A COMPARATIVE STUDY OF SIMPLE AUDITORY REACTION TIME AND TACTILE SENSITIVITY IN BLIND AND SIGHTED INDIVIDUALS

Dissertation submitted to

THE TAMILNADU DR.M.G.R MEDICAL UNIVERSITY

CHENNAI – 600032

In partial fulfilment of the requirement for the degree of

Doctor of Medicine in Physiology (Branch V)

M.D. (PHYSIOLOGY)

APRIL 2016

DEPARTMENT OF PHYSIOLOGY

COIMBATORE MEDICAL COLLEGE

COIMBATORE – 14.

CERTIFICATE

This dissertation entitled **"A COMPARATIVE STUDY OF SIMPLE AUDITORY REACTION TIME AND TACTILE SENSITIVITY IN BLIND AND SIGHTED INDIVIDUALS"** is submitted to The Tamil Nadu Dr. M.G.R Medical University, Chennai, in partial fulfilment of regulations for the award of M.D. Degree in Physiology in the examinations to be held during April 2016.

This dissertation is a record of fresh work done by the candidate **Dr.P.VINUPRADHA,** during the course of the study (2013-2016).

This work was carried out by the candidate herself under my supervision.

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I, **Dr. P.VINUPRADHA** solemnly declare that the dissertation entitled **"A COMPARATIVE STUDY OF SIMPLE AUDITORY REACTION TIME AND TACTILE SENSITIVITY IN BLIND AND SIGHTED INDIVIDUALS"** was done by me at Coimbatore Medical College, during the period from July 2014 to June 2015 under the guidance and supervision of **Dr.R.SHANMUGHAVADIVU, M.D.,** Professor, Department of Physiology, Coimbatore Medical College, Coimbatore.

This dissertation is submitted to The Tamilnadu Dr. M.G.R. Medical University towards the partial fulfillment of the requirement for the award of M.D. Degree (Branch - V) in Physiology. I have not submitted this dissertation on any previous occasion to any University for the award of any degree.

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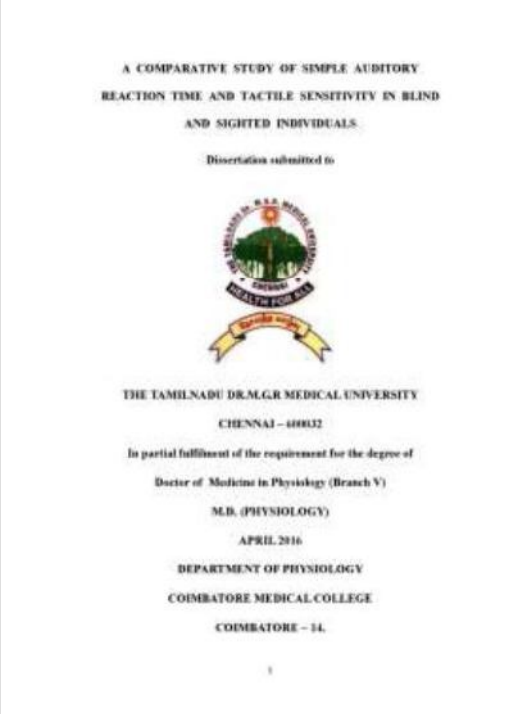

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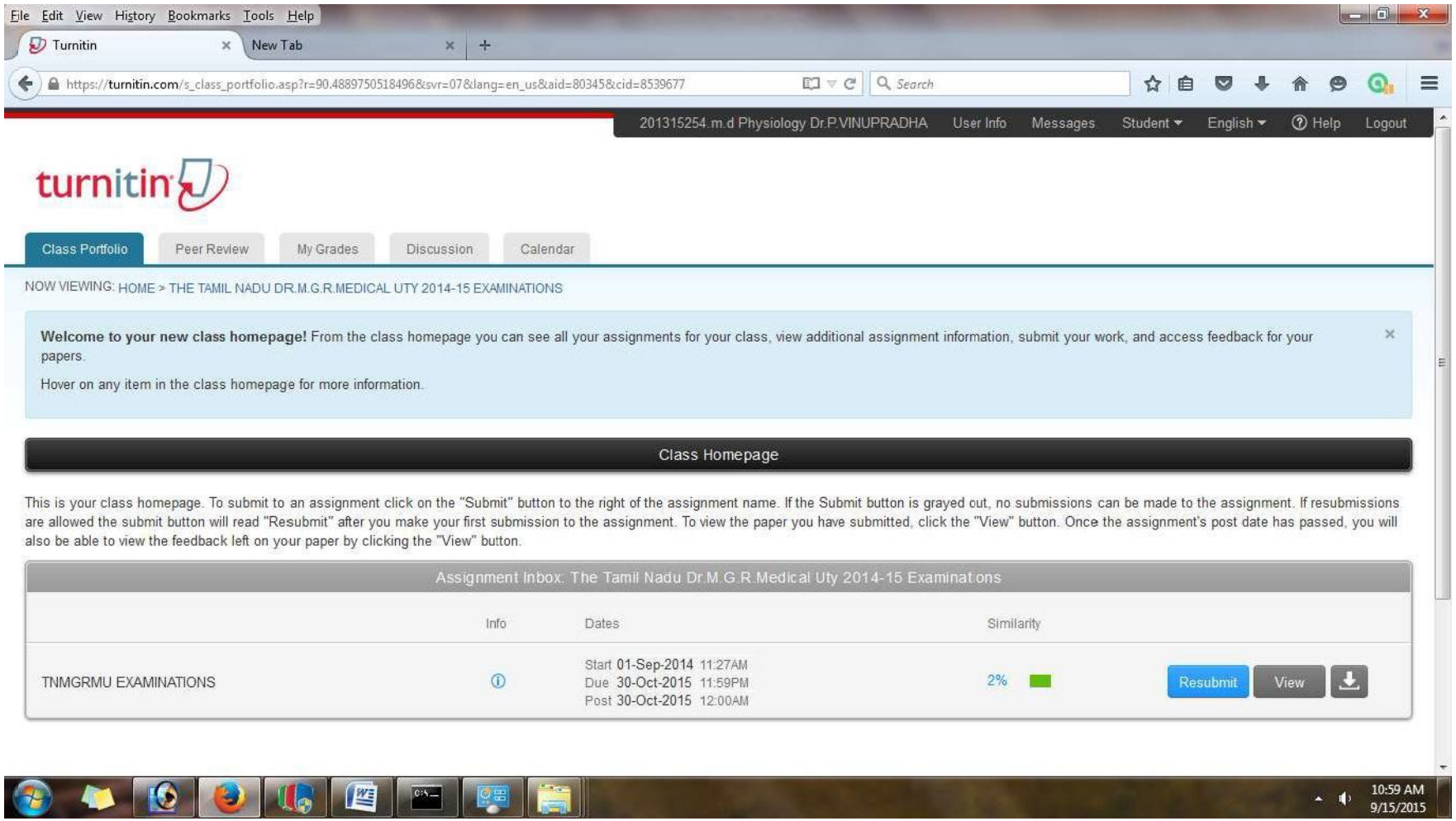
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A COMPARATIVE STUDY OF SIMPLE AUDITORY REACTION TIME AND TACTILE SENSITIVITY IN BLIND AND SIGHTED INDIVIDUALS

CONTENTS

ABBREVIATIONS

GPS	- Global Positioning System
IOI	- Inter Onset Interval
S-W Monofilament	- Semmes Weinstein Monofilament
WEST	- Weinstein Enhanced Sensory Test
VPT	- Vibration Perception Threshold
GABA	- Gamma Amino Butyric Acid
LOC	- Lateral Occipital Cortex
RT	- Reaction Time
ART	- Auditory Reaction Time
TST	- Tactile Sensitivity Threshold
BMI	- Body Mass Index

INTRODUCTION

INTRODUCTION

Man is a social creature and his development requires constant confrontation and exchange of information with the environment.[1] Sense organs play a vital role in human - environment interaction. Human beings rely on their sense organs for acquiring information about their immediate surrounding world.

Humans experience the environment through several modalities at the same time. The brain processes these information to create a coherent and unified experience of perception.[2] The multi sensory nature of perception has several behavioural advantages which includes improved recognition and rapid response to the stimuli.[3] If in case any one of the senses is severely impaired, as for instance, a person with profound loss of vision, he has to compensate by other senses to a great extent.

Over millions of years, the nature developed vision – a refined form of biotechnology to execute specific function. Since humans rely mainly on vision to acquire and construct spatial and form representations, blindness may have an unfavourable effect on spatial information processing which is congregated via other senses. In contrary, blind individuals perform better in auditory and tactile tasks.[4,5]

Blind people need to do major adjustments so as to interact efficiently with their surroundings. Since the auditory and tactile sensations are more important in detecting manual location, recognition and manipulation of objects, blind people tend to use it. As a consequence, the blind people can identify and use objects in a rapid, improved and more effective manner than sighted people, using touch and audition.[6] This enables them to overcome challenges and to carry out day to day activities safely with less dependence upon their care givers.

Blindness provides the scientific community , an exceptional model of how the brain adapts to significant alteration within the environment. An emerging harmony suggests that blind people especially congenital blind show massive reorganisation of functions in occipital areas which is normally dedicated to vision so that they respond to other sensory modalities.[2,3] These reorganizations are often accompanied by behavioural enhancements, particularly in auditory and tactile domain.[7] Auditory localisation and response to it, is highly relevant for proper navigation within the environment, when visual inputs are no longer available.

There are many more evidences for the excellence of blind people. Blind people, being more talented in musical field were appointed as traditional court musicians in ancient China. In ancient Rome, blind boys were employed as Oarsmen.[8]

Some of the famous blind personalities who excelled in different fields were Louis Braille - inventor of a reading system for Blind, Helen Keller- an author and lecturer, Ray Charles - an American pianist, John Milton - a poet, Joseph Pulitzer - a journalist, Eric Weishenmayer – a mountaineer who scaled Mt. Everest and Mark Runyan - Olympic runner. The superior ability of using other senses by blind people gave the opportunity to be employed as detectives in Belgian police department which was reported by many newspapers in 2007. They analysed the telephone call tapes and segregated individual voices accurately in a mixture of voices and sound. Thus they were able to infer the details of the suspect's talk.[7]

Since the end of 19th century pragmatic researches on the phenomenon of sensory substitution in blind subjects were done showing varied results, some confirming the blind subject's ability to compensate visual loss, while some others contradicted.[9] The varied results were thought to be attributed to the problem in methodology, selection criteria and non - matching control participants.[10] It was only after mid 1990s the neuropsychology field aimed at obtaining more concise details about the neural plasticity and the human's ability of adaptation to different sensory interaction with the surrounding. From then studies took into consideration stringent sample selection criteria, degree of blindness, excluding participants with other disabilities etc.

According to the World Health Organisation (2014) estimation there are about 285 million visually impaired people globally, of which 39 million are blind and 246 million suffer from low vision. Almost 90percent of visually handicapped people reside in developing countries.[11] India has 8 million blind and 62 million visually impaired persons.[12]

Loss of vision causes remarkable social challenges more in connection to the activities in which blind people cannot take part. The inability of the blind people to perform many job functions severely restricts their employment opportunities. This may not only affect their economy but also their self esteem.

The production of effective, affordable, user friendly sensory devices for the blind is possible because of today's rapid revolution in human - machine interface by extensively using their superior capabilities in tactile and auditory sensation. The application of echo location and sonar system will open the way for the blind people to involve in recreational and social activities with the sighted social group. It will improve their self confidence and persuade them to learn skills that allow them to uphold a productive employment.

The focus of intervention is to develop new solutions for these blind individuals to interact with the sighted people and the external world in a way that lessens any of the problems that can arise from being blind.

To gain insight towards these solutions basic studies need to be done involving blind subjects, as to how they perceive sound and touch.

The experiments testing the domain of hearing and touch senses in blind and sighted controls is the scope of this present study. Alertness of individuals, particularly blind persons in response to external stimuli is very critical for their day to day activities. Apart from auditory and visual stimulus modality the human - machine interfaces extensively use tactile modality nowadays. Hence the response to an auditory stimuli in the form of reaction time measurement and the sensitivity of the skin to detect the lowest possible tactile stimuli (Tactile Sensitivity Threshold) were determined to draw a hypothesis.

Auditory Reaction Time is defined as the time interval from the execution of an auditory stimulus to the occurrence of suitable voluntary response as swiftly as possible.[13] It is an estimation of sensorimotor association. While evoked potentials proved enhanced auditory performance,[14] the reaction time calculates the alertness of a person - how rapidly a person reacts to a stimulus. The wide use of auditory modality in transport, industries and health care systems has an instant awakening effect.[15]

Touch is the earliest sense to develop in the human system and it plays an integral role in biological, cognitive and social development.[16] Touch not only helps one to feel things closer or in contact with us, but also used remotely with special tools such as the white cane

(international symbol of blindness) providing vibratory and pressure information for a blind person.

Tactile Sensitivity Threshold is the minimum amount of touch that can be detected. Semmes Weinstein Monofilament is a simple to use instrument that measures accurately and provides an absolute numerical record for comparison.[1,17]

Though several recent papers use the cross modal plasticity concept to model and explain the psychophysical experiments, there are only a few outputs in the Indian settings and that too not as the core of reasoning. Hence this study aims to compare the response of blind and normal sighted subjects to auditory and tactile stimuli.

AIMS & OBJECTIVES

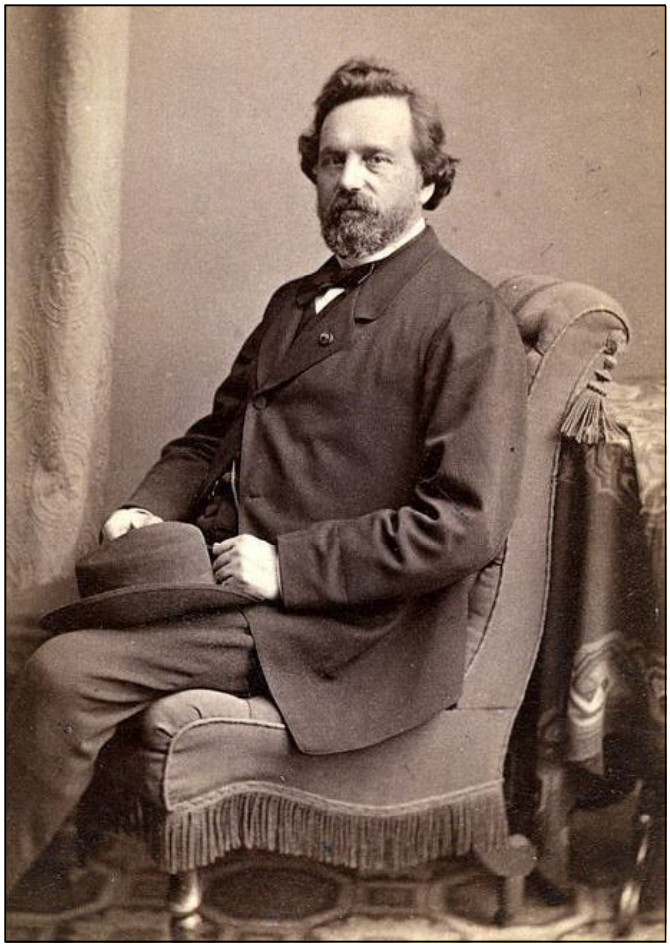
AIM AND OBJECTIVES

- To determine and compare the auditory reaction time in blind and normal sighted subjects

- To determine and compare the tactile sensitivity in blind and normal sighted subjects

- To analyse the influence of various factors like age, gender, body mass index that may associate with auditory reaction time and tactile sensitivity in blind and normal sighted subjects

REVIEW OF LITERATURE



FRANCIUS CORNELIS DONDER

Born	***: May 27, 1818, Tilburg, Netherlands***
Died	***: Mar 24, 1889, Utrecht***
Nationality	***: Dutch***
Speciality	***: Physiology, Ophthamalogy***
Field of Interest	***: Reaction Time in Human***

REVIEW OF LITERATURE

REACTION TIME

The capability to adjust with the environmental modifications for survival and existence is determined by the reaction of the animal. The rapidity of response pivots on the sensory perception, central processing and motor response.[15]

HISTORY OF REACTION TIME

Franciscus C. Donders, a Dutch physiologist was the first scientist to measure reaction time in the laboratory. Until 1865, it was believed that mental processes were so fast so that it cannot be measured. Donders was interested to measure the duration for execution of basic mental processes. He applied electric shocks to the subject's foot separately. When the right foot received the shock, the subject had to press a telegraphic key with his right hand and with left hand for left foot. In one group, the foot which was going to receive the shock was known in advance and the other group subjects were not aware of it. Donders noticed that the difference was 1/15 second between these two conditions. This was the first computation to estimate the duration of a comprehensive mental process. It was in concern with the determination of a choice and an effort of the will in response to that determination.

Donder’s ability to calculate such a brief period precisely was facilitated by Englishman Charles Wheatstone and Mathias Hipp. The Hipp Chronoscope was rotated constantly by a motor, powered with a heavy weight. While measuring the reaction time, it prevented the movement of indicating hand on its dial by a clutch. An electrically energised solenoid was used to hold the clutch in disengaged position. Interruption in the electric current engaged the clutch and rotated the dial swiftly and the re- establishment of the current caused disengagement of the clutch which stopped the dial. This exhibited the elapsed time in thousands of a second. The Hipp Chronoscope unfortunately had a number of serious problems producing inaccurate readings. Willhelm Wundt, built an elaborate laboratory and research programme that focussed on the accurate calculation of psychological processes or "MENTAL CHRONOMETRY. His demand on accurate measurement of reaction time has a powerful impact on the proposal of psychological experiments even in current days.

Another instrument 'CONTROL HAMMER' was designed to standardise the calibration for the Hipp’s Chronoscope and the problem with it was the control hammer itself needed to be calibrated. 'CHRONOGRAPH' another apparatus which accurately measured significantly brief intervals was invented. The chronograph consisted of a revolving cylinder wrapped with a paper smoked with soot.

A 1000Hz frequency tuning fork which had a beard hair glued at its prong was used to draw a wavy line in the time duration of 1 millisecond (1/1000 second).[18]

Donders established that simple reaction time was the fastest followed by recognition reaction time and choice reaction time. [19] Simple reaction time is one response given to a single stimulus and recognition reaction time is the response given to some of the stimuli and not to others. The choice reaction time includes multiple response for multiple stimuli.[13] He also used a subtraction method to calculate the duration for mental processing. By subtracting simple reaction time from choice reaction time, he calculated the reaction time.

