

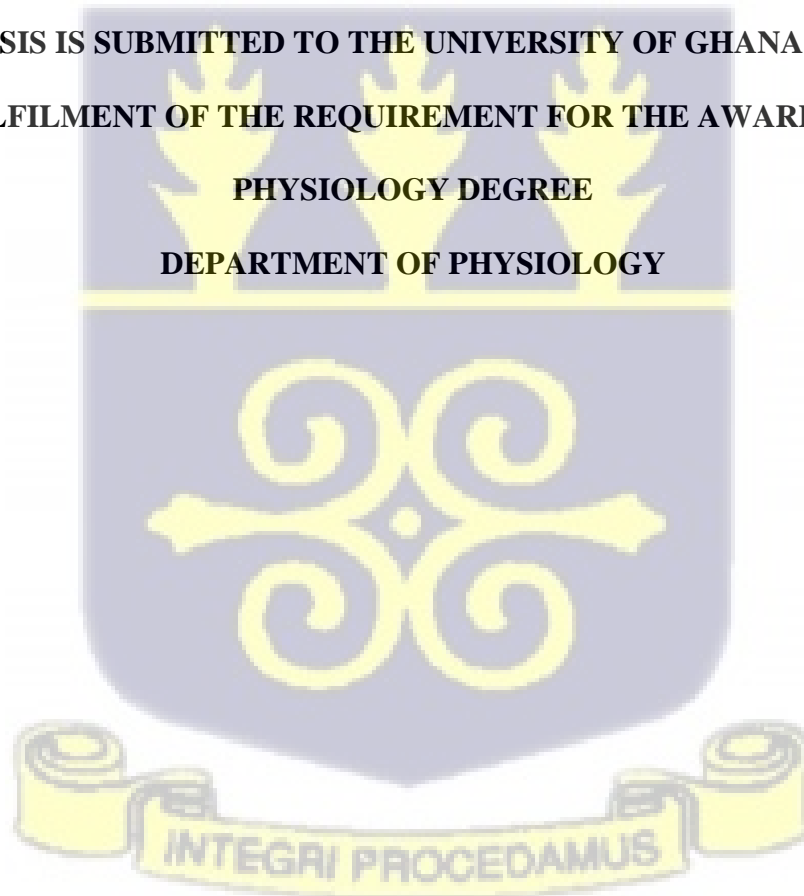
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**LEARNING STYLE ASSESSMENT AND ITS RELATIONSHIP WITH SENSORY  
MODALITIES; A STUDY AMONG THIRD – YEAR MEDICAL STUDENTS AT  
UNIVERSITY OF GHANA**

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**JULY, 2021**

**DECLARATION**

I, SENANU JOHN, author of this thesis do hereby declare that, with the exception of the references to other people's work which has been duly acknowledge, this work has completely my personal original research work.



23/03/22

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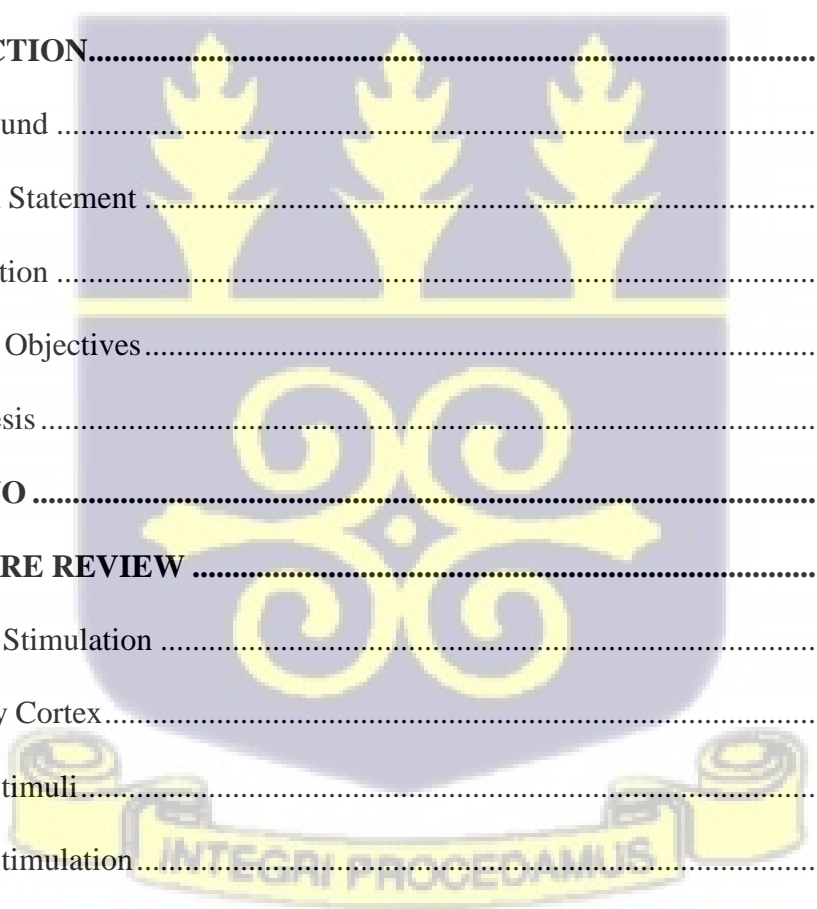
**DEDICATION**

