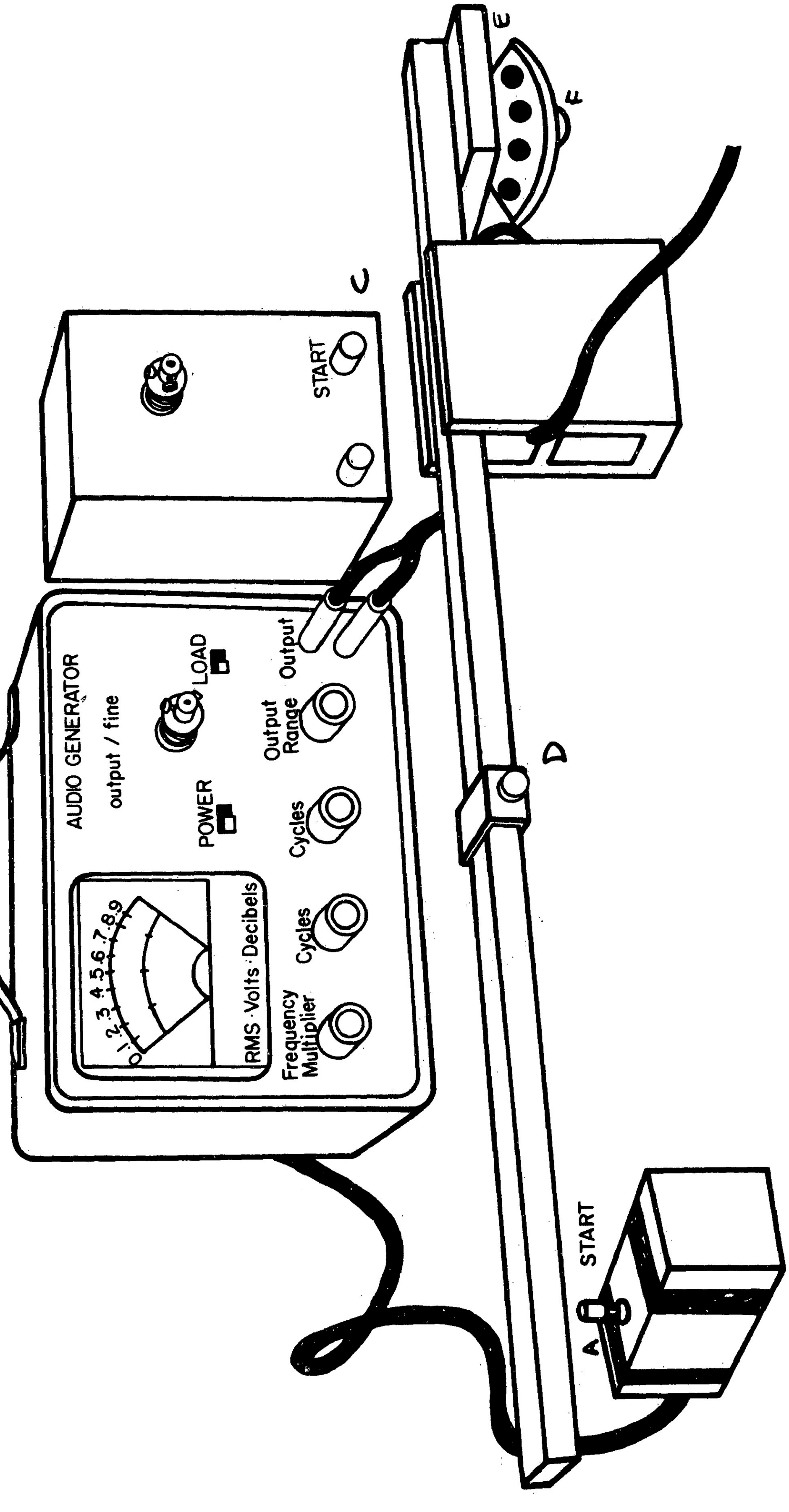


Figure 11 Vibration Apparatus



LEGEND FOR FIGURES 1 and II

Figure 1 Pressure Apparatus

A Subject's control switch

B Metal box housing motor

C U - shaped block attached to aesthesiometer and motor

D Aesthesiometer

E Extension from aesthesiometer

Figure II Vibration Apparatus

A Subject's control switch

B Audio generator

C Metallic control box housing experimenter's start button and motor

D Lever for balance

E Speaker

F Ping pong ball

RESULTS

The purpose of this study was to determine the relationship between sensitivity and eye colour. A breakdown of the number of subjects in each eye colour category is given in Appendix B. When the individual colours were grouped as light (1-3), medium (4-6), and dark (7-9) for clarity of presentation, a trend in the expected direction emerged (Table 1). In all three tasks, the light group had the lowest sensitivity, while in two of the three, the dark group had the highest sensitivity.