DEFINITION

Reaction time is defined as the time interval between the stimulus application and appearance of appropriate voluntary response as rapidly as possible.[13] Reaction time measurement constitutes a simple, non- invasive tool for assessing peripheral and central neural structures, thereby gaining physiological importance.[49]

In day to day life, one has to react immediately to various situations. Examples of reaction time are many simple situations that occur usually in our daily life experience itself e.g. response to a door bell, whistle of pressure cooker or telephone ring.[19]

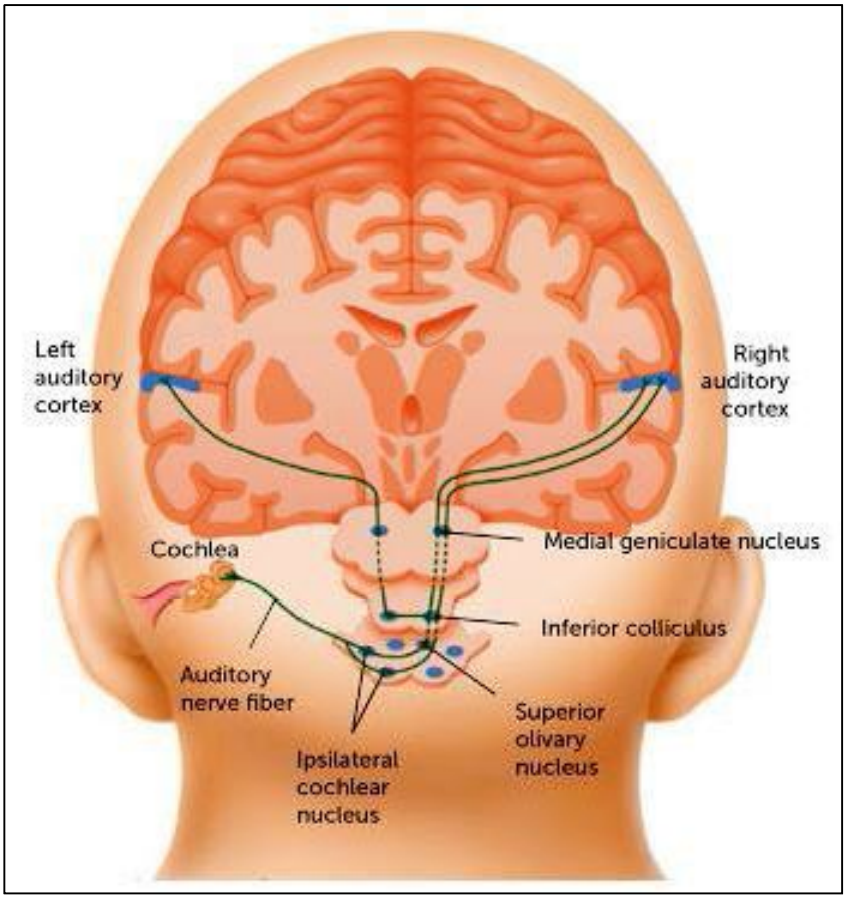
COMPONENTS OF REACTION TIME

Reaction time has three components. (i) Perception Time, (ii) Decision Time (iii) Motor Time. PERCEPTION TIME , the first part, is the time for the application and perception of stimulus. DECISION TIME or COMPREHENSION TIME the second part signifies the time for understanding the type, duration and direction of stimulus. The third part is MOTOR TIME, that is the time for the amenability of the order accepted. [19]

Reaction time is crucial for our day to day lives and intact sensory system, cognitive processing and motor performance are essential for it. It denotes the alertness of a person, the rapid response to a stimulus is based on his reaction time . Therefore it must be lower in certain occupations like Drivers, doctors, pilots, nursing staffs, military people, security guards and sportsmen where alertness is essential for society.[19]

Stimulus → receptor → afferent → integrator → efferent → effector → response

The stimuli could be auditory, visual or tactile and the integrator may be the spinal cord or brain.[13]



AUDITORY PATHWAY

TYPES OF AUDITORY REACTION TIME

- Simple reaction time : one response is observed for one given stimulus.
- Recognition reaction time : response given to certain stimuli and not to others. Yet the correct response is only one.
- Choice reaction time : multiple stimuli with multiple responses. This is more complex and needs longer duration than other reaction times.

Reaction time is influenced by multiple elements like the stimulus arriving at sensory receptor, transformation of the mechanical stimulus to a neural signal by the sensory end organ, neural transmissions and signal processing, muscular activation, soft tissue compliance, and also the selection of an external measurement parameter.[20]

Since auditory pathway is relatively shorter than the visual pathway, the auditory stimulus reaches the cortex faster than the visual stimulus (8-10msec).[21] An early study of Galton assessed that mean reaction times were 158msec for sound stimuli and 187msec for visual stimuli in teen agers (15-19yrs).[21] Differences in reaction time also depends on whether the subject is requested for a simple or complex response. Saville et al. (2012) observed that people with variable reaction time to a visual stimulus also had variable auditory reaction time.[22]

FACTORS INFLUENCING AUDITORY REACTION TIME

Reaction time is found to be influenced by physiological as well as pharmacological factors. They are –

- AGE
- GENDER
- HANDEDNESS
- AROUSAL
- TYPE OF PERSONALITY
- FASTING
- DISTRACTION
- PUNISHMENT
- INTELLIGENCE
- STRESS
- PRACTICE
- FATIGUE
- EXERCISE

AGE

Simple reaction time decreases from childhood period to the late 20s, and then gradually increases up to 50s, and thereafter prolongs rapidly as the person gets into his 70s and above. [23] Jevas and Yan (2001) stated that age associated decline in reaction time was similar for both males and females. Welford speculated that the reason for age related increase in reaction time was not just the ordinary mechanical factors like the velocity of nerve conduction.[23] This may be due to the propensity of elderly people to be more cautious and observe their responses more completely postulated Botwinick.[24] MacDonald et al. suggested that older adults were usually associated with a worse recognition of stimuli, and slower reaction time. The inconstancy might be an effective tool to measure the general neural integrity.[25]

According to Anupama Batra, the probable causes for the delayed responses are Axonal shrinkage and Axonal degeneration that occurs as age advances. Aging lengthens the duration of mental processing time and also reduces the velocity of neuronal conduction or due to lack of co – ordination as age advances, especially during rapid movements. The lack of co-ordination might be due to inability to preserve an adequate equilibrium between agonists and antagonists muscles. Decline in motor skills as age increases could also be a reason.[19]

GENDER

Consistently in all age groups, males reacted faster than females, and practice did not reduce it.[26] Bellis reported that mean reaction time to sound was 200 msec for females and 190 msec for males,[27] whereas Engel observed the difference to be 242msec (female) and 227msec (male).[28] Adam et al. observed that males apply a more intricated strategy compared to females.[29] Even though males had faster reaction time , the females were more accurate on aiming at a target.[30]

HANDEDNESS

The cerebral hemispheres are specially designed for non identical tasks. The left half of the brain is considered as verbal and logical brain, and the right half is speculated to control creativity, face recognition, spatial relations, and emotions. Usually the left hemisphere commands the right hand and the right hemisphere commands the left hand, and we may think that the reaction time for the left hand should be shorter when involved in spatial relationships such as pointing at a target.

Dane and Erzurumluoglu observed that the left handers react rapidly with their left hand but no difference in the reaction time between the right and left handers while handling with right hand in hand ball players.[31] But Peters and Ivanoff noticed that right handers

were rapid with their right hand and in left – handers, it was same with both the hands.[32]

Usually the preferred hand is generally faster, but a point to be remembered is that preferred hand can never be a good guide to decide which hemisphere is dominant. In a majority of people, a dominant right hand denotes a dominant left hemisphere. However, in 20%-25% of right – handed people, the right hemisphere is dominant, in whom the response time for the right half of body was prolonged because the instructions had to be initiated in the right half of the brain and then cross over to the left half, and then to reach the right hand.[33] Musicians seem to have an equally competent hemispheres to pay attention to stimuli than non-musicians, and their reaction times is decreased as well.[34]

STIMULUS INTENSITY

The longer the duration of the stimulus, the faster the reaction time, reported Wells. The weaker stimulus produces the longer reaction time. However, reaction time becomes constant after the stimulus gets to a certain strength.[35]

AROUSAL

The most scrutinised component influencing reaction time is 'arousal' or the state of attention. Reaction time is faster with an intermediate level of arousal, and deteriorates while the subject experiences extremes of emotions.[23]

Etnyre and Kinugasa concluded that subjects response by extending their leg to an auditory stimulus had shorter reaction times when they executed an isometric contraction exercise of the leg muscles for 3 second before the stimulus. It was in such a way that the isometric contraction enabled the brain to act swiftly .[36] A similar finding was obtained by Masanobu and Choshi[37] also. They observed that not only the isometric exercise but also the moderate muscular tension (10% of maximum) decreased the pre-contraction reaction time of subjects in a choice reaction time task. Ironically, muscle tension had no influence on movement time. It is also proved by Davranche et al. that exercise enhanced reaction time by the state of arousal.[38]

PRACTICE AND ERRORS

Visser et al.[39] established that training decreased the reaction time and improved the precision on a complex task. Various studies showed that adequate amount of practice reduced the reaction time than when subjects were unfamiliar to a reaction time endeavour.[35,40]

FATIGUE

Welford observed that reaction time increased when a person is exhausted.[23] Singleton also noticed that the lengthening of reaction time due to exhaustion is more pronounced to complicated tasks than with simple tasks. Mental fatigue has greater effect than physical fatigue.

DISTRACTION

Welford[23] reviewed studies showing that distractions increase reaction time. Bertelson [41] found that reaction time is shorter when the warning is shorter. This occurs probably because the ability to maintain muscle tension and attention at a peak level is possible only for a few seconds.[42]

Trimmel and Poelzl observed that background noise inhibited some parts of cerebral cortex which in turn increased the reaction time.[43] Richard et al. (2002) noticed that reaction time was prolonged when a simulated driving task was given to the college students simultaneously with an auditory task.[44]

ALCOHOL

The harmful effects of alcohol on reaction time has been reviewed by Moskowitz and Fiorentino (2000).[35] Hernandez et al. concluded that alcohol prolonged the reaction time by decreasing the muscle activation and not the muscle action.[45]

ORDER OF PRESENTATION

Welford observed that reaction time is faster when several stimuli are given in an identical order as a “run” pattern rather than applied in a mixed order. This is called the "sequential effect.[23,35]

PERSONALITY TYPE

It was noticed that anxiety (Welford) and extroverted personality (Brebner) reduced the reaction time. [23,39]

Apart from the above mentioned factors, Robert J. Kosinski of Clemson University in his Literature Review says a type of stimulus, number of valid stimuli, breathing cycle, brain injury, finger tremors, affective priming, stimulant and depressant drugs, illness and learning disorders also influence the Reaction Time.[39] More complicated tasks also demonstrated increased reaction times. The "memory drum" theory, was suggested by Henry and Rogers (1960) also reviewed by Klapp (2010) denoted that more complex responses took longer time as it required more stored information.

Nikam LH et al. showed that BMI, ART and VRT were significantly higher in older age groups. Since females had higher BMI they had longer reaction time than males. Prolonged reaction time in females with higher BMI could be due to fluid and salt retention produced by female sex hormones which affects sensorimotor co-ordination. [46]

Shenvi and Padma, observed that reaction time showed no significant difference for low pitch sound and high pitch sound stimuli in either males or females. [47] N Misra compared simple visual and auditory reaction time of feet and hands in normal male and female subjects, using an electric circuit and showed ART was significantly faster in the hands than feet. ART showed a delayed response on the left side (both foot and hand), which was more marked in feet than hand.[48]

Namita, Din Prakash Ranjan, Dhangauri N. Shenvi observed a statistically significant difference between males and females for ART and VRT during both the day and night shift in a hospital and it was higher in females. Though the reaction time was found to be more during the night shift as compared to day shift, the difference was not significant.[49]

Sugata Jadhav, Nishant Bansod, Saroj Diwanji studied the reaction time in various phases of menstrual cycle and observed that reaction time in premenstrual phase was significantly increased than post menstrual phase in females.[50] S.Das[51] also observed these changes and it may be due to the fluctuating levels of estrogens and progesterone during the menstrual cycle. These hormones may affect the auditory processing by enhancing the inhibitory effect of neurotransmitter GABA and also the availability of neurotransmitters at the synapse. [50]

The results were similar in studies done by Nene AS, Pazare,[52] Sunil Kumar et al.[53] and Pawar et al.[54]

The progesterone, by non genomic action inhibits adenyl cyclase. The metabolites of progesterone acts in the brain by binding to $GABA_A$ receptor and increase the affinity to GABA. It favours influx of Cl^- ions in to the cell and hyper polarise the cell. Thus the neural transmission is inhibited. Also elevated aldosterone level in luteal phase causes fluid retention by acting on mineralocorticoid receptors.[55]

Following exercise, a remarkable reduction in reaction times was observed and it was more obvious in males compared to females. Overall, there is moderately high support that exercise reduced reaction time, and the outcome can be implicated in athletic events. This result is validated by the fact that exercise increases heart rate as a physiological response, that suggests an arousal state. It is proposed that moderate exercise persuaded an arousal state that increased the cognitive function. It may be possibly due to the increased blood flow to the brain and muscle, which in turn allowed a rapid information processing and thus decreased the reaction time.[56] Ajay M. Gavkare observed that the reaction time was shorter in athletes which could be due to improved concentration, perfection in task, better muscular coordination, enhanced performance in the speed.[15]

Vandana S, Daulatabad in her study showed that the reacting ability of sprinters were faster and quicker than controls, that definitely

affected sprint performance. This finding is of appreciable interest for coaches and athletes in sports involving reaction skills.[57]

R. Niruba and K.N. Maruthy[58] and Prabhjot Kaur[59] assessed Auditory and Visual Reaction Time in diabetic patients and reported that auditory reaction time was prolonged in them compared to normal individuals. Raised blood glucose affects many metabolic pathways in the nerves which leads to accumulation of sorbitol and depletion of myoinositol. The excessive glucose inhibits nitric oxide production thus reduces the blood supply to nerves. These changes impair the ability of the nerve to transmit signals.

Walia, Lilyin studied the effect of Cold Pressor Test (CPT) on visual and auditory reaction time. It showed an increase in VRT and ART with CPT which was probably due to the decreased conduction velocity of nerves. The mechanism could be the cold and pain induced increased sympathetic activity which in turn causes vasoconstriction.[60]

Study of reaction time in smokers by Ichaporia RB, Kulkarni reported that the basal ART was significantly lower than normal and further reduced significantly after smoking one cigarette. The decrease in ART after one cigarette probably could be due to the stimulant action of nicotine on the nervous system.[61]

Annie W.Y. Ng and Alan H.S. Chan stated that the human-machine interfaces regularly apply the auditory and visual stimuli

modality nowadays, and the application of tactile modality is also increased. These modes of input / output channels are employed in the designing of smoke detector alarm, communication systems in military, lighting adjustment system, vehicle driving systems, and many other industrial applications to provide the timely alert information.

Auditory modality is vastly used in industries, transport and health care system and it has an instant arousal effect whereas tactile modality finds its application in unmanned aerial vehicle ground control station simulation. The recent technology of using touch navigation display system in cars give a better driving experience and reduction in workload. Now a days multi sensory alert system is gaining popularity that applies integration of auditory, visual and tactile systems. The combination of various stimulus modalities should be appraised in subsequent studies so that a more user friendly human – machine interface can be designed.[62]

Clara Suied and Patrick Susini pointed out that sound system is widely used in hospitals and airlines navigation systems to provide information. Recently, the usage of sound modalities in cars to give warning signals, Global Positioning System (GPS) based navigation systems, and adaptive cruise control system aid the drivers to overcome potential dangerous events by providing timely alert.

The conclusion was a decrease in IOI (Inter Onset Interval) reduces the RT. IOI is defined as the time interval between the onset of one

sound pulse to the onset of the next. IOI can regulate the warning sound systems and the temporal irregularity may arouse the listeners.[63]

Reaction time to the tactile stimuli was notably shorter, followed by the auditory stimuli and then the visual stimuli. The visual reaction time was 34% longer than tactile response time and 5% longer than auditory reaction time. The auditory reaction time was 28% longer than the tactile response time. The response to the auditory and visual stimuli is influenced by various factors like age, gender, education level, choice alternative, time spent on computer, and preferred / non - preferred finger. The reaction time declined up to 21-30 years after which, the reaction time prolonged slowly as the age increased.

The reaction time of the females was observed to be shorter than males. The primary education status significantly increased the reaction time than that of tertiary and secondary education status groups. Besides, the reaction time is proportionately shorter as the time spent on computer in daily life increases.

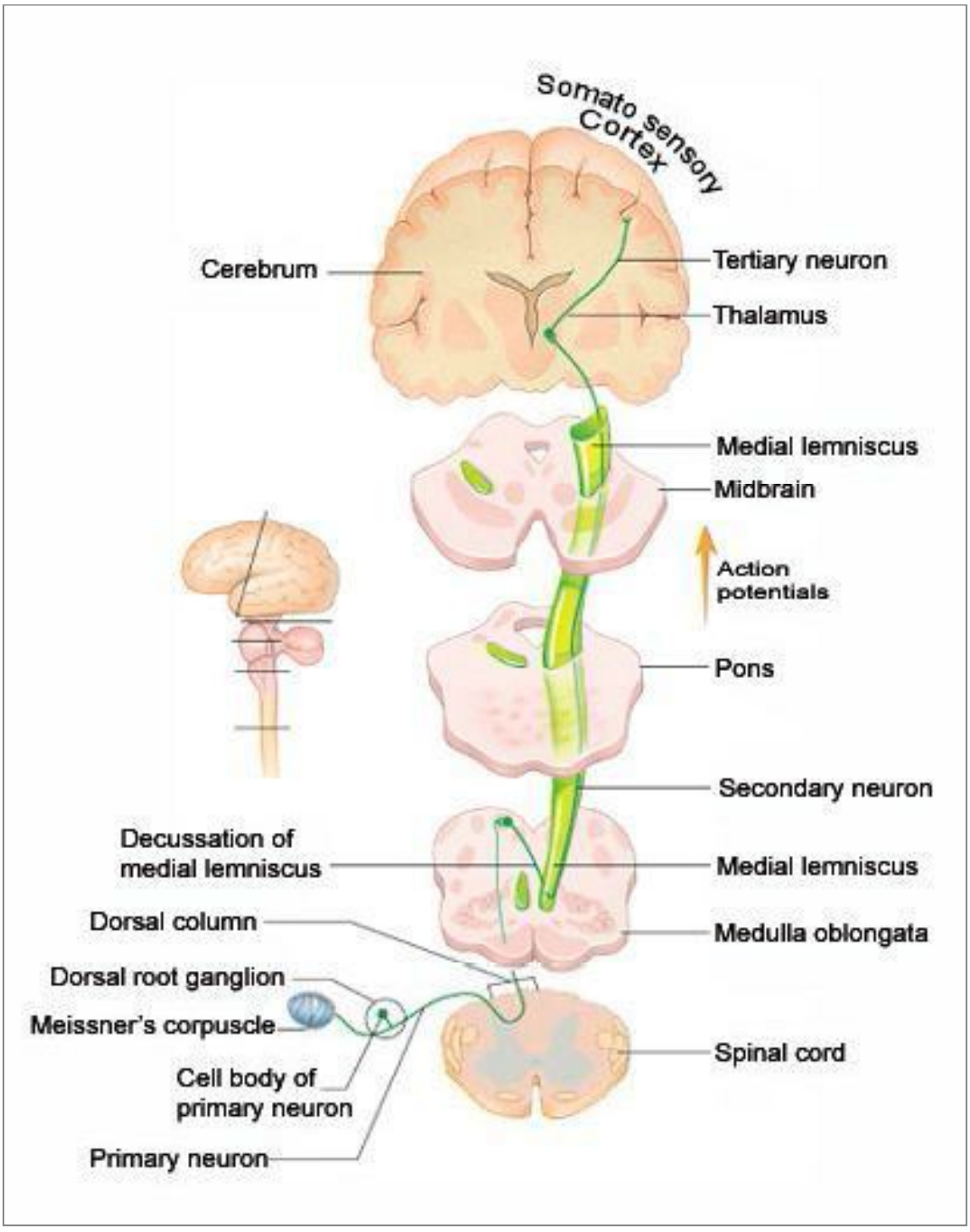
It is observed that the left finger response time was longer than the right finger response time. Apart from that, single choice task had faster reaction time, followed by a two choice task and so on. The response time to the tactile stimuli did not depend on the tactile location i.e. wrist or the leg.[62]

Vivek K Sharma et al reported that both yoga training and physical exercises were more effective in reducing the effect of examination

stress on reaction time and the effect of yoga was immediate and more pronounced than physical exercise in Young Female Medical Students. [64]

TACTILE SENSITIVITY

Touch is critical for our social and emotional lives. Perhaps the most biologically valuable and socially cherished sensation is touch. Our skin is the largest sensory organ, and it is one of the most important sensory organs.[65] Skin is a highly complex organ supplied by receptors which mediate tactile sensation, temperature, pain, as well as itch. A new born deprived of touch fails to thrive and may even die without any other deprivation. The touch sense is very important in manual location, handling and recognition of objects. Touch allows us to explore and manipulate the external world and it is fundamental to human interaction.[67] The first sense to be developed in an embryo is touch, and the first site on the human body to develop touch sensibility are the ones that have the largest representation in the primary somatosensory cortex.[1] Apart from skin, touch can also be elicited from lips, mouth, tongue, gums, throat, oesophagus, trachea, periosteum, tendons, and muscles. All hollow organs, many blood vessels and brain are insensitive to touch.[66]



TOUCH PATHWAY

Touch or the cutaneous sense or exteroceptive sensation which arise from the surface of the body can be divided into two groups.[68]

1**. EPICRITIC SENSATION** – mild or light sensation that is perceived more accurately. These include

Fine touch or tactile sensation is the light touch arising from the surface of the body.

Tactile localisation is the ability to locate the area of skin where tactile stimulation is applied.

Tactile discrimination is the ability to locate the two adjacent areas of skin where tactile stimulation is applied.