I dedicate this work to my mother who has been very instrumental and encourages me to tow the path of education.



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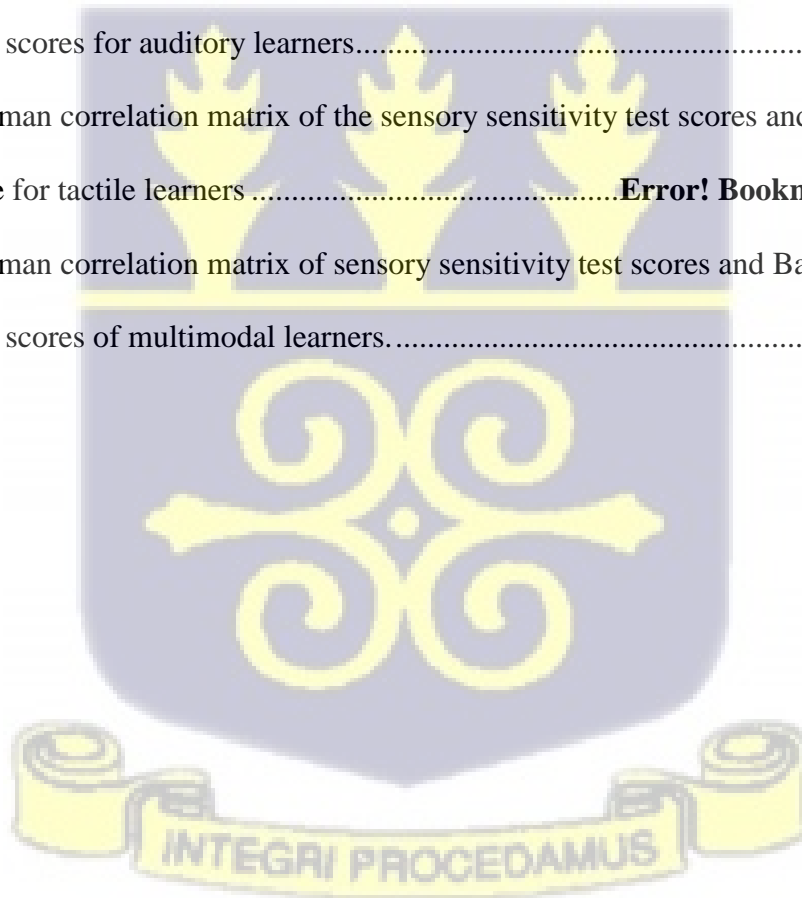
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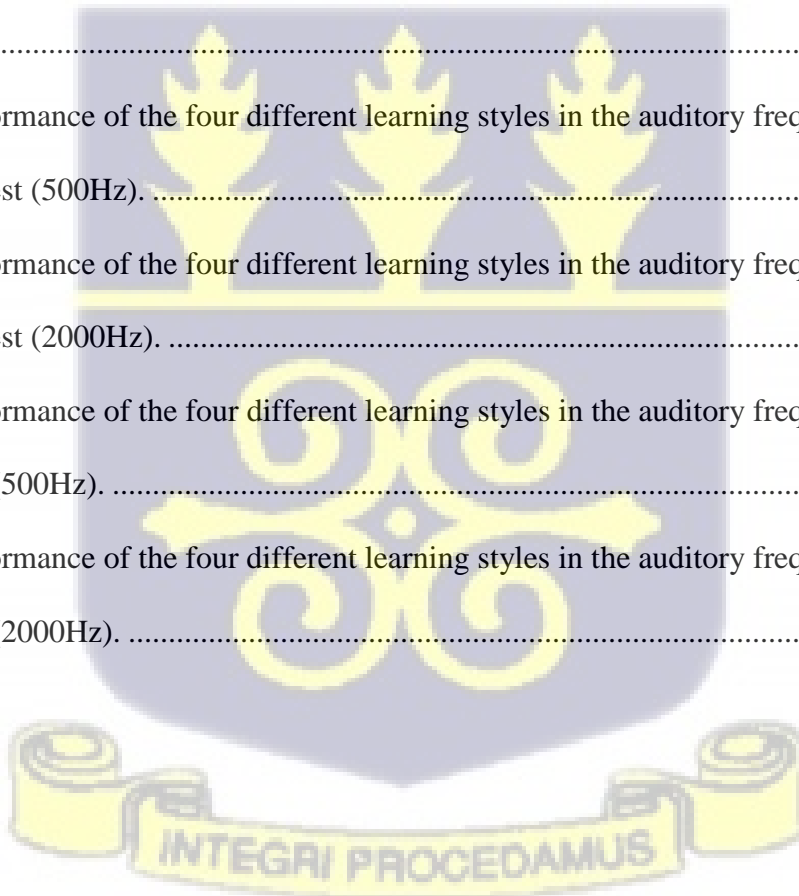
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## ABSTRACT