TABLE I

MEAN THRESHOLDS AND STANDARD DEVIATIONS ON THE THREE TASKS FOR EACH EYE COLOUR GROUP

COLOUR	NUMBER	PRESSURE (gm)	VIBRATION (uV)	CFF (cps)
1 - 3	37	1.45	122.05	43.04
		s.d.=.88	47.83	3.05
4 - 6	37	1.47	136.51	42.72
		.70	47.30	2.18
7 - 9	34	1.61	131.56	42.61
		.94	59.82	2.49

To examine the relationship between eye colour and sensitivity on the tasks, Pearson correlations were calculated between the eye colour score (1-9) and threshold scores for all three tasks (Table 2). One tailed tests of significance were used.

TABLE 2

PEARSON CORRELATION COEFFICIENTS
FOR ALL SUBJECTS (n=108)

	EYE COLOUR	PRESSURE	VIBRATION	CFF	AGE
sex	-.1318	.0894	.0788	-.4004***	-.0266
eye colour		.0789	.0780	-.134	-.1920*
pressure			.2272*	-.0935	.0209
vibration				-.1961*	.0876
CFF					-.3407***

$p<.001$*** sex: 0 = male

$p<.05$* 1 = female

No significant correlations emerged between eye colour and sensitivity on any of the three tasks. However, significant correlations were found between sex and CFF. This negative correlation indicated that of the subjects tested, males had higher CFF thresholds than females, a higher CFF threshold indicative of greater sensitivity. Another significant correlation was with pressure and vibration. Results also indicated that high CFF values correlated with low vibration values. The other significant correlation was between age and CFF, the younger subjects being more sensitive to the CFF task than the older ones. Age also correlated with eye colour, suggesting that the older subjects had lighter eyes. Due to the highly significant correlation between CFF and sex, Pearson correlations were calculated separately for females (Table 3) and males (Table 4).

TABLE 3

PEARSON CORRELATION COEFFICIENTS .

FOR FEMALES (n=65)

	PRESSURE	VIBRATION	CFF	AGE
eye colour	-.0600	.1767	-.1118	-.2301*
pressure		.3005**	-.1870	.0124
vibration			-.3810***	.1223
CFF				-.4048***
$p<.001$***				
$p<.01$**				
$p<.05$*				

Eye colour did not correlate with any of the sensitivity measures for the females. The pattern of correlations in this analysis was identical to that of the total sample, except that the strengths of the relationships were greater.

When the Pearson correlation coefficients for males was examined (Table 4), a different pattern emerged. Relationships were noted between eye colour and CFF, and eye colour and pressure, which were not observed for females. The negative sign of the first correlation indicates that light eyed males were more sensitive to the CFF task than were any other eye colour group. The positive eye colour pressure correlation also indicated that light eyed males were more sensitive to touch than their dark eyed counterparts. Moreover, the two correlations between pressure and vibration and between CFF and vibration observed in the total sample and female group, were not observed with males. The age and CFF correlation, although weaker, also appeared in this group.

TABLE 4

PEARSON CORRELATION COEFFICIENTS

FOR MALES (n=43)

	PRESSURE	VIBRATION	CFF	AGE
eye colour	.2891*	-.0267	-.2844*	-.1248
pressure		.1155	.1145	.0310
vibration			.1159	.0185
CFF				-.2775*

$p < .05*$

As Pearson correlation coefficients indicated a strong relationship between sex, age and certain variables, partial correlation coefficients were computed to examine this effect (appendix C). The most notable result of these analyses was that when age and sex were controlled for, the partial correlation (second order) between eye colour and CFF was significant ($p < .01$).

DISCUSSION

The purpose of this study was to examine the generality of the relationship between sensory thresholds and eye colour. From past research, it was hypothesized that there would be differences in sensitivity between individuals with different eye colours, specifically, blue more sensitive that green, hazel or brown. This hypothesis was not supported in the overall sample, nor with female subjects. With the male subjects, eye colour was correlated with two of the three measures, CFF and pressure. In both cases, as hypothesized, the light eyed male was more sensitive than the dark eyed male.

The reason why eye colour was not found to be related to sensitivity differences in females is unclear. It should be noted that Smith and Misiak (1973) who also found a relationship between eye colour and CFF, only used male subjects. However, Millodot (1975) used both male and female subjects in his study which reported a relationship between eye colour and corneal touch thresholds. Unfortunately, Millodot did not present separate analyses for his male and female subjects, so it is impossible to ascertain whether the relationships were the same for both sexes.