2. **PROTOPATHIC SENSATION** – primitive or crude sensation. These include

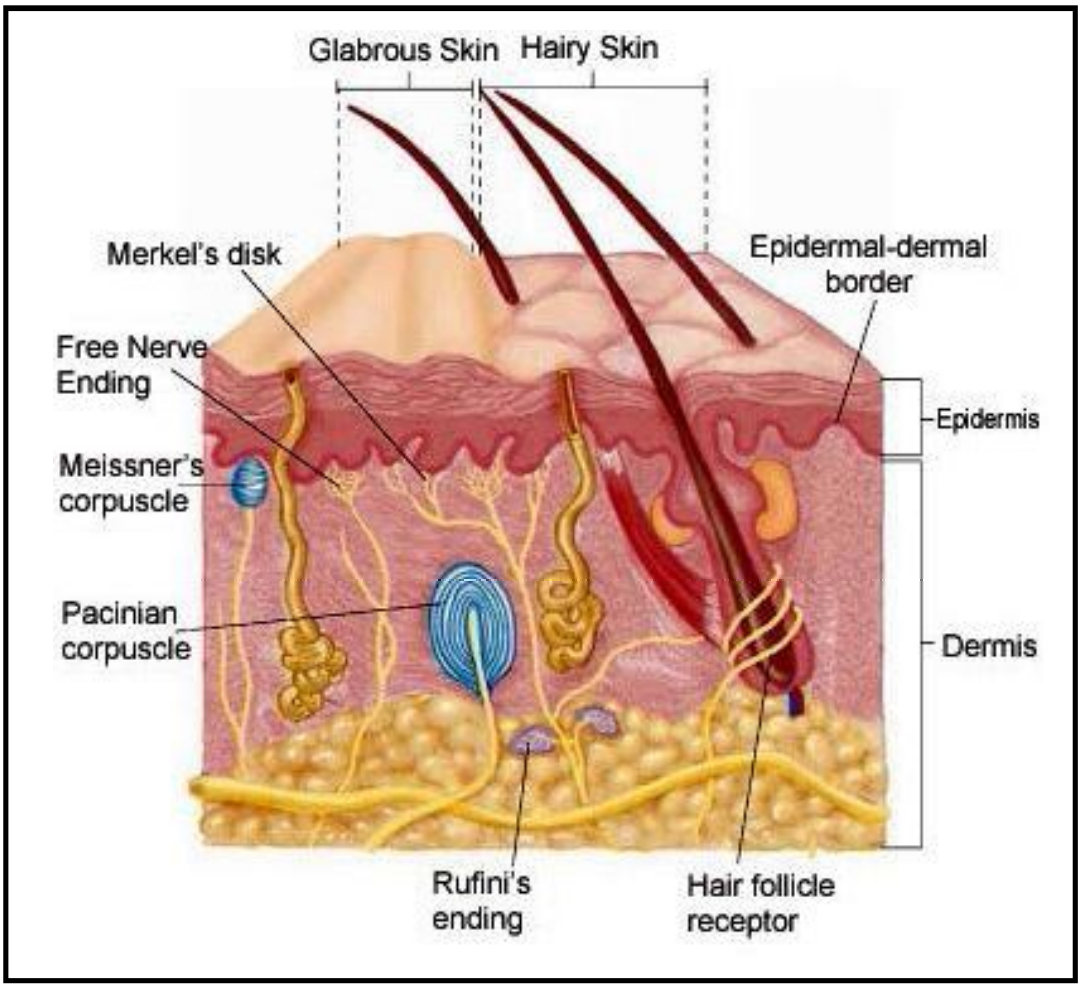
Pressure sensation

Pain sensation

Temperature sensation

Also the touch sensation has discriminative and affective functions. The discriminative functions register the spatial and temporal occurrences on the skin and the affective functions register pain and positive emotional experiences related to touch.[65]

We have two main types of skin, glabrous skin (non- hairy skin) on the palms of the hand and on the sole of the foot and hairy skin on rest of the body.



STRUCTURE AND LOCATION OF RECEPTORS IN SKIN

The glabrous and hairy skin serve different functions which are reflected in their different innervations. Various sensory inputs are processed in the spinal cord and brain which makes us aware of how we should respond to the stimulation. [65] There are several different skin receptors that mediate different aspects of touch and those signals travel in different types of nerve fibres.

RECEPTORS

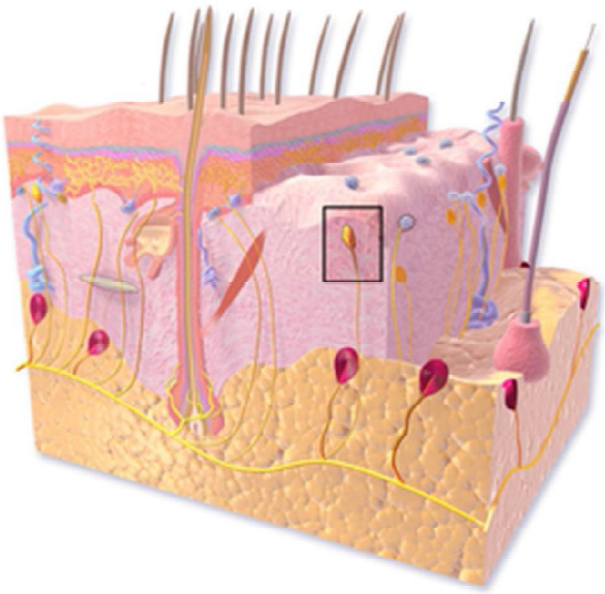
Sensory receptors are specialised cells which receive the stimuli from the external or internal environment. They transduce these signals into neural signals.

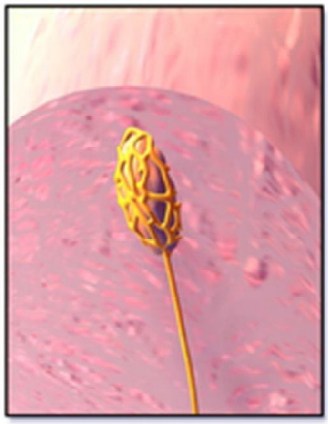
A stimulus is a change of environment of sufficient intensity to evoke a response in an organism. The external stimuli may be mechanical, chemical and thermal.

Cutaneous receptors for tactile sensibility are

- Free nerve endings
- Meissner's corpuscles
- Merkel's discs
- Pacinian corpuscle
- Ruffini's end organ
- Krause's end bulb
- Hair end organs

Of these various receptors, Meissner's corpuscles and Merkel's disc are present densely in glaborous skin particularly in finger tips.[66,68,69]





Tactile Corpuscle

(Meissner's Corpuscle)

Apart from the above classification the receptors can be divided into

- Rapidly adapting receptors
- Slow adapting receptors

The discharge of impulses set up by stimulation of the receptor diminishes in frequency but not in amplitude and later disappears even though the stimulus is applied continuously with the original intensity. This phenomenon is called adaptation.

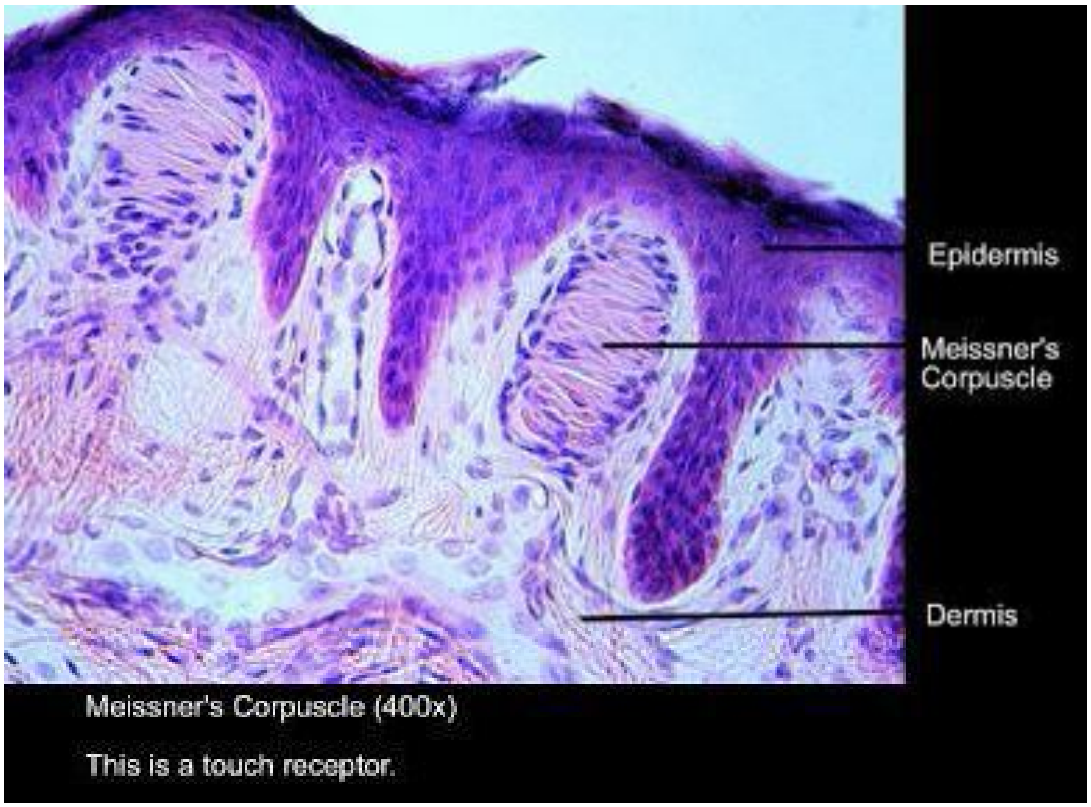
Slow adapting receptors (e.g Merkel's disc) also called static or tonic receptors in the skin produce a repetitive discharge in response to a prolonged stimulus whereas Rapidly adapting receptors also called phasic or dynamic receptors, fire action potential at a decreasing rate during the same stimulus application. e.g Meissner's corpuscle.[69]

STRUCTURE AND LOCATION OF MEISSNER'S CORPUSCLE

They are small encapsulated receptors supplied by A beta type of myelinated nerve fibers. They are present in non hairy parts, especially finger tips, lips, nipples, and orifices of the body.

RECEPTIVE FIELD AND FUNCTION

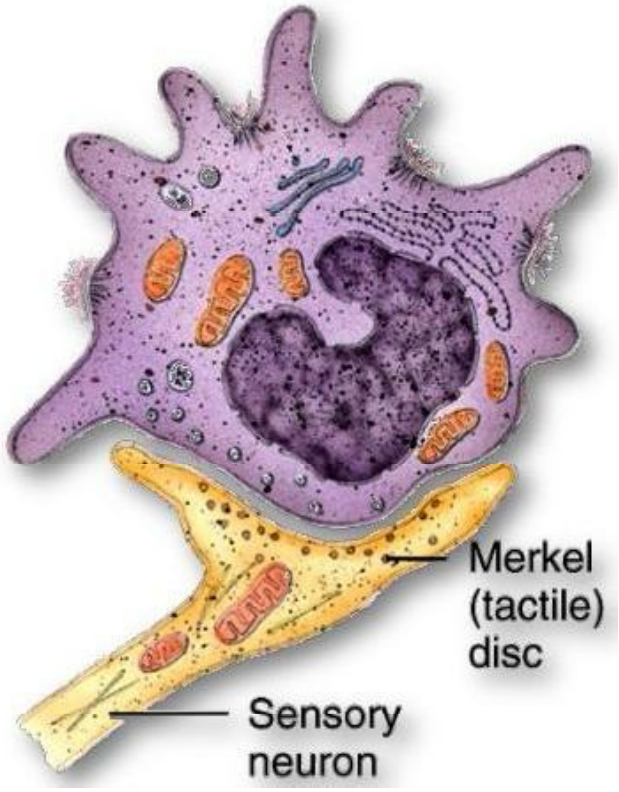
These receptors can be stimulated only by deformation of the small region of the skin lying just above the receptor i.e they have a small receptive field. They are used to detect the rate of stimulus



HISTOLOGY OF MEISSNER'S CORPUSCLE

Merkel Cells

- On Merkel (tactile) discs
- Respond to touch stimuli



application when the skin is moved over an object. This is especially important to blind people using Braille.

STRUCTURE AND LOCATION OF MERKEL'S DISC

Merkel's discs are the most superficial mechanoreceptor present in the epidermis of both hairy and non hairy skin. They are unique because the transducer is not the nerve terminal but the epithelial cells (merkel cell) that make up the disc. The merkel's cell along with merkel's disc are called merkel apparatus or Iggo – dome receptors. The merkel's cells form synaptic connections with branches of a large single group II afferent myelinated fibre. They are present abundantly at finger tips, lips, nipples.

RECEPTIVE FIELD AND FUNCTIONS

They have a small receptive field which is used to detect the location of a stimulus. Along with Meissner's corpuscles, they play an important role in localising touch sensation. They also help in determining the texture of what is felt.[66,67,68]

METHODS OF TESTING TACTILE SENSATION

Direction of movements across the skin is also used as a method to quantify tactile sensibility.[65] Although touch sensitivity is a genetically conditioned trait, it can also be modified by varied environmental factors like the physical activities, to a great extent.[67]

Tactile sensation is measured by Different forms.

Tactile threshold,

Tactile contrast,

Two point discrimination,

Tactile spatial frequency,

Grating discrimination etc .

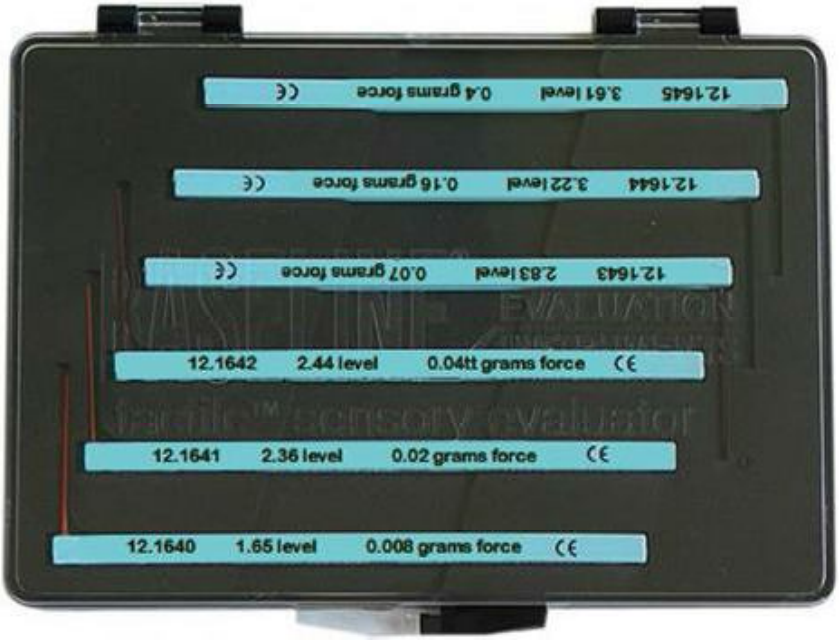
TACTILE SENSITIVITY THRESHOLD

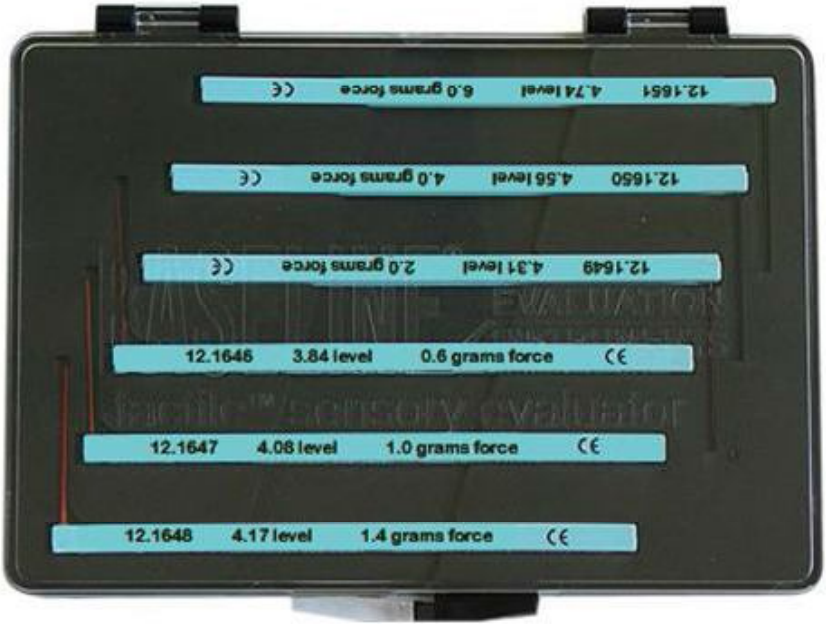
Tactile Sensitivity Threshold is the smallest, lightest amount of touch that we can detect.[69]

The instrument used for determining the tactile sensitivity of the skin is known as esthesiometer and the method of measuring the level of tactile sensitivity is termed as esthesiometry. Sir Edward Henry Sieveking, an English physician born in Bishopsgate, London was the first to devise esthesiometer in 1858 for measuring tactile sensitivity of the skin.

Esthesiometers are available based on specific task for which it is applied.

1. A caliper like manual device with adjustable points is used to determine the smallest distance between two distinguishable sites on the skin.





SEMMES-WEINSTEIN MONO FILAMENT

2. Dr.Weinstein designed a 3 point esthesiometer which is used to identify between two points and an equal area of one point i.e the addition of areas of two points is equal to the third point.

3. Touch or pain threshold can be measured by another type of esthesiometer which is made of nylon monofilaments. These filaments are numbered according to varying degree of calibrated diameters in proportion to the force that is applied. The force required to make the monofilament buckle upon contact with skin determines the tactile sensitivity.

Sensibility Testing with the Semmes - Weinstein Monofilaments in Rehabilitation of the Hand by Judith A. Bell – Krotoski provides the extensive details about s Semmes Weinstein monofilament.

Von Frey, the scientist who discovered the monofilament method of testing tactile sensitivity used the hairs to determine only the normal threshold levels. But Dr.Weinstein used hairs with full range of forces with the objective of determining the level of functional loss also.

The S-W monofilament device is a simple, hand - held, practical testing method which also finds its application in clinical practice, aiding in detecting early peripheral nerve disorders. The test is highly sensitive, reliable and provide a valid colour peripheral nerve mapping.

Another advantage of this device is that it decreases the vibration of examiner's hand.

The monofilament evaluation is a simple to perform test and also measures precisely. It gives a definitive pictorial and numerical data of sequential measurements of the same patient, or among different group of patients, for comparison with and without treatment, in different parts of the body and abnormal areas can also be mapped exactly. Due to the presence of callus, the plantar aspect of the foot requires additional inputs for detecting the tactile threshold. There are two types of Semmes Weinstein monofilament kit, the long kit and the mini kit. The mini kit is used more in clinical set up whereas the long kit is widely used for research purposes.

Even though the force applied by the monofilaments in the minikit donot overlap, the minikit is also more sensitive than the long kit. The long kit includes more number of monofilaments that is necessary to test within the normal subjects. It is very much essential to include the lighter above - threshold monofilaments to measure accurately in normative studies.

The Weinstein Enhanced Sensory Test (WEST) is an improved version of Semmes Weinstein monofilament, holding the minikit monofilaments in one holder. It has a rounded tip with a nonslip coating, with less fragile handle as an added feature. It also possess

colour coding system for easy identification and classification of degree of abnormality.

Most of the monofilaments are 38 – cm in length with various standard diameters and are fixed to an individual rod at 90 - degree angle. The monofilaments produce force depending upon their diameter size and length. If the length of the filament is same, the force produced during application of the monofilaments depends on the diameter.

Weinstein's esthesiometer is provided with a 3 digit number showing the common log of the force, usually measured in tenth of a milligram, to evaluate sensitivity. Another method, also developed by Weinstein and his team, known as WEST gives the result in grams [eg 0.068gm] which is equivalent to the force of application of filament. This is considered to be a more accurate measure, as the skin area stimulated by both heavy and light forces can be approximately equal.

Semmes and Weinstein conducted numerous studies using monofilaments among which some of them dealt with the concept of normative threshold levels.

Many recent researches confirmed the original normal threshold values described by Weinstein with modern instruments. More studies emphasised in dividing the devices used in clinical settings to test the

rapid versus slow adapting receptors. Some researchers say that the monofilaments are referred to as those that test only slowly adapting fibres. There are about three thousand end organs in a $10mm^2$ area of the skin. It would seem futile to stimulate the rapid or slow adapting fibres selectively when various stimuli are given with different instruments testing sensibility.