Background: Cognitive ability refers to the overall mental ability including conceptualizing, rationality, organization, critical thinking and learning. Research into various field such as neurocognitive and andragogy have identified different types of learning. Understanding and easing the learning process is the ultimate goal educating. Therefore, attention has been drawn to learning styles. Though there is considerable debate in research, the auditory, visual and tactile learning styles are often identified in students. Individuals differ in their preferred sensory modality for absorbing, retaining and processing of information. Whiles various researches have been conducted on learning style little is known about the role sensitivity plays.

Aim: The aim of the study is to investigate the relationship between sensitivity to sensory modalities and cognitive performance.

Method: The Barsch questionnaire was administered to 94 pre-clinical students to identify the preferred learning styles. Average performance in Pelli Robsin contrast sensitivity test was accepted as a measure of visual sensitivity, average performance in puretone audiometry, frequency discrimination task and frequency modulation task were accepted as a measure of auditory sensitivity and average performance in two point discrimination task were accepted as measure of tactile sensitivity. The Kruskal Wallis test was used to compare sensitivity scores among the four groups (visual, auditory, tactile and no/equal preference).

Results: Majority of the participants were unimodal learners 76.6% and the most preferred unimodal learning modality was visual, 41.5%, followed by auditory, 25%, and tactile, 9.6%.The visual learners had higher sensitivity Pelli Robsin contrast sensitivity test of 88% while auditory learners had a higher sensitivity in the puretone audiometry task, ( $20 \pm 5$ )Hz for the right ear and

( $19.5 \pm 5$ )Hz for the left ear. Tactile group had a higher sensitivity in the two point discrimination task of ( $1.20 \pm 0.17$ ) mm. Only the auditory learning modality had a positive correlation with the auditory sensitivity test  $r = 0.526$ ,  $p = 0.014$ .

Conclusion: Students have preferred learning styles (either unimodal or multimodal) adopted in learning. There was a positive correlation between only the auditory cognitive modality and sensitivity to auditory sensory tasks. Thus, knowledge of learning styles have significant impact on sensitivity to sensory modalities especially through the auditory modality.