Several factors might be considered in attempts to explain why eye colour might be less strongly related to sensitivity in females than in males. First, it appears that the menstrual cycle affects sensitivity (Millodot & Lamont, 1974). No attempt was made in the present study to record the menstrual phase, hence variations in sensitivity produced by fluctuations in hormonal levels would be a source of extraneous noise. While this effect of menstrual hormones does not appear in women taking "the pill" (Millodot & Lamont, 1974), information about whether subjects were using "the pill" was not collected in the present study. However, it should be noted that 27 out of the 65 women in the present study were between 16 and 19 years of age, while the youngest in Millodot's 1975 study was 23. It is therefore probable that more of his subjects were on "the pill". Accordingly, his female subjects may have yielded less variable sensitivity differences due to the lack of hormonal fluctuations and this might account for his failure to observe differences between males and females.

The correlation between CFF and eye colour with male subjects simply replicates Smith and Misiak's finding and does not provide direct support for Millodot's suggestion that eye colour is related to sensitivity in general. However, the correlation between eye colour and pressure on the back of the hand in male subjects, does provide such support. Obviously, eye colour per se, could not directly influence sensitivity of the hand, so this correlation must indicate that some underlying factor is related to both eye colour and sensitivity. It is not clear why a similar correlation was not observed between eye colour and vibration thresholds as measured on the ball of the finger. This difference could reflect either the difference in threshold measuring techniques (pressure versus vibration) or in anatomical locus (ball of the finger versus the back of the hand). Further research is needed to clarify which sensory thresholds are related to eye colour and whether these relationships are general to other areas of the body.

The present results suggest that eye colour may be an indicator of individual differences in sensitivity, at least for male subjects. Although the mechanisms underlying this relationship are not clear, one plausible line of speculation is that greater melanin concentrations (as would be found in dark eyed individuals) cause increased sensory thresholds. While direct support for this suggestion is lacking, there are various pieces of information linking melanin or melanin production with CNS functioning. Melanin is produced by two types of cells, melanocytes and mast cells. Anatomically, melanocytes originate from the neural crest which in turn eventually forms the spinal cord. As the neural crest folds over to form a tube, the cells lying dorsoventrally migrate to form a sheet extending from the brain stem to the lower spinal cord. Along with forming melanocytes, the cells differentiate into spinal ganglia, sympathetic ganglia, chromaffin cells, and perhaps Schwann cells (from Wasserman, 1970). Although the true physiologic function of the mast cell is unknown, it is known that it produces granules containing histamine, heparin, and, in the rat and mouse, serotonin (Miller & Keane, 1972).

Melanin has also been found to be related to certain CNS disorders. In general, these disorders are associated with a decrease in the amount of melanin in a particular area of the body. Happy and Collins (1972) commented on their finding of a relationship between eye colour and autism. In their sample of autistic children, they found an overrepresentation of light eyed and an underrepresentation of dark eyed children. The authors discussed the possibility that autism may be a dysfunction of the ARAS (ascending reticular activating system). It was shown that the ARAS uses noradrenaline, an end product of melanin synthesis, as a transmitter substance. Happy and Collins suggest that an underproduction of melanin may account for the greater number of light eyed autistic children.

Melanin has also been shown to be implicated in certain biochemical reactions. Wasserman (1970) notes that the drug chlorpromazine, used in treating schizophrenia, has a high affinity for, and forms charge transfer complexes with melanin. This is shown in that it; 1) activates melanin transport, 2) may cause hyperpigmentation as a side effect, or 3) cause symptoms of Parkinsonism. Hence one would suspect that melanin plays a protective role in the CNS, with a decrease in melanin being associated with various extrapryamidal disorders. This may be seen in such cases as phenylketonuria which is typically associated with minimal iris pigmentation and absence of melanin in the substantia nigra (Wasserman, 1970). Recently, McGinnes, Correy and Proctor (1974) have shown that melanin functions as an amorphous semiconductor switch. They noted that melanin's ability to function as an electronic device may be related to it's appearance at locations in the body where energy conversion or charge transfer occurs, i.e., skin, retina, mid-brain, and inner ear. The physiological implications of this finding for the role of melanin in neural processes were not made explicit by McGinnes et al. However, since melanin has high resistance at low voltages, it might be suggested that large amounts of melanin would provide increased resistance to weak signals. This would be consistant with the dark eyed (higher melanin) individuals being less sensitive. Carrying this argument further, at higher voltages, melanin switches to a low resistance, possibly permitting greater passage of current. This might be consistent with Worthy's (1974) finding of faster reaction times in dark eyed individuals.