While using a monofilament test, both slowly and rapidly adapting fibers are triggered producing a quick response that can be appreciated in persons whom the stimulus was applied initially. It is hard to appreciate a slow enough monofilament application which cannot excite the rapidly adapting sensory receptors.

It is better to interpret force in ordinal rank than pressure. Pressure is calculated by the formula, force divided by area. As values of pressure may vary according to the area of measurement, this could be misinterpreted. Both force and pressure are only different measurement units that is used for reporting and the stimulus applied do not change. As the filament is buckled against the skin, a crescent - shaped edge alone will have contact with the skin but not the entire area of the monofilament tip.

Measurement of the crescent – shaped area at the edge of monofilament that establish a contact with the skin is needed to calculate the pressure accurately which is not practically possible. While testing the nylon gets twisted on the skin, pushing a sharp edge into the skin

and so the area stimulated by the monofilament is not correctly described. The gm/mm^2 measurement of the S-W monofilament is only a description of arithmetic and not the function.[17]

The finger pulps have very high density of tactile receptors approximately of 100 - $140/cm^2$ and also the epidermis covering them is of varying thickness. The facial skin is the most sensitive area of the human body and then comes the digital pulp. This may be because of the presence of high density tactile receptors that correlates with the size of the cortical representation. If the area of representation in the cortex is larger, it denotes that the density of receptors within a given area of the skin is higher. Less sensitive areas of the body to touch have lower density of receptor and, at the same time, small cerebral cortex representation.[1]

The advantage of WEST esthesiometer is that the contact tip has a bulb like structure so it presents the same contacting face when the tip bends. One critisim of this monofilament in evaluation of tactile sensibility is its lack of control on applying the stimulus. This is because of the elastic property of the monofilament.

The force that can be applied is limited because of the flexibility of the filament and its capability of buckling at certain pressure. Application of any exploratory device exceeds the constancy of normal TST without this elasticity.

The chances for variation in the inference may be as small as milligrams in one test to as large as 100gms in another. This is due to the lack of limitation on the force applied and the inability to control certain factors like vibration. Computer based devices are also available to measure light touch sensation but they lack the mode of detecting protective sensation levels.

In clinical settings, a minimal modification may be needed in the monofilament application, as soft skin areas can easily accommodate the entire tip of the filament whereas in case of thick inelastic skin, it may not be possible. It is less precise to report the sensitivity threshold in pressure because variable contact surface area may give inaccurate results.

Semmes Weinstein monofilament has the capacity to determine a wide a range of responses and WEST monofilament has colour coding also.

Normal		0.0045–0.068	1.65–2.83
Blue	Diminished light touch	0.166–0.408	3.22–3.61
Purple	Diminished protective sensation	0.697–2.06	3.84–4.31
Red	Loss of protective sensation	3.63–447	4.56–6.65
Red-lined	Untestable	>6.65	>447

These values can be used for standardization and comparison in the treatment programmes worldwide and is relatively inexpensive.

MERITS OF MONOFILAMENT TESTING

The major benefit of monofilament evaluation is that the filaments buckle during the maximum force and the force exerted is almost constant until the filaments are either being severely curved or removed from the skin contact. Control on the velocity and force of application is also possible. On the other hand, buckling of the filament reduces the effect of vibration of the investigator's hand.

Neurophysiologists widely use monofilaments in their studies to evaluate the receptor response. Like many other methods, with cautious contemplation of their physical properties, the monofilament testing can be made more empirical.

The monofilaments are highly valuable in identifying the initial alteration in the sensation of leprosy patients, as there could be a change or reduction of their nerve damage along the course of treatment.

NORMAL TACTILE SENSITIVITY THRESHOLD

The 2.83 Semmes Weinstein monofilament is recognised in almost all areas of the body and it serves as a cut - off value for normal versus aberrant peripheral nerve function, and the thicker filaments measure the loss and degree of abnormality.

A normal individual will sense the 2.83 filament most of the times when applied, but not 100% through the procedure. In foot, the 3.61 filament was recognised to be a more appropriate predictor of normal than at other sites. The monofilament test gains significant application in Carpel tunnel syndrome and other entrapment syndromes where sensory change detection is critical for early intervention. The establishment of a recognition level on initial patient testing will serve as a reference value for future comparison and to observe the prognosis on subsequent testing.

Hunter had used this filament for transient stress neuropathy and subjected the patients for testing prior to and following some activities as well as the change in positions that might make them symptomatic again.[17]

Weinstein and group designed an air - based oral and corneal esthesiometer which uses gram – force for measurement. One typical example of the uses of such device is the detection of lesser sensitivity of the smokers upper throat.

A Comparative study of two different techniques in diagnosis of diabetic polyneuropathy, using a 10-g S-W Monofilament Examination (SWME) and Vibration Perception Threshold (VPT) was done by Mythili A.

The 10 g (5.07) monofilament has been identified to be an ideal tool to measure the risk of foot ulcer. However, the specificity increased when 1 g monofilament was used in these patients .[70]

Shahram Baraz et al. compared the precision of monofilament evaluation at different areas of feet in diabetic neuropathic patients and concluded that sensitivity does not increase with increasing the number of points examined which prevents time consuming as a screening test.[71]

Galdón PM et. al., reinforced the proposal of using haptic icons to design new assistive technologies for blind people. A better user experience and acknowledgement were noted for the blind than for sighted users and for multimodal rather than unimodal learning processes.[72] Thus the use of vibro tactile feedback on mobile phones can be beneficial for persons with visual impairment.

FACTORS INFLUENCING TACTILE SENSITIVITY THRESHOLD

BIOLOGICAL FACTORS - age, gender, height and weight of the body.

OCCUPATIONAL FACTORS - influence the thickness of epidermis.

MENTAL FACTORS - intelligence measured with school marks in children and care received from parents.

SOCIAL FACTORS - such as the level of education of the subject's parents, number of children in the family, material status of the family.

AGE

Many researchers [1,74,75] have studied the influence of age on tactile sensitivity. Several mechanisms have been putforth for the decline in sensory processing with age. Studies showed significant lowering of tactile sensitivity in aged persons. Because of the progressive degeneration of the nervous system, ageing involves the deterioration of all senses.[1,73,74,75,76]

Contrary to this expectation human skin becomes increasingly thinner with age. This implies that the sense of touch like that sense of temperature could be an exception to the general tendency of the senses to weaken in the process of ageing.[77]

Apart from the peripheral reasons, James C. Craig et al studied about aging and tactile temporal order and explained the reason which includes increased stimulus persistence and also decline in the rapidity of cognitive processing . This latter mechanism would probably have a huge impact on tasks which demands a higher level of cognitive load.[78]

Jun Murata et al. suggested that the manual dexterity in the hand function was attenuated as age increased and effect was associated with a decline in tactile sensibility rather than a change in the muscular strength of the hand.[74]

SEX

The skin of women is thinner than men's skin. Two factors have been put forth for this thinner skin. They are cultural factors and biological factors. The women's occupation, at least in our culture involves more light and precise works. If the sensitivity of females was determined mainly by the cultural factor, higher sensitivity should be observed already in small girls. However, if a biological factor (e.g. a hormonal one) alone was responsible for the increased sensitivity in women, the differences should appear only in adults or in post pubescent children.[45] There are studies pointing out the significant changes in the tactile sensitivity of women in various phases of the menstrual cycle.

Metka Moharic , Gaj Vidmar studied tactile thresholds in healthy subjects using Von Frey's esthesiometer and documented that touch sensitivity is not dependent on age or gender.[79]

HEIGHT AND BODY MASS INDEX

The height and weight of a person also influences tactile sensation. Firstly, with the fixed number of receptors, increased height and mass of the body results in the lower density of receptors per surface area unit. Secondly, the body mass index being highly eco - sensitive trait reflects the level of biological development. It may also reflect the effect of numerous environmental factors that modify the feature. Assuming that the number of receptors is established in the perinatal period, the tactile sensitivity is related to the receptor density, which decreases with age, and obese children should be less sensitive than their slimmer peers. [45]

OCCUPATION

Elżbieta Kaluga, Elżbieta Rostkowska concluded that certain athletic sports training may intensify the tactile neural basis, and others may decrease tactile sensation. The probable reason for the difference appreciated in athletes could be due to the variations in the epidermal thickness.[69,80]

OTHER FACTORS INFLUENCING TACTILE SENSIBILITY

Teresa Tavassoli et al. studied the variations in autism candidate gene GABRB3 regulating touch sensation in addition to social and communication defects. Individual with autism spectrum conditions(ASC) often shows atypical tactile sensitivity. It is suggested that normal variability in tactile sensibility is concerned with the difference in function of GABA . The result showed that depending up on the specific genotype present in specific polymorphism in the GABRB3 gene, a person may have lower or higher tactile sensitivity. [81]

DEFINITION OF BLINDNESS

Blindness is defined as visual acuity of less than 3/60 or a corresponding visual field loss to less than 10°, in the better eye with the best possible correction.[11]

CAUSES FOR BLINDNESS *[6,82,83]

THE WHOLE GLOBE – anophthalmos, microphthalmos, pthisis bulbi, disorganised / removed globes

CORNEA - corneal scarring due to trauma or infection, vitamin A deficiency, measles, ophthalmia neonatorum, keratitis

LENS - congenital cataract, aphakia, amblyopia

UVEA - coloboma, aniridia, uveitis

RETINA – retinal dystrophies, retinopathy of prematurity, retinoblastoma, albinism, other retinopathies

OPTIC NERVE – optic nerve atrophy, optic nerve hypoplasia

OTHERS -buophthalmos, glaucoma

The causes listed above are only the conditions that may lead to permanent blindness. The permanent and complete blindness has a great impact on individual, society, and also the nation.

AUDITION AND BLIND

Pritesh Hariprasad Gandhi [2] did his study with 50 congenitally blind people measuring simple auditory reaction time with various types of auditory stimuli. Reaction time to horn & bell is slower than the control but the ringing and whistle sound is faster than control. The outcome of his study was that there was no statistical difference between blind and normal. Bernard [80] observed that the difference was not significant in ART between blind and sighted adolescents.

Gitesh Dubal et al., compared simple auditory reaction time between congenital blind male and sighted and concluded that blinds have faster reaction time and also negative correlation exists between BMI and auditory reaction time.[84]

TACTILE SENSITIVITY AND BLIND

Daniel Gold Reich studied the passive tactile acuity of blind and sighted people on a fully automated grating orientation task and reported that a remarkable increase in acuity in blind people, independent of the amount of childhood vision, perception of light , or Braille reading. Tactile acuity was firmly dependant on the contact force between the skin and the stimulus surface . The acuity was 23 years younger for blind people than the average sighted subject of the same gender.[85]

Van Boven et al.,[86] Grant et al.[87] also found superior performance of passive tactile acuity in blind subjects. The results suggested that cross modal plasticity may be the fundamental cause for tactile acuity intensification in blindness. Cross modal plasticity is central in origin whereas the influence of gender and age may be of peripheral origin. [85] Patrice Voss[88] quoted the superior capability of blind people in both the auditory (Collignon et al., [89,90]) and tactile (Sathian and Stilla, [91]) domains. Researchers described this improvement was probably mediated by cross - modal plasticity.[89,90,91]

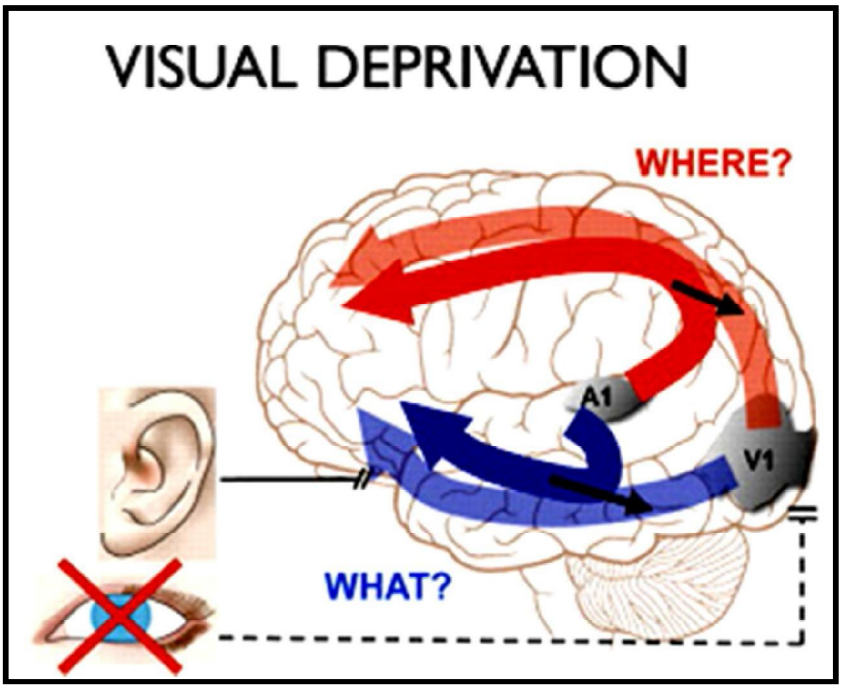
It is also possible to raise a question, whether blindness is mandatory for the evolution of increased tactile sensation? Undeniably, it is confirmed that training itself leads to enhanced execution.[92]

Prior studies have proved that tactile sensitivity can be intensified in normal sighted individuals through rigorous training (Sathian and Zangaladze[93]). This suggests that blindness may act as a facilitator to reinforce the tactile sensitivity, because this motivates the practice of the nonvisual senses to compensate for visual deprivation.[93]

The ability to overlook unrelated auditory or tactile stimuli while processing an auditory or tactile task has been confirmed in congenitally blind individuals (Hötting & Röder, 2004).[94]

CROSS MODAL PLASTICITY

Cross modal plasticity is the reorganisation of neurons to integrate the activities of two or more senses. It is a type of neural plasticity that occurs following the loss of sensation due to any cause. This is in particular with permanent sensory loss such as congenital blindness or deafness. In these circumstances cross modal plasticity can reinforce other senses to compensate for the loss of hearing or vision. It is possible because of the formation of new connections to the cortical area that no longer receive sensory input.[83,95,96]



RE-ROUTED PATHWAY IN BLIND

PLASTICITY IN BLIND

Blind individuals show enhanced auditory and tactile sensations denoting cross modal plasticity. The somatosensory and or auditory cortex is able to recruit the visual cortex. The cross modal plasticity rearranges the network of neurons i.e increased connections have been formed between these cortical areas. This feature helps the blind people to react with greater speed and accuracy to the external environment. The dorsal visual stream is used by the sighted subjects in identifying the spatial information visually but in the blind it is re – routed to work with the sense of touch.

Evidences show that inspite of volume reduction, the occipital cortex remains functionally active. The volume reduction may be due to the absence of visual input to the lateral geniculate body which inturn is a cardinal input to primary visual cortex. In contrast, the visual association areas receive major input from polymodal association areas which suggests the possible contribution of existing thalamo - cortical and cortico – cortical links in the cross modal plasticity of congenital blind.[5]

Various studies proved altered anatomical connectivity,[97] functional connectivity[98,99] high metabolic activity,[100] abnormally elevated glucose utilisation,[101] in occipital cortex of early onset blindness.

Tomas Ortiz et al. noticed that repetitive passive tactile stimulation showed the activity of occipital areas and appreciation of spatial patterns in blind people and concluded that late and congenital blind are less capable of cross modal plasticity. The reason may be due to a well established neuronal network present in late blind subjects or a complete lack of visual input in congenital blind. The study also replicated that visual cortical activity patterns excited by tactile sensation are more eminent in early blind subjects than in late blind subjects. This denotes that, in most cases, tactile training induced cross modal plasticity in occipital areas and this neuronal plasticity would need some antecedent stimulation of the visual pathway.[2]

Amedi et al observed that tactile object recognition activates the lateral occipital cortex (LOC) in congenital blinds which indicates that object identification per se, in the absence of visual imagery is adequate to evoke a response in LOC. The LOC activation mechanism may differ in blind and sighted people. Visual imagery may be enhanced by tactile exploration in sighted subjects but pure tactile response enhancement following cross modal plasticity is observed in blind subjects.[3]

The possible mechanisms which lead to cross modal plasticity are the formation of new connections or the unmasking of pre-existing connections. The shift in connections represents early and

rapid plastic changes. If sustained and reinforced it may lead to slowly emerging but more persistent structural alteration with dendritic arborisation, sprouting and growth.[4,102] This may be accounted for the magnitude of difference in reorganisation between early and late blind.[103]

Sadato et al. observed the activation of visual association cortex in blind individuals during the tactile discrimination task is irrespective of the age at when blindness appears. The striate cortex is activated only in congenital blind subjects. It denotes that tactual activation of V1 area depends on age of onset of blindness. Considering both tactile and visual processes are represented and balanced in association cortex, visual deafferentation causes less demand on bottom – up processing in blind which inturn provides the opportunity to expand the tactile representation to the visual association cortex. In early onset blindness, V1 is also recruited as top – down processing leading to better performance in them than late onset blindness.[104] Butchel et al. reported activation of V1 area in late blind but not in congenital blind.[105]

Cohen et al observed that occipital cortex is activated intensely in congenital and early blind groups than late blind subjects. Repetitive transcranial magnetic stimulation of occipital cortex deranged the Braille reading in congenital and early blind but not in late blind.[83] They also proposed that the susceptible period of cross modal plasticity does not increase above 14 years.[83]

Albert postma et al suggested the extensive haptic experience of congenitally blind and limited haptic experience in late and blind folded subjects is the reason behind the difference in performance.[6]

Catherine Y Wan et al was the first to test the performance of congenital and early blind as a separate group and observed congenital blind performed better in pitch discrimination task and years of blindness did not predict task perrformance.[106]

MATERIALS & METHODS

MATERIALS AND METHODOLOGY

STUDY PLACE:

This study was done in Department of Physiology, Coimbatore Medical College, Coimbatore.

STUDY PERIOD:

The study period is one year, extending from July 2014 to June 2015.

STUDY DESIGN:

This is a cross sectional comparative study

SAMPLE SIZE:

200, including 100 blind people and 100 normal sighted people

SAMPLING METHOD:

This is a non - probability purposive type of sampling

INCLUSION CRITERIA:

Blind persons with no light perception including congenital blindness, early and late blindness within the age of 21 – 60 years both males and females with a minimum duration of five years of blindness were included in the study. Congenital blind included people without vision since birth, early blind were people with loss of vision before 14 years of age and late blind were people with loss of vision after 14 years of age. Age and sex matched people with normal vision (> 6/9 or 20/30) and hearing acuity were chosen as a control group.

EXCLUSION CRITERIA:

- Deaf and dumb
- Alcoholics and smokers
- Persons having clinical evidence of any central nervous system disorder or Psychiatric disorder or
- Any muscular weakness
- Peripheral neuropathy
- On chronic medications
- Systemic illness such as diabetes mellitus, hypertension and thyroid disorders
- Persons not giving consent

were excluded from the study

MATERIALS:

A proforma was used to collect information regarding age, sex, height, weight, age at onset of blindness, duration of blindness with further details of alcohol intake, smoking, diet , drug intake, auditory disturbances, occupation and education.

DIRECT RT (version 2014) software was used to record auditory reaction time. SEMMES WEINSTEIN AESTHESIOMETER MONOFILAMENT SET (Fabrication Enterprises, USA) was used to record tactile sensation.

METHODOLOGY:

The institutional ethical committee approval was obtained prior to the commencement of the study. The study was carried out after the detail explanation of the procedure and informed oral consent was obtained from both the study group, the blind and normal sighted. Visual acuity was tested for all the subjects. Blind people with no perception of light alone were included in the study. Rinne's test and Weber's test were done to rule out any auditory disturbances in selected subjects.

RINNE'S TEST:

After giving proper instruction to the subject, a vibrating tuning fork of 512Hz frequency was placed over the mastoid process. As per instruction the subject raised his hand when he stopped hearing the sound. Then the vibrating tuning fork was placed in front of the same side ear with its prongs parallel to the ear canal. If he hears the sound still the subject is considered to have normal audition. i.e air conduction is better than bone conduction.

WEBER'S TEST :

The subject's bone conduction was tested by this test. The 512 Hz vibrating tuning fork was placed on the vertex and the subject was asked whether he was able to hear the sound equally on both sides or the sound lateralized to one side. Normal individuals hear equally on both sides.