## CHAPTER ONE

### 1.0 INTRODUCTION

#### 1.1 Background

One's cognitive ability is the overall mental ability involving rationality, conceptualizing, organization, critical thinking, understanding and enlightenment (Gottfredson, 1997). Learning is the process of obtaining improved conception, cognition, habits, expertise, morals, point of view, and predisposition (Gross, 2012). Throughout the world, new strategies and theories, keep coming in to facilitate student learning process. Research into fields such as psychometry, neurocognitive, behavioristic psychology, and andragogy has identified various type of learning ( Capellan, 2017)

This include associative learning which is subdivided into pavlovian conditioning, reflex and modelling. In Pavlovian conditioning, the learning process occurs as a result of combining a naturally effective stimulus (eg, food) with an initially unbiased input (for example, a ringing bell), in which the neutral stimulus learns to elicit a response (Galizia et al, 2013). Under reflex, the learning is achieved by rewarding or punishing to change the strength of habit. For modelling, learning occurs by observing the behavior of others. (Plotnik & Kouyoumdjian, 2013).

Secondly, non- associative learning which is subdivided into habituation (addiction) and sensitization. Under habituation, when a stimulus is repeated, one or both components of inherent processing (thus feedback probability and reaction time) declines. An example occurs when small song bird exhibit habituation when a stuffed owl (predator) is placed in a cage; the bird first react as if it were a genuine predator. The bird begin to react less and less, indicating they have become accustomed to the situation .Whereas in sensitization, following a repeated administrations of a stimulus, a response amplitude gradually increase. The repetitive tonic excitation of the outermost

nerves that occurs when someone touches their arm repeatedly is a daily instance of this phenomenon (Joseph, 2013).

In addition, we do have enculturation, episodic learning, tangential learning, dialogue learning, formal learning, informal learning, non-formal learning and incidental learning (Jungle, 2007). Individuals do acquire beliefs and actions that are acceptable or required in their environmental culture through the process of enculturation. Episodic learning occurs when an alteration in attitude occurs as an outcome of an event. For instance, episodic learning occurs when a person develops a phobia for dogs after being bitten by one. Tangential learning is a method through educating oneself introduced to a topic in an environment that they already appreciate. Others may be inspired to study the use of real musical equipment after playing a video game (Penny, 2014). Dialogue learning occurs through the process of dialogue (Vella, 2002). Formal learning occurs when a teacher and a student have a formal arrangement as in a college system. Also, non-formal learning is a structured studies besides the conventional educational system. For instance, in global youth groups, learning can be done by acquainting with others to undertake projects together. Informal learning is less regimented than non-formal learning .It can happen as a result of daily experiences, for instance looking forward to avoid danger when walking (Lertkittisuk, 2019). Under Incidental learning, Learning happens as a result of different pursuit – an event, incident, occurrence, — and not outlined by the teacher or the learner. This learning occurs in addition to or in contrast to the instructor's intentions and the expectations of the students. With the four phase of learning, insensate in proficient, sensate in proficient, sensate proficient and insensate proficient, learners go through each stage faster or slower depending on how much or little they know about a topic (Kent, 1991).

Understanding and easing the learning procedure is the ultimate goal of educating. Therefore, attention has been drawn to the study of learning styles within the field of education. The way a learner receives and processes information is referred to as their learning style and is defined as a unique and consistent method of learning knowledge, skills and attitude through study and experience (Kolb & Kolb, 2013). Furthermore, an individual's chosen learning style is how he or she learns best (Sadler-Smith, 2001). Although there is considerable debate in the research, the auditory learning style, visual learning style and tactile/kinesthetic learning style are the three instructing techniques that are frequently identified in students (Gilakjani & Ahmadi, 2011).

Individuals differ in their preferred sensory modality for absorbing, retaining and processing new information, according to theory (Cassidy & Eachus, 2000.). In particular, how well a person absorbs and retains knowledge is greatly determined by whether the information is delivered in the person's preferred learning mode (Zapalska & Dabb, 2002). A visual learner, for example is said to learn best when presented with graphical or other visual stimuli such as diagrams, charts or maps, whereas an auditory learner does better with spoken stimuli, such as lecture. A visual learner, according to the learning style hypothesis, must see, observe, record, and write in order to learn. (Dunn, 1993; Zapalska & Dabb, 2002). An auditory learner prefers spoken and heard information, such as that found in dialogue and discussion (Dunn, 1993; Zapalska & Dabb, 2002). Kinesthetic learners love to learn in an atmosphere where he or she can touch the material and be physically involved with the information to be learnt (Dunn, 1993; Zapalska & Dabb, 2002). Environmental, emotional, and cognitive elements, as well as previous experiences, influence student learning style. Learning style refers to how pupils learn rather than what they learn (Gokalp, 2013; Fardon, 2013). Understanding the diverse learning styles of students enrolled in medical school will lead to a more successful learning experience since they can employ and focus

on the styles and approaches that really work for them more during studies (Alavi & Toozandehjani, 2017). In addition, Barman et al. (2014) found that students' knowledge of their styles can help them enhance their academic performance.