At this point, further speculation about the possible role of melanin in determining sensitivity levels would not be productive, since direct tests of the effects of increasing melanin concentrations, can, and should be conducted. The present findings are limited to having demonstrated that eye colour is a potentially useful indicator of individual differences in sensitivity. Whether melanin plays a role in sensitivity needs to be determined by further research.

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APPENDICES

APPENDIX A

INSTRUCTIONS TO SUBJECTS

Pressure

Please place your dominant hand, palm down on the table infront of you. Your task in this phase of the experiment will be to press this switch (E points to switch), once you feel a light touch here (E touches the appropriate area). Would you please practice pressing the switch so you get a feel for it. (Subject practices and E makes sure it is being done correctly). Now remember, press the switch when you feel a light touch. With this and following phases, you will be given a familiarization trial, so you get an idea of what to expect before the actual trial begins. Are there any questions? Would you please put on the darkened goggles. Now remember, press the switch when you feel a light touch. Ready?

Vibration

I'm going to again ask you to place your dominant hand, palm up on the table infront of you. The ping pong ball from the middle of the speaker is to lightly rest on the ball of your third finger. Now place this switch so you can easily reach it with your other hand. This phase of the experiment is divided in two parts. The first part is where the ping pong ball is steady and then it will start to vibrate. Your task is to press that switch (E indicates it) when you detect a vibration. The other half of this phase is exactly the opposite, where the ping pong ball is vibrating and then it will stop. Again you task is to press the switch when you think it's stopped vibrating. Are there any questions? Would you practice pressing the switch so you get a feel for it? You have to really press it hard. You will be given a trial of each method so you get an idea of what to expect. Are there any questions? Please put the glasses on. Ready?

Critical Flicker Fusion

Sit on this chair if you will. Do you know anything about critical flicker fusion? This phase of the experiment is different from the other three, in that you actually control the entire phase of the experiment yourself, with that switch. It was built so you could start and stop the run by pressing the switch. From the hole in the board, you will perceive either a steady light which begins to flicker or a flickering light which becomes steady. Your task is to press that switch when you detect a change. You will press that switch twice, once to start each trial and again when you detect a change. Are there any questions? You will be given a familiarization trial of each method before we start. Are you ready? Remember, this phase is entirely up to you, you press the switch to start the trial and press the switch to stop it. Would you practice pressing the switch so you get a feel for it?

Eye Colour

Now, the last task I have, is for you to stare at a spot on the wall so I can check your eye colour. (If glasses were worn these were removed.)

Debriefing

I'm working under the hypothesis that blue eyed people are more sensitive to touch than are brown, green or hazel. An opthamologist at the University of Wales looked at sensitivity as a function of eye colour. By stimulating a point in the cornea with an instrument similar to the first one we used, he found blue eyed indiviuals to have more sensitive corneas than brown, green or hazel. From there he went on to speculate that perhaps corneal sensitivity reflected overall tactile sensitivity, that is that generally blue eyed people were more sensitive to touch than the others. However, there was no empirical data to support this idea. In essence then, my thesis is an extension of his original hypothesis. By looking at pressure and vibration, I'm hoping that eye colour is correlated with these measures. The last task, the critical flicker fusion, is a replication of a study done in the States, and they did find blue eyed people to be more sensitive to that task than any other colour.

Do you have any questions about any part of this. Thank you for your time and I'd appreciate it if you wouldn't say anything to your classmates about this as I'm still testing and it may contaminate my results. When I'm finished, I'll present the results to your class as a whole.

APPENDIX B

FREQUENCY COUNT ON EYE COLOUR AND SEX

COLOUR	MALE	FEMALE	TOTAL
1	4	1	5
2	5	17	22
3	3	7	10
4	7	13	20
5	5	10	15
6	1	1	2
7	7	4	11
8	6	5	11
9	5	7	12
total	43	65	108

APPENDIX C

Table 1 First Order Partial Correlation Coefficients Controlling for Sex

	EYE COLOUR	PRESSURE (gm)	VIBRATION (uV)	CFF (cps)
eye colour		.0919	.0895	-.1830*
pressure			.2218**	-.0633
vibration				-.1801*

n=108 p<.05*, p<.01** df=105

Table 2 First Order Partial Correlation Coefficients Contolling for Age

	EYE COLOUR	PRESSURE (gm)	VIBRATION (uV)	CFF (cps)
eye colour		.0845	.0970	-.1938
pressure			.2263**	-.0919
vibration				-.1775*

n=108 p<.05*, p<.01** df=105

Table 3 Second Order Partial Correlation Coefficients Controlling for Sex and Age

	EYE COLOUR	PRESSURE (gm)	VIBRATION (uV)	CFF (cps)
eye colour		.0972	.1082	-.2476***
pressure			.2210**	-.0607
vibration				-.1605

n=108 p<.01**, p<.001*** df=104