Using the above tests the person having normal hearing were included in the study and others excluded.

ANTHROPOMETRIC MEASUREMENTS:

MEASUREMENT OF HEIGHT:

The height of the subjects was measured in centimeters using stadiometer in erect posture.

AUDITORY REACTION TIME TESTING WITH

DIRECT RT SOFTWARE

MEASUREMENT OF WEIGHT:

The weight of the subjects in light clothing, was measured in kilograms using a standard weighing machine with their arms relaxed at their side with both feet together.

BODY MASS INDEX (BMI) :

BMI was calculated using the quetelet's index.

BMI = weight in kgs / height in meters ^{2}.

A thorough clinical check up with general and systemic examination including the respiratory, cardiovascular, abdomen and central nervous system was done.

PROCEDURE FOR RECORDING AUDITORY REACTION TIME :

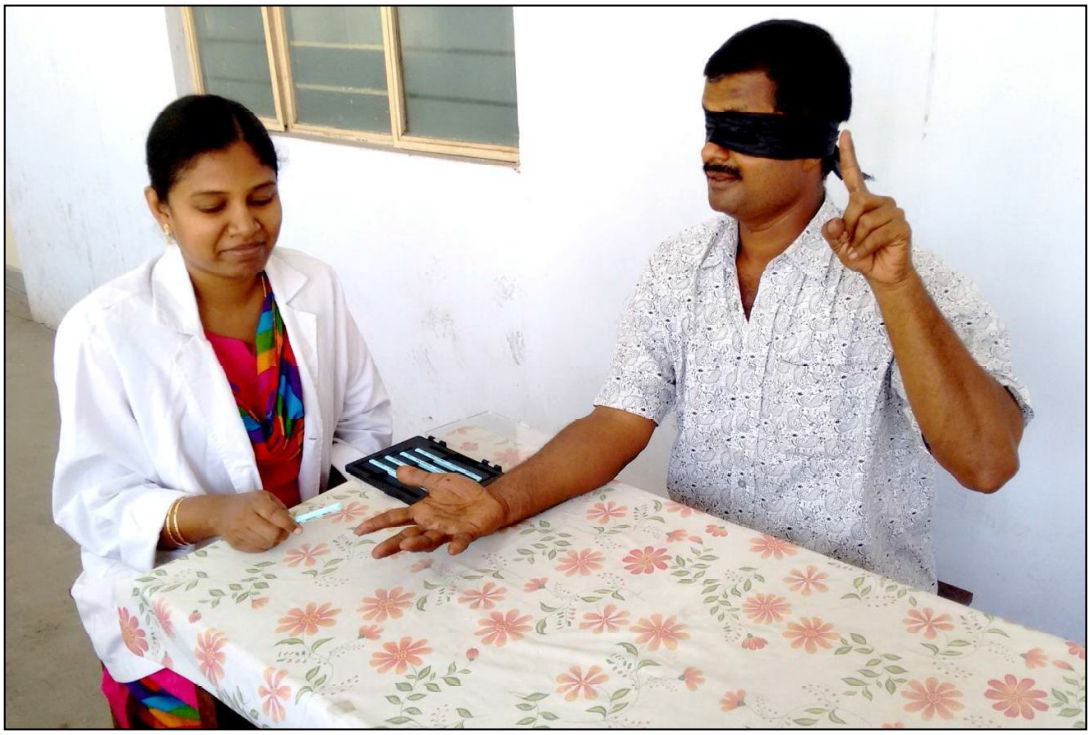
The subjects were made to sit comfortably and the procedure was explained to them. The procedure was carried out in a sound treated room with adequate light. The test was done using DIRECT RT software from a laptop computer. The testing procedure was quite simple, noninvasive and harmless to the participants. A 1000 Hz beep sound was presented at random intervals to the participants ear through a head phone and the subject pressed the space bar of the system that is placed in front of them as per the given instruction.

Care was taken to make the subject sit comfortably and the dominant hand to be used to press the space bar was resting on the table and properly supported. It was instructed to keep the hand ready in front of the space bar and the subject pressed the space bar with their index finger as soon as he / she heard the beep sound. Adequate trials were given to the subjects so as to alleviate their anxiety. Number of trials given varied depending upon the subjects, as some of the blind people found it difficult and anxious about the task. Adequate trials were given till they felt confident and comfortable with the procedure. After the trials, both the study group, the normal sighted and the blind were blind folded with a dark black cotton cloth and ten readings were taken. The minimum, maximum and the mean of the auditory reaction time were recorded using DIRECT RT software in milliseconds. The test was done in the morning between 9am to 11am for all the subjects after breakfast.

PROCEDURE FOR MEASURING TACTILE SENSITIVITY

The blind folded subjects of both the study group, the normal sighted and blind remained sitting with his / her arms on the table in a supinated position.

The subjects were instructed about the procedure in detail. Tactile Sensitivity Threshold was measured using SEMMES – WEINSTEIN monofilament kit containing a set of 20 monofilaments with a plastic handle.



TACTILE SENSITIVITY TESTING WITH SEMMES-WEINSTEIN MONO FILAMENT

Each monofilament exerts a specific pressure and the measurements can be done in various units like pressure in grams/ sq.mm, force in grams, force in millinewtons, target force and evaluator size which is the conversion of grams to $\log_{10}$ 0.1mg. The conversion chart is given in the user manual which is standard for all manufacturers. The evaluator size is marked on the handle of each monofilament. Each subject underwent a pre-test with a thick, easily perceptible filament for experience. Then the filaments were applied in a perpendicular fashion till it bends about 90 degrees for about 1 to 1.5 seconds in the index finger of the dominant hand one by one in ascending order of evaluator size. The subject should respond by raising the left hand when he / she was able to perceive the sensation. Care was taken to prevent any sound which may distract the subject's concentration. Delayed response of more than 3 seconds was not considered. The least pressure force the person identified is the tactile sensitivity threshold (TST) of the subject. Three trials were given for each filament and 2 out of 3 positive responses were considered as ability of perception. The measurements were taken by the same person between 9am to 11am after breakfast.

The readings obtained were entered in Microsoft Excel 2007 data sheet in a computer and was analysed using XLSTAT 2014 Statistical Software. Descriptive Statistics of the data were presented as percentages, mean and Standard Deviation. Non parametric tests were used to compare between groups.

RESULTS & ANALYSIS

RESULTS AND ANALYSIS

The present study group includes a total of 200 subjects. It is divided into two groups

(i) Normal sighted subjects - 100

(ii) Blind subjects - 100

The mean age of normal sighted group is 36.550 ± 8.369 years and for blind is 36.670 ± 8.534 years. The mean ± SD for BMI (body mass Index) is 22.037 ± 3.760 and 21.74 ± 2.645 for normal and blind respectively. Since there is no statistically significant difference in age and BMI in both the groups, they are similar in distribution.

TABLE 1. MEAN AGE AND BMI IN NORMAL SIGHTED AND BLIND GROUPS

PARAMETER	NORMAL SIGHTED	BLIND	KOLMOGROV-SMIRNOV TEST	P-VALUE
Age years (Mean ±S.D)	36.550± 8.369	36.670± 8.534	D=0.040	1.000
BMI (Mean ±S.D)	22.037± 3.760	21.74 ± 2.645	D=0.170	0.111

TABLE 2. GENDER FREQUENCY OF STUDY GROUP

GENDER	NORMAL SIGHTED	BLIND	TOTAL
Male	74	74	148 (74%)
Female	26	26	52 (26%)
Total	100	100	200 (100%)

As per table 2. The percentage of male is 74% and female is 26% in both study groups.

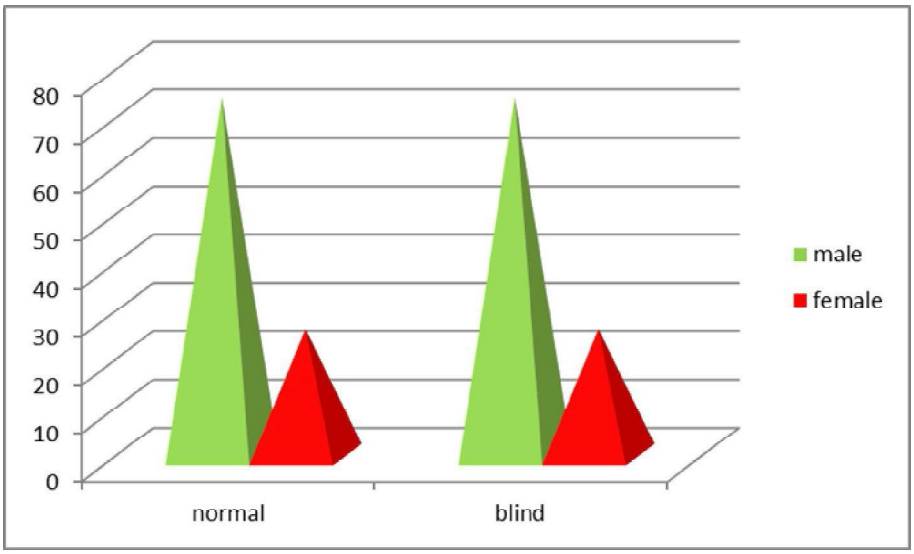


Chart I. Gender frequency of study group

TABLE 3. AGE FREQUENCY OF STUDY GROUP

AGE GROUP (IN YEARS)	NORMAL SIGHTED	BLIND	TOTAL
21-30	33	33	66(33%)
31-40	37	35	72(36%)
41-50	25	25	50(25%)
51-60	5	7	12(6%)
Total	100	100	200(100%)

As shown in table 3. the maximum number of study subjects were in the 31 to 40 years age group (36%) and the least number were in 51 to 60 years age group (6%) in the overall category.

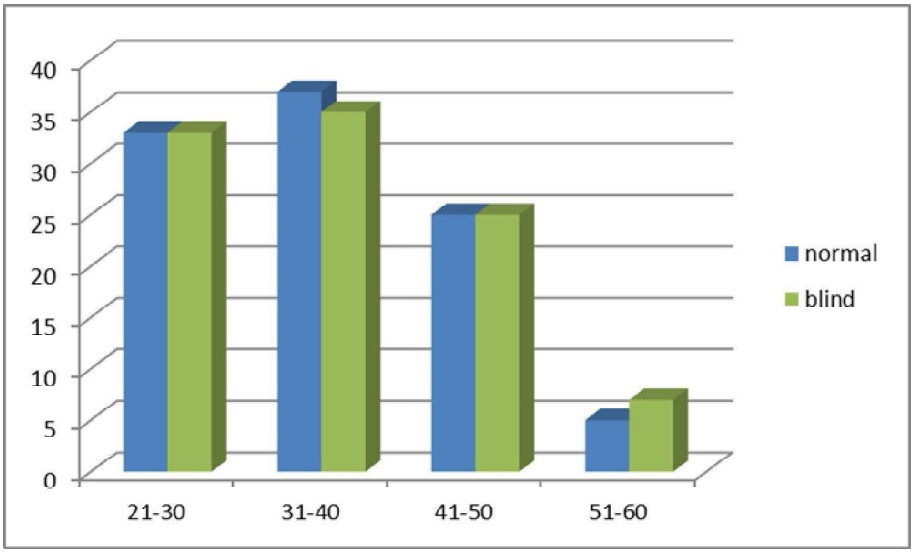


Chart II. Age frequency of study group.

TABLE 4. BMI FREQUENCY OF STUDY GROUP

BMI	NORMAL SIGHTED	BLIND	TOTAL
Normal	83	93	176 (88%)
Overweight	10	5	15 (7.5%)
Obese	7	2	9 (4.5%)
Total	100	100	200 (100%)

Table 4. explains that out of 100 sighted subjects, 83 have normal BMI, 10 are overweight, 7 are obese and in blind subjects 93 have normal BMI, 5 are overweight and 2 are obese in a total of 100. BMI classification used in this study is based on WHO classification. Most of the subjects in both study group belong to normal BMI category.

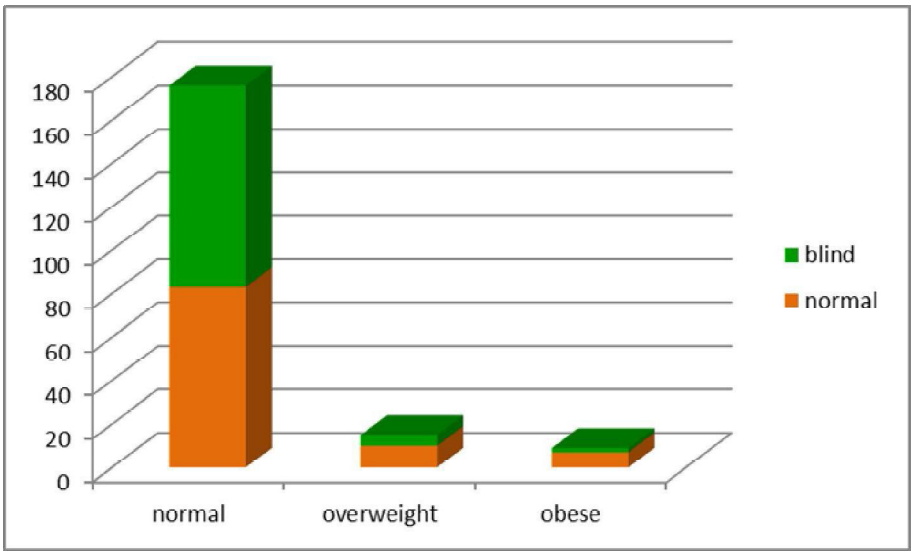


Chart III. BMI frequency of study group

TABLE 5. AUDITORY REACTION TIME IN NORMAL SIGHTED AND BLIND SUBJECTS

ART (in millisecs)	NORMAL SIGHTED	BLIND
Minimum	158	150
Maximum	318	236
Mean ±S.D	207.990 ± 38.336	181.890 ± 17.742

Table 5. shows that maximum value of ART as 318 msec and 236 msec in normal sighted and blind and minimum value of 158 msec and 150 msec in normal sighted and blind respectively.

TABLE 6. TACTILE SENSITIVITY THRESHOLD IN NORMAL SIGHTED AND BLIND SUBJECTS

TST (EVALUATOR SIZE)	NORMAL SIGHTED	BLIND
Minimum	2.360	1.650
Maximum	4.560	4.080
Mean ± S.D	3.155 ± 0.633	2.379 ± 0.624

Table 6. represents minimum TST (Tactile Sensitivity Threshold) in normal sighted and blind as 2.360 and 1.650 respectively; maximum TST value of 4.560 and 4.080 in them respectively. The evaluator size is the log scale of the force given in the instrument.

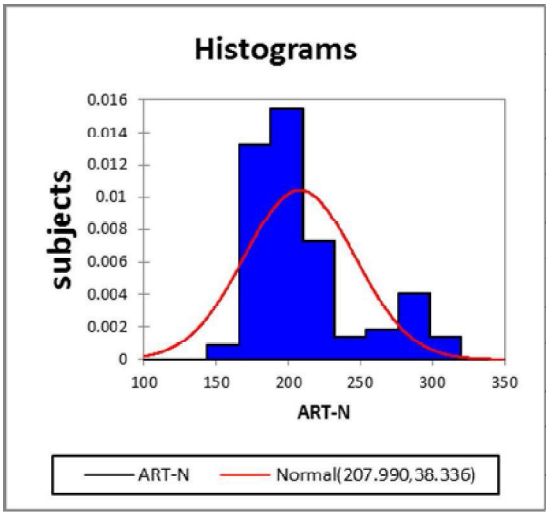


Chart IV (i) Distribution of values of ART (msec) in normal sighted subjects in relation to normal curve.

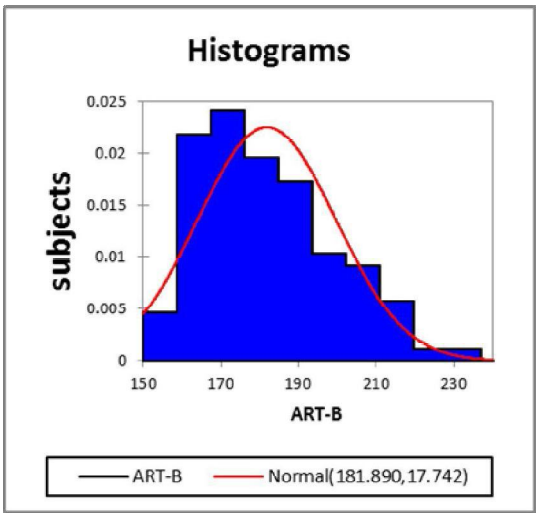


Chart IV(ii) Distribution of values of ART (msec) in blind subjects in relation to normal curve.

The above charts indicate that ART values do not fit exactly to the normal distribution curve.

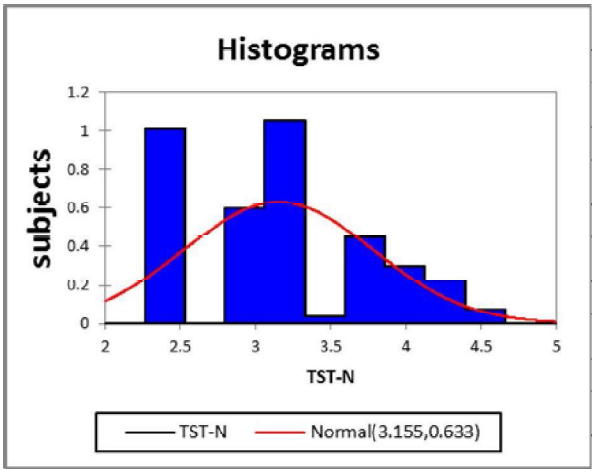


Chart V (i) Distribution of values of TST(evaluator size) in normal subjects in relation to normal curve.

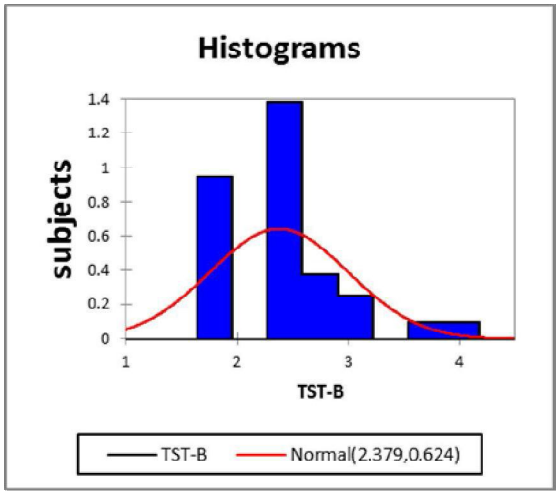


Chart V(ii). Distribution of values of TST(eval.size) in blind subjects in relation to normal curve.

The above charts indicate that TST values do not fit exactly to the normal distribution curve. The values are skewed to left. So non parametric tests are used for analysis.

TABLE 7. COMPARISON OF ART IN NORMAL SIGHTED AND BLIND SUBJECTS

ART (msec)	NORMAL SIGHTED	BLIND	MANN-WHITNEY TEST	P VALUE
Mean ±S.D(m sec)	207.990±38.336	181.890±17.742	U=7257.000 Expt =5000.000	<0.0001*

*significant

Table 7. shows the comparison of mean value of auditory reaction time in normal sighted and blind . The difference is significant with a p value of < 0.001.