A measurable change in the physical or chemical structure of an organism's internal or external environment is referred to as stimulus (Leavell & Bernal, 2019). Sensitivity is defined as an organism's or organ's ability to notice external stimuli and respond appropriately (Blundell, 2005). We learn and experience the world through our sensory system, which allow us to comprehend what is in our surroundings and how our bodies react and function in response to it (Laird, 1985, Ayres & Robbins, 2005).

### **1.2 Problem Statement**

For a long time, analysts and instructors alike assumed that a person's insight influenced how they learnt, but subsequent testing revealed that pupils with the same IQ performed dramatically differently on similar learning tasks (Harrison et al., 2003). Other than the now-defunct IQ-based hypothesis, there have been considerable initiatives to investigate the topic of learning style and tools to test and explain individual learning styles over the last 35 years. Whiles various studies on learning style sensory modalities have been conducted, little is known about the role of sensitivity. The relationship between one's self-assessed learning style and one's sensitivity to sensory modalities performance employing various stimulus types not well investigated. Furthermore, there is a dearth of information on the difference between objective and subjective learning metrics. The capacity to objectively identify a person' preferred learning style can impact instructional tactics, resulting in improved academic performance.

### **1.3 Justification**

Assessing the role of sensitivity to sensory stimuli and its effects on learning would establish knowledge on how sensitivity to sensory stimuli affects or impacts learning. This would also help learners identify best ways that suit them in learning effectively and efficiently.

This would also provide relevant information on students preferred learning styles during academic studies. Findings could shed light on alternative approaches to assist people with learning disabilities

### **1.4 Aim**

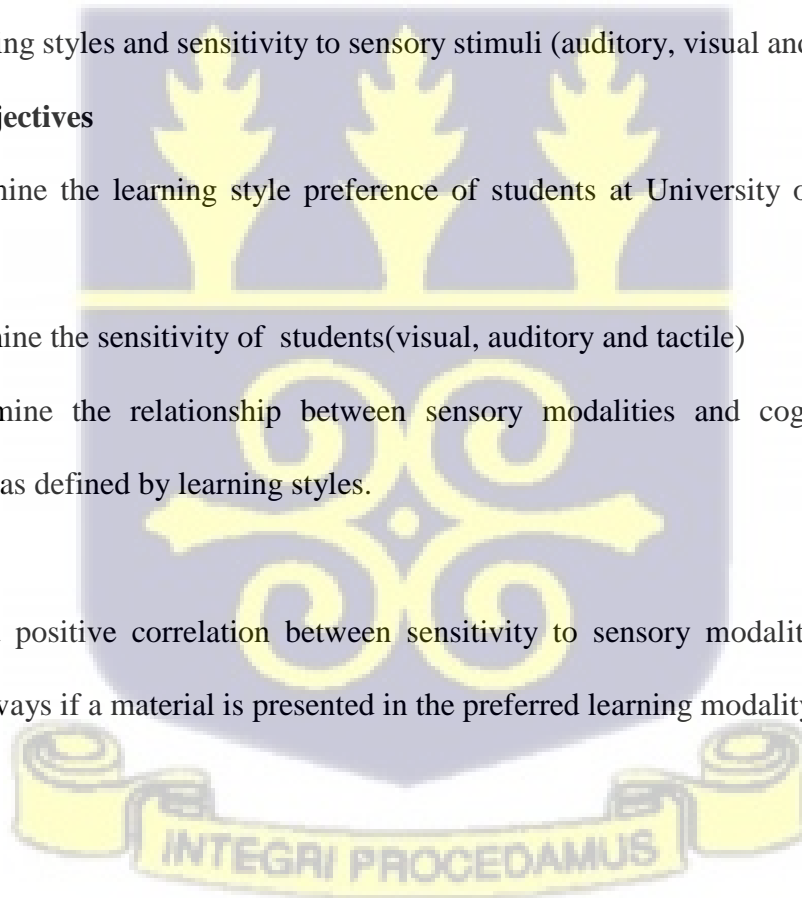
The aim of this study is to investigate the relationship between cognitive processing pathways as defined by learning styles and sensitivity to sensory stimuli (auditory, visual and tactile stimulus).