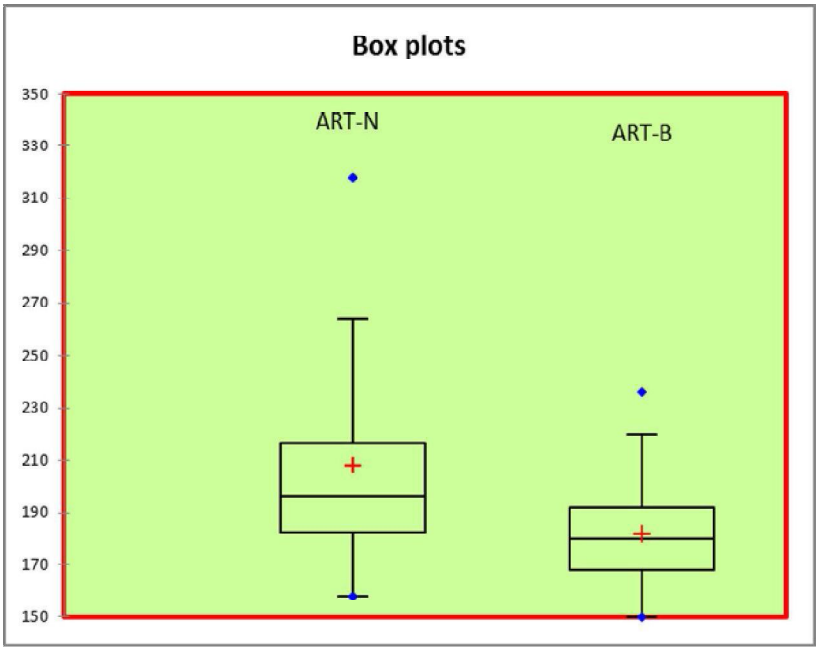


Chart VI. showing ART (Auditory Reaction Time) in normal sighted and blind subjects

TABLE 8. COMPARISON OF TST IN NORMAL SIGHTED AND BLIND SUBJECTS

TST (evaluator size)	NORMAL SIGHTED	BLIND	MANN-WHITNEY TEST	P VALUE
Mean ±S.D	3.155±0.633	2.379±0.624	U=1945.000 Expt=5000.000	<0.0001*

*significant

Table 8. expresses the values of tactile sensitivity threshold in normal sighted and blind groups , the difference being significant with a p value of < 0.001 in Mann – Whitney test.

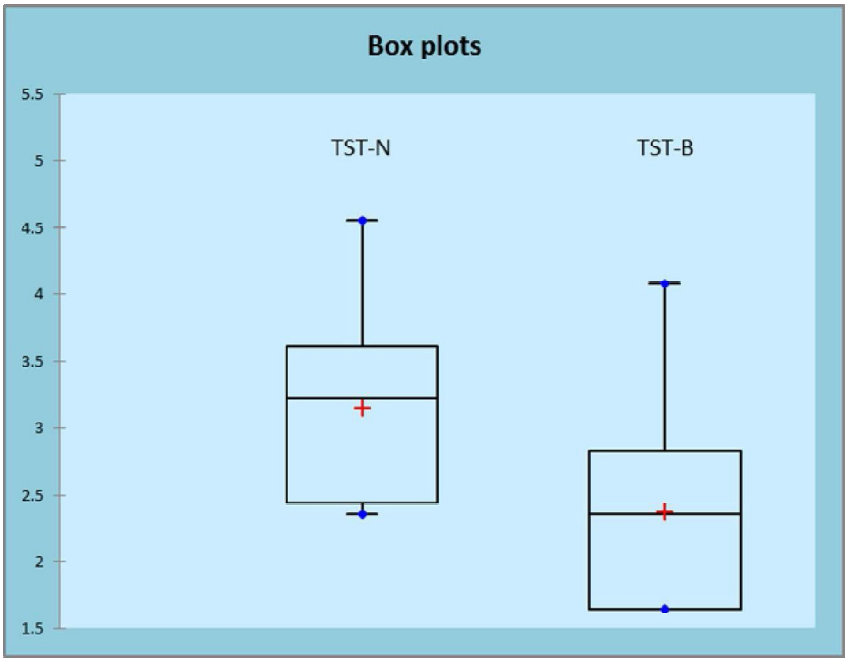


Chart VII. shows tactile sensitivity threshold in normal sighted and blind subjects

TABLE 9 . COMPARISON OF ART IN MALES AND FEMALES OF THE STUDY GROUP

GENDER	NORMAL SIGHTED	BLIND SUBJECTS	MANN – WHITNEY TEST	P VALUE
Male	209 ± 38.715	183 ± 18..554	U =3935 Expt =2738	<0.0001*
Female	202.654±37.458	176.885±14.356	U=511.500 Expt =338.00	0.002*
MANN-WHITNEY TEST	U=822.5 Expt = 962	U=771 Exp = 962	-	-
P VALUE	0.275	0.133	-	-

*significant, ART in msec

Table 9. compares the male and female within normal sighted subjects and blind subjects represented in columns and also compares male and female subjects in blind and normal sighted separately. The inference is no statistically significant difference between males and females in both the blind and normal sighted subjects. But statistically significant difference exists between normal sighted and blind males and also in females.

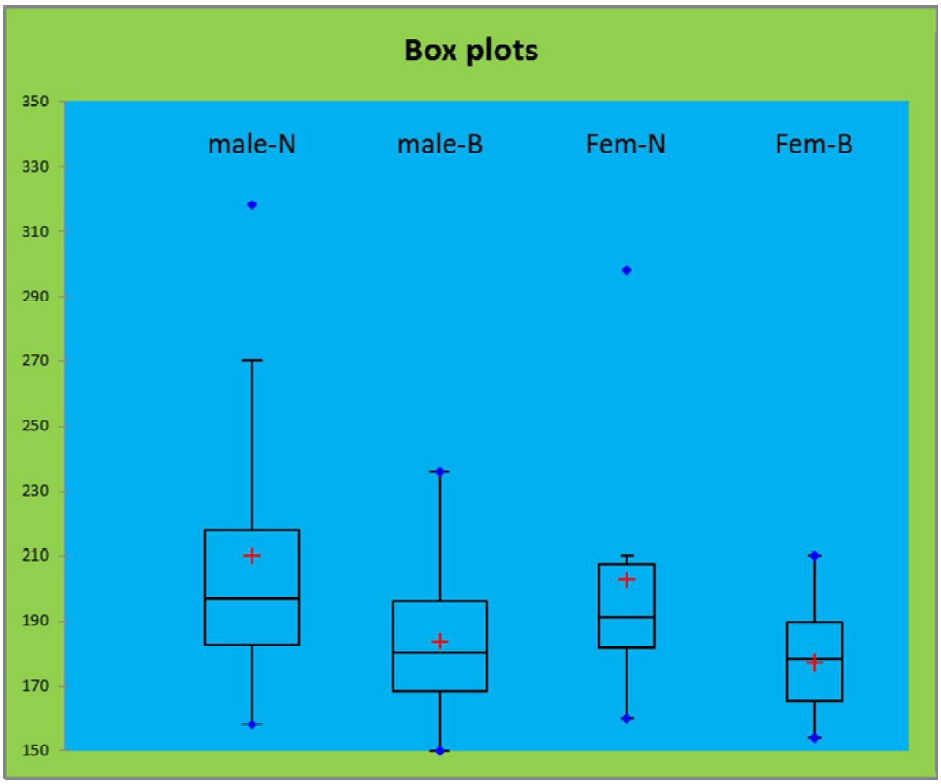


Chart VIII. shows the comparison of ART in males and females of both blind and normal sighted.

Compared to male and female normal sighted subjects, male and female blind have reduced ART.

TABLE 10. COMPARISON OF TST IN MALES AND FEMALES OF THE STUDY GROUP

GENDER	NORMAL SIGHTED	BLIND SUBJECTS	MANN – WHITNEY TEST	P VALUE
Males	3.240 ± 0.658	2.433 ± 0.639	U=4416.500 Expt =2738.00	< 0.0001*
Females	2.913 ± 0.490	2.225 ± 0.565	U=554.500 Expt =338.000	< 0.0001*
MANN – WHITNEY TEST	U = 684.5 Expt = 962	U = 774 Expt = 962	-	-
P VALUE	0.0263*	0.1415	-	

*significant, TST in Eval. Size

On comparing the TST with males and females, in both groups females have 2.913 ± 0.490 (normal) and 2.225 ± 0.565 (blind) which are lesser than males. The difference is significant only between males and females of normal sighted but not in blind subjects. A significant difference is observed between normal sighted and blind males as well as females.

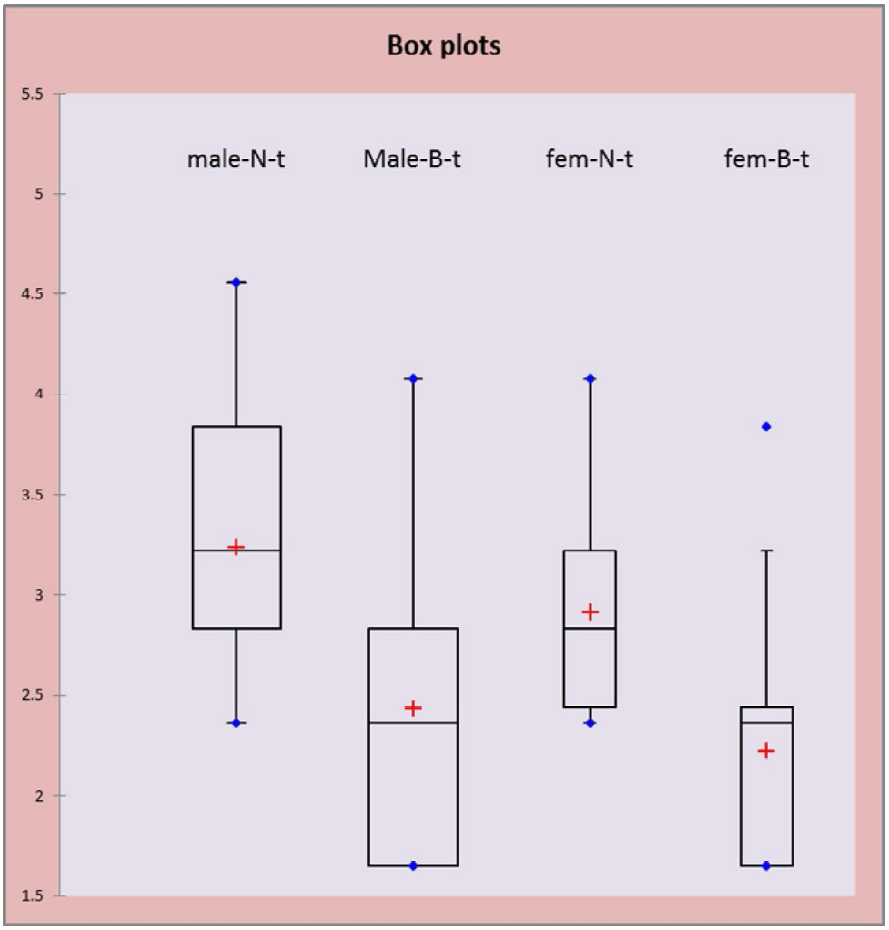


Chart IX. shows the mean, median, minimal and maximal values of males and females TST of both the study groups. The male and female blind have lower TST.

TABLE 11. COMPARISON OF ART IN DIFFERENT AGE GROUPS

AGE GROUP	NORMAL SIGHTED	BLIND SUBJECTS	MAN – WHITNEY TEST	P VALUE
21-30	183.212±14.157	172.273±12.258	U =780.500 Expt =544.500	0.002*
31-40	209.054±36.060	181.886±16.662	U =969.500 Expt =647.500	0.000*
41-50	227.320±40.229	188.440±17.098	U=514.000 Expt=312.500	<0.0001*
51-60	267.000±39.925	203.857±19.987	U=31.500 Expt =17.500	0.028*
KRUSKAL WALLIS TEST	K = 35.524	K = 21.245	-	-
P VALUE	0.000*	0.0001*	-	-

*significant, ART in msec

Table 11. shows that within the same age group significant difference is present between normal sighted and blind by Mann – Whitney U test. On comparing different age groups within the normal and blind subjects Kruskal Wallis test shows significant difference.

TABLE 12. COMPARISON OF TST IN DIFFERENT AGE GROUPS

AGE GROUP	NORMAL SIGHTED	BLIND SUBJECTS	MANN – WHITNEY TEST	P VALUE
21-30	2.732±0.419	2.225±0.587	U=809.000 Expt=544.500	0.001*
31-40	3.049±0.515	2.240±0.549	U=1129.000 Expt =647.500	<0.0001*
41-50	3.696±0.503	2.610±0-653	U=561.000 Expt =312.500	<0.0001*
51-60	4.020±0.517	2.974±0.546	U=32.500 Expt =17.500	0.017*
KRUSKAL WALLIS TEST	K =39.39	K = 14.773	-	-
P VALUE	0.000*	0.002*	-	-

*significant, TST in Eval.size

Table 12. shows significant difference between the normal sighted and blind subjects in various age groups. On comparing the different age groups in normal sighted and blind individually, a significant difference is observed and as the age increases the TST also increases.

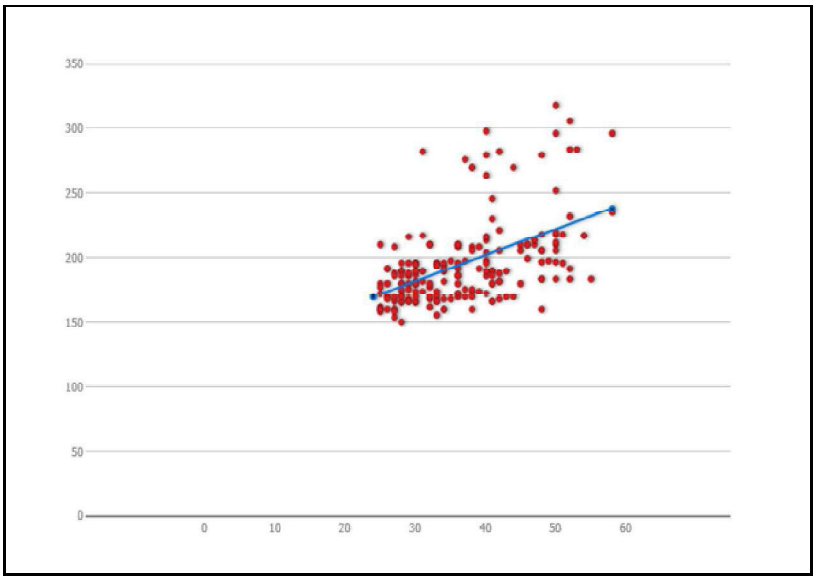


Chart X (i) . The above scatter plot chart shows a moderately positive correlation between age and ART in both normal sighted and blind subjects.(Pearson correlation R = 0.5224)

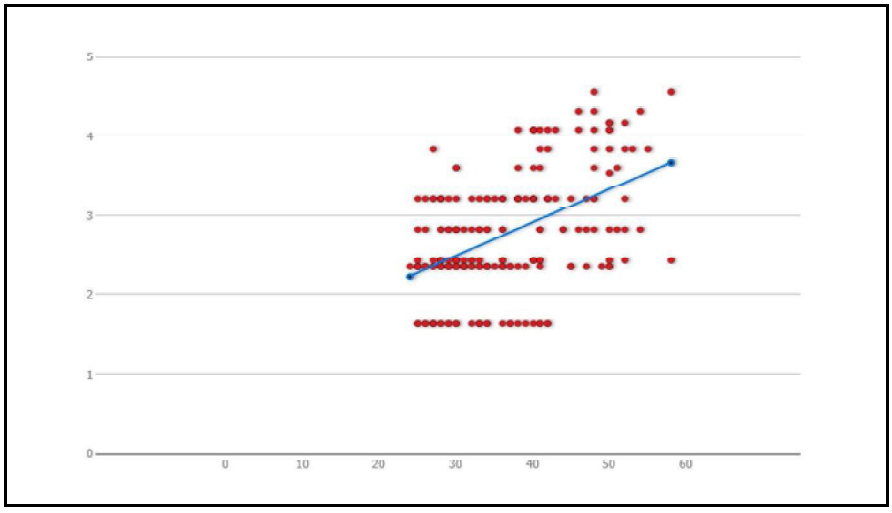


Chart X (ii). The above scatter plot chart shows a moderately positive correlation between age and TST in both normal sighted and blind subjects.(Pearson correlation R = 0.4784)

TABLE 13. COMPARISON OF ART AND BMI

GROUP	NORMAL	OVERWEIGHT	OBESE	K-VALUE	P-VALUE
SIGHTED	201.542±0.511	239.700±42.957	239.143±42.831	13.771	0.001*
BLIND	181.516±17.728	184.400±20.120	193.000±18.385	0.881	0.644

*significant, ART in msec

Table 13. shows that the difference between normal, overweight and obese is significant in normal sighted subjects whereas not significant in blind subjects.

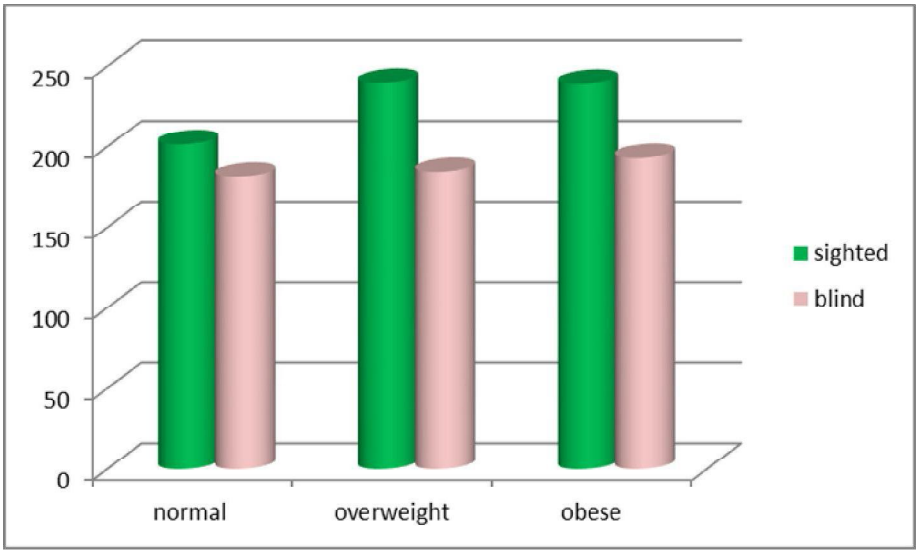


Chart XI shows the comparison of ART and BMI.

A significant difference exists between normal, overweight and obese in normal sighted subjects whereas no significant difference is observed in blind subjects.

TABLE 14. COMPARISON OF TST AND BMI

GROUP	NORMAL	OVERWEIGHT	OBESE	K-VALUE	P-VALUE
SIGHTED	2.971±0.511	3.979±0.375	4.160±0.225	34.823	<0.0001*
BLIND	2.350±0.605	2.578±0.899	3.220±0.000	4.230	0.121

*significant, TST in eval.size

Table 14. shows a significant difference between normal, overweight and obese in normal sighted subjects but not in blind subjects.

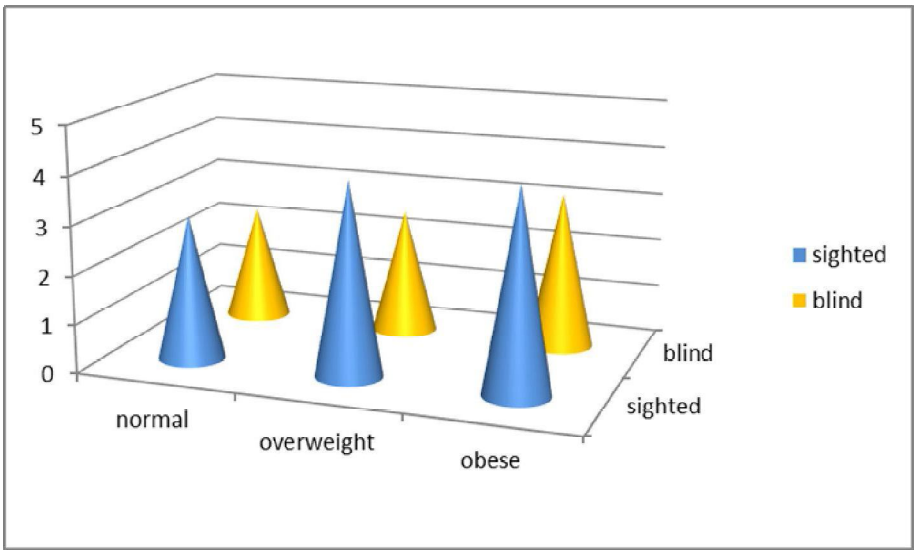


Chart XII shows the comparison of TST and BMI.

A significant difference is observed between normal, overweight, and obese sighted but not in blind.

TABLE 15. WITHIN GROUP COMPARISON OF ART & TST IN BLIND SUBJECTS

TEST	CONG. BLIND	EARLY BLIND	LATE BLIND	KRUKSAL WALLIS TEST	P VALUE
ART (msec)	174.391±13.714	186.258±19.105	191±17.404	16.021	0.000*
TST (Eval. Size)	2.165±0.581	2.458±0.572	2.700±0.683	14.959	0.001*

*significant

Table 15. shows a significant difference between congenital, early and late blind subjects in both ART and TST.