### **1.5 Specific Objectives**

1. To determine the learning style preference of students at University of Ghana Medical School.
2. To determine the sensitivity of students (visual, auditory and tactile)
3. To determine the relationship between sensory modalities and cognitive processing pathways as defined by learning styles.

### **1.6 Hypothesis**

There will be a positive correlation between sensitivity to sensory modalities and cognitive processing pathways if a material is presented in the preferred learning modality of students.



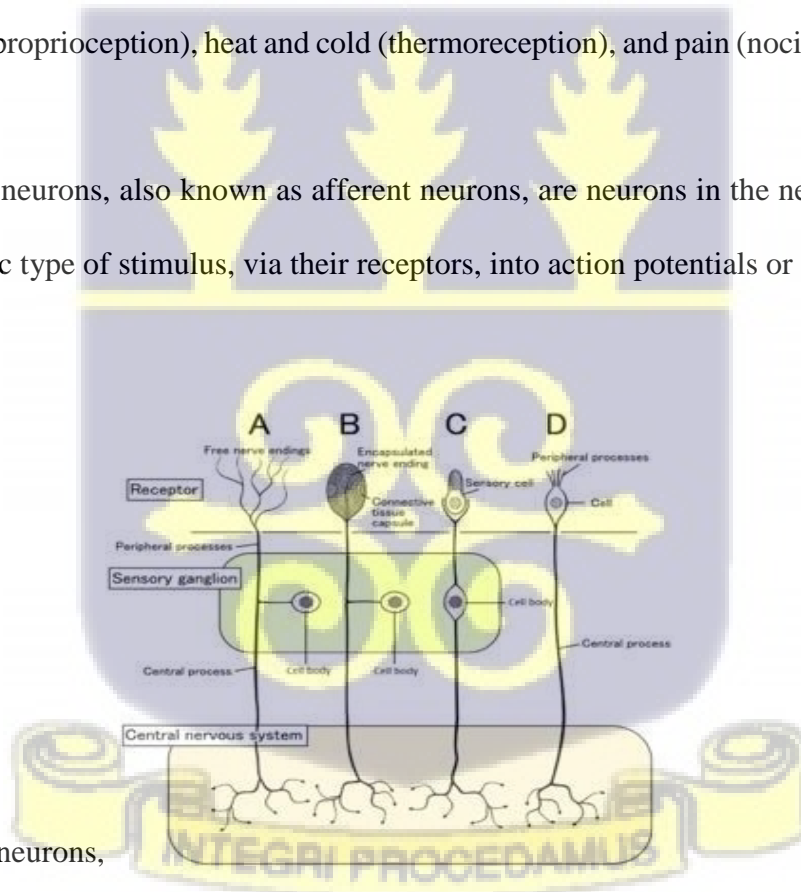
## **CHAPTER TWO**

## 2.0 LITERATURE REVIEW

### 2.1 Sensory Stimulation

Our biological systems responsible for sensation give us important information about ourselves and our surroundings, such as the identities and positions of things, the speed with which we move within the environment and the safety of substances we consume (Johnson, 2002). Based on the type of stimulus detected, our sensory systems have been categorized into five main sensory modalities since ancient times: ophthmoception (vision), audioception (hearing), tactioception (touch), olfaction (smell), (gustaoception) taste. Others senses have been identified and group under the somato-visceral modality, which include touch category (mechanoreception), position and movement (proprioception), heat and cold (thermoreception), and pain (nociception) (Gebhart, 1995).

**Fig 2.1** Sensory neurons, also known as afferent neurons, are neurons in the nervous system that convert a specific type of stimulus, via their receptors, into action potentials or graded potentials.