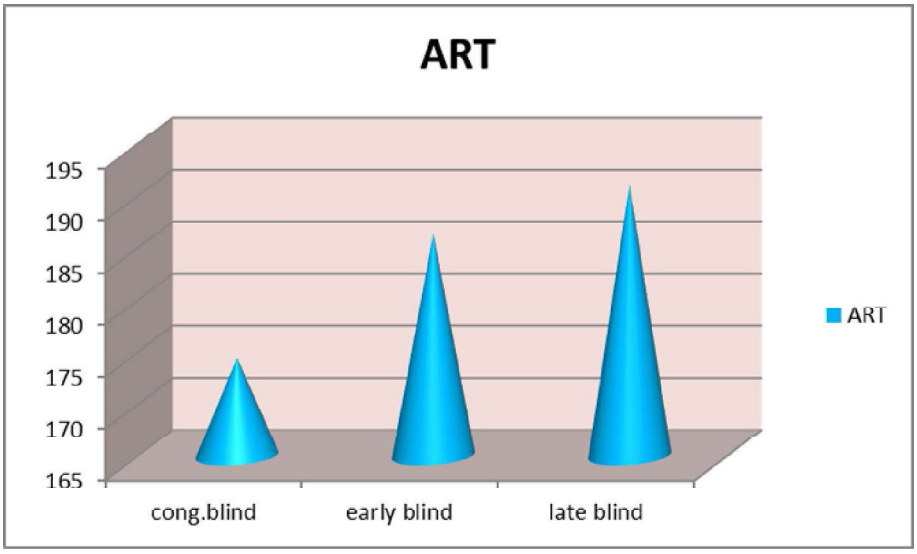


Chart XIII shows the ART difference between congenital, early and late blind.

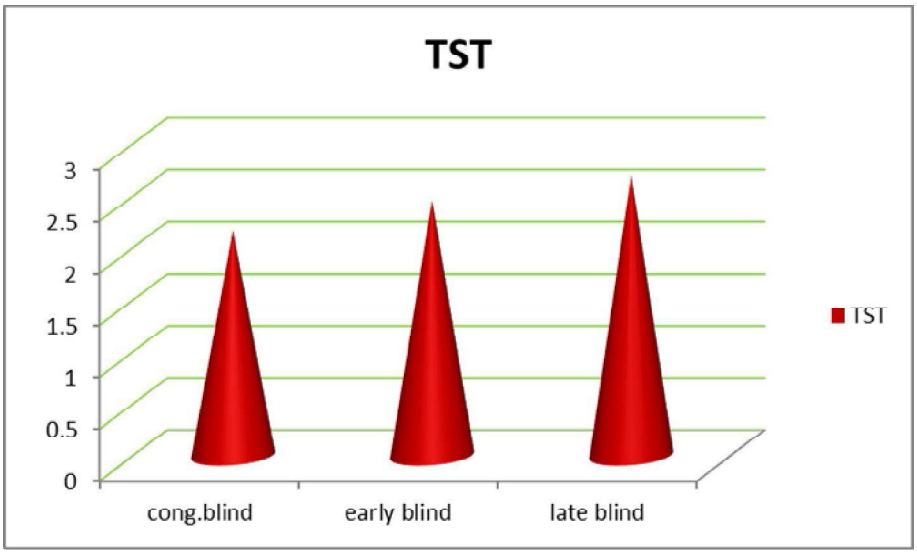


Chart XIV shows the TST difference between congenital, early and late blind.

DISCUSSION

DISCUSSION

The present study determined the simple auditory reaction time and tactile sensitivity threshold levels among normal sighted and blind subjects. Comparative analysis of auditory reaction time and tactile sensation were done to elucidate any significant difference between the blind and age, sex matched normal sighted subjects. The purpose is to investigate whether the subjects who lack any one sense have an enhanced ability of the other senses and to discuss the scientific reasons if so.

AUDITORY REACTION TIME IN BLIND AND NORMAL

The mean auditory reaction time in the present study for normal sighted subjects is 207milliseconds. Previous studies have reported auditory reaction time as 160msec (Brober&Welford)[35], 174msec (Niruba,)[58], 284msec (Shelton,)[107] in normal persons. The varied results may be attributed to the different methodologies adopted, instruments used, sample size in their studies.

The mean auditory reaction time in blind subjects is 181.890msecs. There is a statistically significant difference between the normal sighted and blind group i.e. the blind persons had a faster reaction time than the normal sighted persons.

Gitesh Dubal et. al[84] (2013) in his study involving normal and blind subjects also showed that blind persons had faster reaction time (43msecs faster) to simple auditory stimulus than the normal sighted subjects.

Nieymar .et. al[106] reported that the blind individuals process auditory information more efficiently than the normal people. Mario Liotti et al[107] found that high density focused dichotic listening task were markedly faster in blind than normal sighted. Collignon O et al[90] explained that the utilisation of occipital areas for auditory processing is the reason for the extraordinary abilities in [spatial processing of sounds] blind people than the normal people. Kirsten Hotting et al[7] reported that increased utility of auditory system produced better perceptual auditory tasks because of compensatory behaviour in blind. Kujala et al.,[108] in their study also found that the blind persons reacted faster than sighted to auditory stimuli. In blind animals and humans, their auditory processing occurs even in occipital cortex which are normally used for vision. This extension of auditory area up to visual area enhances the ability of auditory spatial tuning . This massive cross modal reorganisation is the cause for superior performance of blind subjects.

Contrary to the findings in the present study, Bernard[109], Necimye On Yildirin et al[110], Gandhi et al[13] concluded that the difference in simple ART is not significant between blind persons and normal sighted persons.

These studies have been done on a small group (less than 50 nos.) and the mean age of the study participants was under 24 years which may have an implication on the outcome. But in this study the mean age is 36.550± 8.369 years for normal sighted subjects and 36.670± 8.534 years for blind subjects.

AUDITORY REACTION TIME AND GENDER

The auditory reaction time is not significantly different between males and females in both the normal sighted as well as the blind subject groups. Hence the gender seems to have no influence upon the auditory reaction time in this study. This outcome is consistent with the findings of Prabhjot kaur et al.[59] Radosław Zajdel et al.[111], Annie W.Y. Ng and Alan H.S. Chan[62] also observed that the difference in auditory reaction time is not significant between males and females in their study using various methods.

Various independent researchers have given controversial results regarding the effect of gender on auditory reaction time. Studies done by Nikam et al., [46] Namitha et al[49] , Shelton et al[21] showed that the males have a shorter reaction time than females for auditory stimulus. It could be due to the motor component rather than a central processing mechanism. Men are relatively stronger when compared to females and so response is faster in males.[21]

Sugata Jadhav et al.,[50] and Sunil Kumar[53] et al., suggested the cause for increased auditory reaction time in females is because of the hormones that cause water and salt retention which in turn persuade the process of axonal conduction and neurotransmitters availability at the synapse, in the luteal phase of menstrual cycle.

AUDITORY REACTION TIME AND AGE

The present study also analysed the age as a factor in the measurement of auditory reaction time. Age has a positive correlation with auditory reaction time (r=0.5224) i.e as the age increases reaction time also increases in both normal and blind. Thus the subjects become slower to respond to an auditory stimuli as they grew older. But in general, the response time of an individual becomes faster up to the age of 21 to 30 years and thereafter starts increasing as age increases as evidenced by Annie.W.Y.et.al [62] and Welford et al.,[23] As this present study group starts from the age 21 years there is an increase in auditory reaction time in both the blind and sighted groups.

The probable reasons for this phenomenon is due to the impact of ageing process on myelination of neurons , axonal degeneration and shrinkage which prolongs the mental processing and the speed of conduction of neurons.

Loss of coordination increases with age because of the inability to maintain fine balance between agonist and antagonist.[19] Hair cell damage, and cognitive decline also plays a role. According to surwillo's findings the period of the alpha cycle increases with age. This slowing of brain activity is responsible for the progressively longer decision making, that increases the reaction time. [112] Whereas Sharon M Abel and Nadine M Armstrong results indicate that there is no difference even in choice reaction time as age increases.[113] The choice reaction time includes multiple response for several stimuli and the reaction must correspond to the correct stimulus.[13]

AUDITORY REACTION TIME AND BMI

On discussing about the Body Mass Index in our study a significant difference is observed in ART between normal Body Mass Index, overweight and obese subjects among the sighted group. In the blind group though the reaction time increases as Body Mass Index increases, it is not statistically significant. This may be due to the presence of only two obese subjects in the blind group.

Nikam LH et al.[46], Jayashree, Simran Grewal et al,.[113] showed a positive relationship between reaction time and Body Mass Index whereas Gitesh Dubal[84] reported a negative correlation which was not explained. Body Mass Index influences the sensory motor coordination.

Various neurophysiological studies have shown that the regions of the brain involved in cognition, reasoning, memory, processing speed, sensorimotor performance and attention are influenced by BMI. The increased sensory threshold and slowing of nerve conduction in obese has been proved by nerve conduction studies.

Various pathophysiological changes including vascular changes, systemic inflammation, impaired insulin regulation can influence executive function via the vascular pathway. It is also suggested that adipose tissue secretes various cytokines, chemokines and tumour necrosis factors that cross the blood brain barrier and may alter the brain functions. Abnormal levels of adipokines result in disrupted myelination that alters the axonal conduction. Hence neuronal and myelination abnormalities along with axonal degeneration might be the cause for an increased reaction time in obese subjects.[113] Nene AS.et al.,[52] DN Deore et al.,[114] reported that auditory reaction time is increased in subjects with higher and also with lower BMI than normal.

TACTILE SENSITIVITY THRESHOLD IN BLIND AND NORMAL

The tactile sensitivity threshold mean value in normal sighted and blind are 3.155±0.633 and 2.379±0.624 respectively. There exists a significant difference between these groups with a p value of < 0.001, the blind subjects having decreased threshold or enhanced sensitivity.

Daniel Goldreich and Ingrid M Kanics, [85] also proved that tactile sensation is enhanced in blind and suggested that cross modal plasticity may under lie the cause.

TACTILE SENSITIVITY THRESHOLD AND GENDER

In this study the tactile sensitivity threshold is lower in females than males in both normal sighted and blind. But it is not statistically significant in blind subjects. Anne D. Berquin et al.,[115] Daniel Goldreich and Ingrid M Kanics,[85] Agnieszka kozlowska[1], Elżbieta Kaluga, Elżbieta Rostkowska,[69] Van Bowen et al[86] had similar findings in their research studies. One possible explanation may be due to a peripheral cause that the skin is thinner in women. This is because of the biological factor, which in turn is conditioned hormonally, or the cultural factor, that allows only lighter and precise work for females in our region.[1] Daniel Goldreich and Ingrid M Kanics[85] also proposed that the effect of gender may be peripheral in origin.

TACTILE SENSITIVITY THRESHOLD AND AGE

On comparing the different age groups in normal sighted and blind subjects separately, in both the groups TST increases significantly as the age increases. This finding is identical to the research done by Agnieszka kozlowska,[1] Thornbury et al,[116] Bowden et al[117,] Jun Murata et al,[74] Tremblay et al.,[75]

Eventually deterioration of all senses occurs as age increases that results from progressive degeneration of the nervous system. The reasons for increase in TST with age has been discussed in many other studies as well. Wickremaratchi and Llewelyn[76] reported that the density and distribution of cutaneous tactile receptors decrease with age. Bruce MF et al.,[118] confirmed this finding histologically in his study. The morphological changes, the decrease in myelinated afferent fibers and cutaneous receptor end organs are thought to explain the progressive decline in sensation.[45,118] Whereas Woodward[120] says that the relationship between increasing age and the decrease in tactile sensation may not be attributed to the modification in the mechanical properties of the skin but may include other factors like changes in the nervous system which influence the rate of conduction, quantity or quality of information processing.

Not only the tactile sensation but the temporal processing also increases with age says James C. Craig et al[78]. Based upon the task, the older subjects have two to five times higher thresholds than the younger subjects.[78] Daniel Goldreich and Ingrid M Kanics[85] in their study among normal and blind people also put forth the peripheral causes for increase in TST with age. He also observed that the acuity of the blind subjects were 23 years younger than the average sighted subject of the same gender.

Surprisingly, Gordon E. Legge et al.[77], observed that there is no age associated deterioration in tactile acuity in blind individuals and the high acuity is preserved even in old age. They proposed that the active use of touch not only in Braille reading but also in day to day activities, may result in conservation of tactile acuity throughout the lifespan.[77]

TACTILE SENSITIVITY THRESHOLD AND BMI

The TST is lower in normal BMI persons in comparison to overweight and obese. This is statistically significant only in normal sighted (p value < 0.0001) but not in blind group. The study done by Agnieszka Kozłowska found that the TST is increased as the body mass index increases.[1]

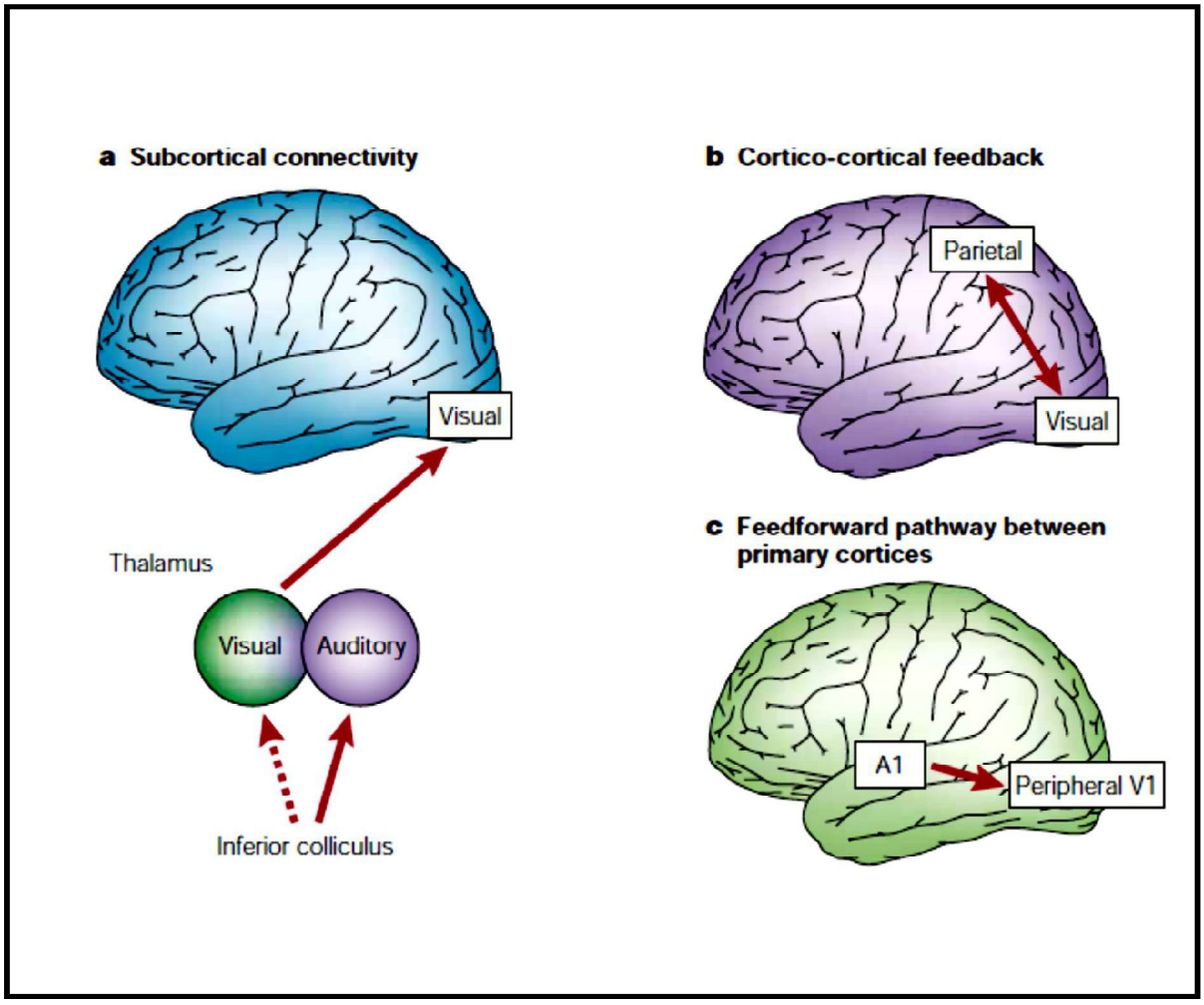
Tactile sensitivity may be affected by the dimensions of the body in a variety of ways. The number of receptors established during the perinatal period is fixed and it declines with age. With the fixed number of receptors, the increased BMI of the body results in reduced receptor density per surface area unit which results in decreased sensitivity. Then, BMI and height being an eco sensitive trait, is influenced by environmental factors that may modify the tactile sensitivity.[1]

REASONS FOR ENHANCED AUDITION AND TACTILE SENSATION IN BLIND

Two reasons has been put forth for increased auditory and tactile sensation in blind. The enhancement may possibly be exhibited by massive cross modal plasticity. In blind individuals, the areas of visual cortex becomes extremely amenable to nonvisual input. Superior behavioural capability might demand the extra cerebral resources allocated to auditory and tactile processing following loss of vision. On the other hand, profound training in the auditory and tactile cues may be more advantageous for blind people and this add-on experience may be the most significant factor underlying enhanced performance.[88]

Sathian and Zangaladze,[93] suggested that visual deprivation might facilitate the tactile acuity enhancement as it promotes the repeated use of other senses to compensate for the loss of vision. The reason not to reject this hypothesis is reversible short term visual deprivation in normal sighted subjects may remarkably increase tactile acuity (Kauffman et al.[119]).

The lack of visual inputs in the occipital cortex of blind people might facilitate and augment the anatomical as well as functional plasticity arising out of intensive practice in other sensory modalities. According to Wong et al.[92] the effect of training may influence only a particular type of task or the sensory modality, rather than all other superior abilities that are exhibited by blind persons.[88]



CROSS MODAL PLASTICITY

Albert Postma et al reported that the blind displayed faster object - to-location matching i.e haptic processing of peripersonal space.[6]

Ptito et al highlighted that despite the massive volume reduction, the somatosensory or auditory inputs activate the visual cortex in the blind subjects. This suggests a reorganisation of the neuronal pathways that relay sensory inputs to the occipital lobe.[5]

The possible mechanisms that are suggested for the non visual information processing by the occipital lobe of blind are

(i) Direct thalamo - cortical connections to visual cortex

(ii) Cortico cortical connections from somatosensory to visual cortex

The limited use of touch by the sighted people could be the reason for the appreciated difference between blind and sighted. We normally look at what our hands are doing, and attentional resources could become dominated by the visual channel in these circumstances.[121]

COMPARISON OF CONGENITAL, EARLY AND LATE BLIND

In this study, a significant difference is present between congenital, early and late blind subjects in ART and TST. Both for auditory reaction time and tactile sensitivity threshold the congenital and early blind subjects show an enhanced performance than the late blind subjects.

Only very few studies are available for comparing all the three subgroups - congenital, early and late blind. Most studies included congenital blind in early blind group or else they compared congenital with late blind.

The probable reason for enhanced performance in early blind could be the cross modal plasticity. Many studies have proven the cross modal plasticity by various methods.

AUDITION

Catherine Y Wan et al [105], Gougoux et al.[122], Kujala et al.[108], Hotting and Roder[123], Collignon et al.[89], Charles Leclerc et al, [124] Alho et al.[125], Voss et al[88] put forth the cross modal plasticity phenomenon for better performance of congenital/early blind than late blind.

Catherine Y Wan et al [105] concluded that early blind performed better than late blind and the enhanced performance was even more pronounced in congenital blind for auditory tasks.

Charles Leclerc et al observed a posterior shift in the N1 attention effect in evoked potential which was considered to be an illustration of compensatory reorganisation in congenital blinds. This gains significance because it indicates that the superior abilities of blind is depended on stimulus feature analysis rather than improved cognitive or attentive strategies.[124]

Gougoux et al.[122], detected that the discrimination of pitch alteration between sounds was better in blind than sighted controls if the rate of alteration is ten times rapid. The performance of the blind is better when the blindness starts at an early age. i.e cerebral plasticity is maximum during the early years.[122] Brigitte Roder et al, reported that the temporal order resolution is also better in congenital blind than late blind.[121]

TACTILE SENSATION

Tomas Ortiz et al,[2] Cohen et al,[83,126] Sadato et al[103], Sathian et al[127] proposed the cross modal plasticity phenomenon for enhanced tactile sensation in congenital and early blind comparing to late blind.

Apart from these studies, C. Veraart and A.G De Volder [100] proved abnormally elevated glucose utilisation , M.C Wanet Defalque [99] observed high metabolic activity, Chun Shui Yu et al[98] and George Wittenberg et al[97] showed altered functional connectivity for non visual information processing in the occipital lobe is more prominent in early blind than late blind.

Cohen et al[83], Tomas Ortiz et al[2], Sathian et al[127], Sadato et al[103] confirmed the critical period of cross modal plasticity to be around 14 – 16 yrs of age , below which there is a maximal expression of sensory substitution. They also noted that the duration of blindness did not influence cross modal plasticity.

The reasons for superior performance of congenital and early blinds are the anatomical and functional switching of the striate cortex from processing visual information to non visual senses. It denotes the de novo neuronal plasticity in which the new connections are formed between the association areas in response to loss of vision.

Alternatively, the occipital cortex may possess the inherent property of processing of nonvisual information. In accordance to this hypothesis, the visual cortex may be considered as an 'operator' for a particular function depending on the input available. When the vision is present, visual input will mask other senses. Lack of visual input may stimulate the occipital cortex to process non visual informations. In case of late blind persons, there is unmasking of pre-existing connections and establishment of new neural connections. The magnitude of reorganisation differs between early and late blind and even more pronounced in congenital blind.[4] Nevertheless, the findings of previous studies do not show identical area of activation in early and late blind. Thus, further new studies are required to address this prime predicament.

MORE PLASTICITY IN THE CONGENITALLY BLIND

Early visual deprivation alters the receptive field properties in area 17 and prevents formation of specific projections from the thalamus. This allows the existence of more cross-modal projections.

By the time of puberty, projections between the striate and extra striate cortex have developed normally in those who have not suffered from visual deprivation. And also, the late blinds have been exposed to visual stimuli at some point. They reported that they transform tactile stimuli into a visual image because of their previous exposure. Then the cause behind the difference in activation of visual imagery in late blind and sighted is that the late - blind persons do not have competing thalamic inputs. The normally existing reciprocal connections between the medial temporal and V1 may be even more numerous for congenitally blind people as competition from visual input is not an issue.(Amedi et al., 2003 [128]). The increased number of feedback pathways in the congenitally blind thus allows for greater neural plasticity. [129,102]

SUMMARY

SUMMARY

- Auditory Reaction Time and Tactile Sensitivity Threshold were measured and compared between 100 normal sighted and 100 blind individuals. Various factors influencing both auditory reaction time and tactile sensitivity like age, sex, body mass index were analysed.

- A significant difference exists between normal sighted and blind individuals in both auditory reaction time and tactile sensitivity threshold.

- On comparing ART with gender, there is no significant difference between males and females in both normal sighted and blind people. But there is a significant difference between normal sighted and blind males as well as females.

- On comparing ART in different age groups, it is inferred that ART increases significantly as age increases. And also significant difference is present between normal sighted and blind within same age group.

- On comparing ART with BMI, there is a significant difference between normal, overweight and obese in normal sighted subjects but not significant in blind subjects.

- On comparing TST with gender among study groups, a significant difference is present between males and females of normal sighted but not in blind. Statistically significant difference exists between normal sighted and blind people for both males and females.

- On comparing TST with different age groups, TST increases as age increases in both normal sighted and blind. With the same age group, the difference is significant between normal sighted and blind.

- On comparing TST with BMI, a significant difference is present between normal, overweight and obese in normal sighted but not in blind.

- Both ART and TST show a significant difference between congenital, early and late blind.

CONCLUSION

CONCLUSION

Blindness is a functional disorder of vision. Blind people routinely use auditory and tactile cues to acquire information and orientation to the surrounding environment. Increased dependence on audition and touch, along with adequate practice in utilising these modalities is frequently reflected in superior ability of the blind people in executing these tasks. While enhanced hearing ability has been demonstrated by evoked potentials, ART is a perfect, simple, non invasive tool to measure the degree of sensory motor association and Semmes Weinstein Monofilament is a portable, simple to perform esthesiometer which provides accurate measurement of Tactile Sensitivity Threshold.

In order to assess the influence of auditory and tactile compensation in blind people, an attempt was made to study the Simple ART and TST.

In this study, the Simple Auditory Reaction Time and Tactile Sensitivity Threshold are significantly decreased in blind subjects compared to normal sighted subjects. It is also observed that congenital blind subjects have a faster Auditory Reaction Time and increased Tactile Sensitivity followed by early blind and then late blind subjects. This shows that the extent of cross modal plasticity varies according to the age of onset of blindness.

Blindness modifies the neocortical processing of non visual tasks which may be due to cross modal plasticity. Cross modal plasticity may provide a proficient opportunity to augment the localization, recognition, and navigation in blind community.

Among various factors influencing the Simple Auditory Reaction Time and Tactile Sensitivity Threshold - age, gender and body mass index were analysed.

As age increases, both Simple Auditory Reaction Time and Tactile Sensitivity Threshold increases. Gender and body mass index does not have an influence.

LIMITATIONS

The sample size may be increased to evaluate the influencing factors like gender and body mass index. Different phases of the menstrual cycle have an influence on both ART and TST and it should be considered. Evaluation of other facets of auditory and tactile modalities should be considered.

FUTURE SCOPE

Other functions like verbal memory, sound localization and speech comprehension can be analysed. Separate sensory substitution devices can be modelled for congenital, early and late blind. By combining multiple stimulus modality there is a scope for designing many easy to use human- machine interface in future.

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ANNEXURES

CONSENT FORM

I, _____, do hereby volunteer and consent to participate in this study being conducted by Dr.P.VINUPRADHA. I have heard reading aloud and understood the consent form (or) it has been read and explained to me thoroughly. I am fully aware of the study details as well as aware that I may ask questions to her at any time.

Signature / Left Thumb Impression of the patient

Station: Coimbatore

Date:

Signature / Left Thumb Impression and Name of the Guardian

Station: Coimbatore

Date:

ஒப்புதல் படிவம்

பெயர்_____வயது____,முகவரி_____

_____ஆகிய நான் உடலியங்கியல் துறை, கோவை மருத்துவ கல்லூரி பட்டமேற்படிப்பு மாணவி ஆகிய **மரு.பா.வினுபிரதா** அவர்கள் **"பார்வையற்றோர் மற்றும் பார்வையுடையோர் இடையேயான செவியுணர் செயல்பாட்டுத் திறன் மற்றும் தொடு உணர்திறன் வேறுபாடு"** என்ற தலைப்பில் செய்யும் ஆய்வில் கலந்துக் கொண்டு ஒத்துழைக்க சம்மதிக்கிறேன்.

இந்த ஆய்வின் செய்முறை மற்றும் இது தொடர்பான அனைத்து விளக்கங்களையும் கேட்டுக்கொண்டு எனது சந்தேகங்களையும் தெளிவு படுத்திக்கொண்டேன் என்பதையும் தெரிவித்துக் கொள்கிறேன்.

நான் இந்த ஆய்வில் முழுமனதாக சுயசிந்தனையுடன் கலந்துகொள்வதுடன் எந்த நேரத்திலும் இந்த ஆய்விலிருந்து விலகிட எனக்கு உரிமை உண்டு என்பதையும் அறிவேன்.

இந்த ஆய்வில் எனது விவரங்கள் பாதுகாக்கப்படுவதுடன் இதன் முடிவுகள் ஆய்விதழில் வெளியிடப்படுவதில் ஆட்சேபனை இல்லை/ விருப்பம் இல்லை என்பதை தெரிவித்துக்கொள்கிறேன்.

பெயர் :

இடம் :

தேதி :

கையொப்பம் :

PROFORMA

1. I.D No:
2. Address:
3. Age In Completed Years:
4. Sex:
5. Education :
6. Occupation:
7. Physical Status: HEIGHT : WEIGHT: BMI:
8. History of Diseases : Hypertension/ Diabetes/ Stroke/Seizure Disorder/Neuropathy/Psychiatric Problems/ Any Others(Specify)
9. History of any drug intake : yes/no ,if Yes what drug? Duration:
10. Personal Habits : Smoking /Alcohol/Tobacco Chewing/Pan,Guthka,Hans/ Others (Specify) , If Yes Duration of Usage : No.of Times Per Day:
11. Any Physical Disability: Yes /No ,If Yes Specify What Type :
12. Vision : RT LT
13. Blindness Type : CONGENITAL / EARLY / LATE
14. Handedness:
15. History of Braille Use: Yes /No ,If Yes From When?
16. Auditory Reaction Time :
    TYPE OF STIMULUS TIME
17. .Tactile Sensitivity :

MASTER CHART

Master Sheet

I.D	AGE	SEX	BLINDNESS	ART	TST	BMI	BMI - 2	AGE - 2
101	32	M	C	162	2.36	19.6	N	2
102	45	M	L	180	2.36	24.82	N	3
103	47	M	L	210	3.22	18.7	N	3
104	28	M	C	150	1.65	19.55	N	1
105	39	M	E	174	1.65	22.2	N	2
106	54	M	L	217	2.83	23	N	4
107	27	M	C	160	1.65	19.56	N	1
108	33	M	C	174	2.36	22.45	N	2
109	32	M	E	168	2.44	22.45	N	2
110	32	M	C	180	1.65	26.3	OV	2
111	40	M	L	196	4.08	27.56	OV	2
112	41	M	C	180	1.65	19.2	N	3
113	50	M	L	206	2.36	18.9	N	3
114	52	M	L	184	2.83	19.5	N	4
115	49	M	E	198	2.36	19.48	N	3
116	34	M	C	160	1.65	23.5	N	2
117	55	M	C	184	3.84	22.5	N	4
118	36	M	C	172	2.36	21.6	N	2
119	41	M	E	180	2.44	21.5	N	3
120	41	M	L	166	1.65	21.6	N	3
121	50	M	L	220	4.08	22.5	N	3
122	58	M	E	236	2.44	21.6	N	4
123	52	M	E	192	2.44	22.86	N	4
124	42	M	C	168	1.65	23.68	N	3
125	44	M	L	170	2.83	21.56	N	3
126	38	M	C	160	2.36	24.8	N	2
127	37	M	C	176	2.36	18.5	N	2
128	50	M	C	184	2.36	18.9	N	3
129	46	M	L	210	2.83	22.58	N	2
130	33	M	E	156	1.65	21.45	N	2
131	27	M	C	168	1.65	19.25	N	1
132	35	M	C	168	2.36	20.46	N	2
133	51	M	L	196	2.83	20.5	N	4
134	48	M	L	184	4.08	19.54	N	3
135	40	M	E	172	2.44	24.49	N	2
136	41	M	C	190	2.36	22.64	N	3
137	33	M	C	166	1.65	22	N	2
138	37	M	C	198	1.65	21.98	N	2
139	45	M	L	206	2.36	19.46	N	3
140	50	M	L	212	2.44	28.5	OV	3
141	28	M	E	180	3.22	31.6	OB	1
142	27	M	C	160	1.65	24.4	N	1
143	36	M	C	186	1.65	22.5	N	2
144	40	M	E	214	3.22	24.52	N	2
145	29	M	E	176	2.83	19.75	N	1
146	28	M	C	165	1.65	22.2	N	1
147	34	M	L	190	2.36	19.2	N	2
148	41	M	L	190	2.44	19.8	N	3
149	42	M	C	182	3.22	22.48	N	3

Master Sheet

I.D	AGE	SEX	BLINDNESS	ART	TST	BMI	BMI - 2	AGE - 2
150	48	M	C	206	3.22	32.62	OB	3
151	32	M	L	170	2.36	18.76	N	2
152	30	M	C	196	2.36	19.1	N	1
153	41	M	C	166	2.44	18.76	N	3
154	43	M	E	170	3.22	19.52	N	3
155	50	M	L	197	2.83	19.52	N	3
156	47	M	E	214	2.36	24.15	N	3
157	30	M	C	187	1.65	20.64	N	1
158	29	M	C	166	1.65	21.2	N	1
159	25	M	C	158	2.44	19.84	N	1
160	30	M	E	170	2.83	19.56	N	1
161	29	M	E	186	2.36	18.96	N	1
162	32	M	E	210	2.44	18.88	N	2
163	34	M	L	192	1.65	19.88	N	2
164	41	M	L	190	2.83	22.55	N	3
165	40	M	C	186	1.65	21.84	N	2
166	39	M	C	208	2.36	21.22	N	2
167	36	M	C	180	2.36	19.2	N	2
168	33	M	E	196	1.65	19.47	N	2
169	38	M	E	170	3.22	22.2	N	2
170	27	M	C	170	2.36	22.95	N	1
171	29	M	C	168	2.44	24.45	N	1
172	30	M	E	180	2.44	22.84	N	1
173	51	M	E	218	3.61	21.89	N	4
174	48	M	L	160	2.83	22.84	N	3
175	25	F	C	162	1.65	21.64	N	1
176	26	F	C	170	1.65	19.88	N	1
177	34	F	C	160	2.36	19.54	N	2
178	33	F	E	194	2.36	23.22	N	2
179	40	F	E	198	2.44	21.45	N	2
180	37	F	C	170	1.65	19.22	N	2
181	29	F	C	166	2.83	19.88	N	1
182	27	F	C	154	3.84	19.46	N	1
183	38	F	E	176	1.65	19.64	N	2
184	42	F	L	182	1.65	22.47	N	3
185	28	F	C	190	2.36	20.5	N	1
186	26	F	C	160	2.36	22.62	N	1
187	25	F	E	160	1.65	22.28	N	1
188	30	F	E	182	1.65	21.6	N	1
189	31	F	E	190	2.36	21.64	N	2
190	30	F	L	165	2.36	22	N	1
191	27	F	C	166	2.44	23.46	N	1
192	25	F	C	180	2.83	24.88	N	1
193	26	F	C	192	1.65	19.64	N	1
194	25	F	E	160	2.36	28.65	OV	1
195	31	F	E	174	2.36	25.6	OV	2
196	28	F	E	190	2.44	19.62	N	1
197	27	F	C	188	1.65	19.22	N	1
198	30	F	E	180	3.22	20.6	N	1

Master Sheet

I.D	AGE	SEX	BLINDNESS	ART	TST	BMI	BMI - 2	AGE - 2
199	36	F	E	210	2.44	22.35	N	2
200	29	F	C	180	1.65	22.5	N	1
201	31	M	N	182	2.83	21.45	N	2
202	45	M	N	210	3.22	25.6	OV	3
203	46	M	N	200	4.08	19.88	N	3
204	28	M	N	170	2.44	19.5	N	1
205	38	M	N	174	3.22	18.85	N	2
206	54	M	N	217	4.31	18.56	N	4
207	26	M	N	168	2.36	24	N	1
208	34	M	N	194	2.36	22.56	N	2
209	32	M	N	178	3.22	20.58	N	2
210	34	M	N	196	2.83	20.45	N	2
211	40	M	N	216	4.08	19.55	N	2
212	40	M	N	204	2.44	24.22	N	2
213	52	M	N	306	3.22	21.65	N	4
214	52	M	N	284	4.17	25.5	N	4
215	48	M	N	218	3.61	19.98	N	3
216	34	M	N	182	3.22	26.45	N	2
217	53	M	N	284	3.84	30.21	OB	3
218	36	M	N	172	2.83	19.88	N	2
219	40	M	N	280	3.22	19.5	N	2
220	41	M	N	186	3.61	24.6	N	3
221	50	M	N	210	4.08	28.88	OV	3
222	58	M	N	296	4.56	30.5	OB	4
223	52	M	N	232	3.84	22.25	N	4
224	42	M	N	188	3.22	19.32	N	3
225	44	M	N	270	2.83	19.56	N	3
226	36	M	N	170	2.44	19.44	N	2
227	37	M	N	276	2.36	19.54	N	2
228	50	M	N	218	4.17	31.22	OB	3
229	46	M	N	210	4.31	30.98	OB	3
230	30	M	N	166	2.44	19.5	N	1
231	27	M	N	158	2.36	18.99	N	1
232	35	M	N	198	3.22	19.56	N	2
233	50	M	N	296	3.54	20.45	N	3
234	48	M	N	184	3.22	20.54	N	3
235	39	M	N	192	3.22	21.12	N	2
236	41	M	N	190	4.08	32.55	OB	2
237	33	M	N	166	3.22	19.55	N	3
238	36	M	N	208	2.83	19.24	N	2
239	42	M	N	206	4.08	30.99	OB	3
240	50	M	N	252	3.84	29.98	OV	3
241	28	M	N	180	2.44	19.3	N	1
242	28	M	N	170	3.22	19.56	N	1
243	36	M	N	186	3.22	19.52	N	2
244	40	M	N	264	4.08	28.87	OV	2
245	28	M	N	176	2.36	18.99	N	1
246	30	M	N	195	3.61	19.2	N	1
247	34	M	N	190	2.83	19.44	N	2

Master Sheet

I.D	AGE	SEX	BLINDNESS	ART	TST	BMI	BMI - 2	AGE - 2
248	40	M	N	190	3.22	19.68	N	2
249	42	M	N	222	3.22	22.85	N	3
250	48	M	N	206	4.56	28.98	OV	3
251	33	M	N	170	2.83	19.22	N	2
252	30	M	N	196	2.44	19.58	N	1
253	41	M	N	246	3.84	18.68	N	3
254	43	M	N	190	4.08	26.6	OV	3
255	48	M	N	197	4.31	28.75	OV	3
256	47	M	N	214	2.83	19.23	N	3
257	31	M	N	217	2.36	19.24	N	2
258	28	M	N	166	3.22	22.54	N	1
259	25	M	N	178	2.36	18.86	N	1
260	30	M	N	190	2.36	18.75	N	1
261	29	M	N	216	3.22	20.58	N	1
262	32	M	N	210	2.83	19.57	N	2
263	36	M	N	192	3.22	19.98	N	2
264	41	M	N	230	2.83	21.48	N	3
265	40	M	N	216	3.61	22.57	N	2
266	38	M	N	208	3.22	22.57	N	2
267	36	M	N	196	2.36	20.45	N	2
268	33	M	N	196	2.44	20.48	N	2
269	38	M	N	270	3.61	25.45	OV	2
270	28	M	N	180	3.22	22.45	N	1
271	29	M	N	188	2.36	19.82	N	1
272	30	M	N	180	2.44	19.21	N	1
273	50	M	N	318	4.17	29.99	OV	3
274	48	M	N	280	3.84	26.22	OV	3
275	25	F	N	172	2.36	19.5	N	1
276	24	F	N	170	2.36	19.86	N	1
277	34	F	N	168	3.22	22.58	N	2
278	33	F	N	194	2.83	22.45	N	2
279	40	F	N	298	3.22	23.45	N	2
280	38	F	N	270	4.08	31.2	OB	2
281	29	F	N	196	2.36	19.21	N	1
282	28	F	N	174	2.36	19.4	N	1
283	38	F	N	206	3.22	22.75	N	2
284	42	F	N	282	3.84	23.3	N	3
285	28	F	N	190	2.44	19.75	N	1
286	28	F	N	186	2.83	18.88	N	1
287	25	F	N	160	3.22	19.56	N	1
288	31	F	N	282	2.36	18.66	N	2
289	31	F	N	190	2.44	18.66	N	2
290	30	F	N	195	2.83	18.28	N	1
291	27	F	N	186	3.22	22.34	N	1
292	25	F	N	210	2.36	20.63	N	1
293	26	F	N	192	3.22	22.58	N	1
294	26	F	N	180	2.83	18.99	N	1
295	30	F	N	174	3.61	22.88	N	1
296	28	F	N	190	2.44	19.62	N	1

Master Sheet

I.D	AGE	SEX	BLINDNESS	ART	TST	BMI	BMI - 2	AGE - 2
297	27	F	N	208	3.22	24.2	N	1
298	30	F	N	190	2.83	19.35	N	1
299	36	F	N	210	3.22	19.99	N	2
300	28	F	N	196	2.83	19.83	N	1

BMI - 2: BMI STATUS

N - NORMAL

OV - OVERWEIGHT

OB - OBESE

AGE - 2: AGE GROUP

1 → 21 - 30 Yrs

2 → 31 - 40 Yrs

3 → 41 - 50 Yrs

4 → 51 - 60 Yrs