(From sensory neurons,

<https://www.researchgate.net-figure/sensory> neurons)

Our senses have a finite dynamic range within which it operates (Majid & Levinson, 2011). For instance, when it comes to the auditory system, humans can normally hear sounds between 12Hz and 20 kHz, albeit this frequency range decreases with age (Willott, 1991). Furthermore, as humans we are unable to perceive stimulus with very low sound pressure levels such as [0 dB SPL], while sound stimulus with amplitude greater than 120-149 dB SPL produce pain and may cause damage to the auditory system (Nave, 2006). Traditionally, it is understood that this “comfort range” for sound stimulus perception will differ from person to person due to other contributing factors such as genetic related issues (Zelinsky, 2017). To notice and perceive a sound stimulus, individuals with sensorineural hearing loss (deafness secondary to conditions affecting the inner ear, internal acoustic canal, cerebellopontine angle, or vestibulocochlear nerve) will require higher amplitudes and at low sound amplitudes auditory discomfort is felt in people with other related conditions including tinnitus (the sense of sound within the ear in the absence of external sounds) sometimes called hyperacusis (Jastreboff, 2000). This form of narrowed comfort zone is especially problematic for people on the autism spectrum because they exhibit atypical or local superior processing (Burns et al, 2017).

In humans, various researches show positive links that exist between the integrity of the neural processing of sound and cognitive abilities (Kraus et al, 2012), which suggests that the legacy of cognitive involvement and performance is observed through the precision and accuracy of neural function. Furthermore, these findings point to the fact that training oneself for strengthening a cognitive skill leads to enhancement of sensory systems (Anderson et al, 2013). A lot of these insights are derived from the studies of music (acoustic) training, which mostly provides a model to understand and appreciate the biology of auditory learning (Patel, 2014). Making and composing music requires that an individual engage and involve multiple cognitive systems, and to direct and

focus attention to the sounds that are heard, produced, and manipulated. The physical act and skills of producing sound through instrument or voice mandates and involves intricate motor control and stimulating auditory-motor projections (Limb & Braun, 2008). The musician's brain as an auditory learner has been fine-tuned to process sound stimuli, making it a useful specimen in the study of possibilities of experience-dependent plasticity.

## **2.2 Auditory Cortex**

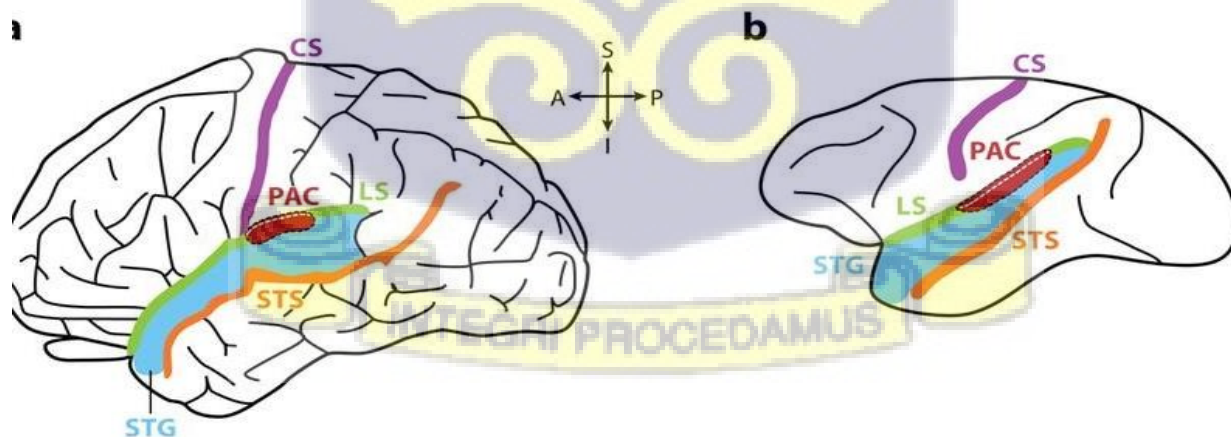
The auditory cortex of the brain has been viewed through studies as the final level in processing the numerous sound stimulus always reaching our ears from our environment and also as an essential part in intellectual tasks that relates to auditory stimuli (Weinberger & Diamond, 1987). The plasticity of this cortex has been studied and reported in diverse ranging to frequency discrimination situations (Weinberger, 2007) or spatial discrimination tasks by other reports (Lee and Middlebrooks, 2011) to auditory pitch extraction studies conducted among individuals (Bizley et al., 2013). Then attentional tasks related to sound stimulus (Otazu et al., 2009), selective attention relating to sound in the hearing setting (Wittekindt et al., 2014), and others such as predictive coding (Malmierca et al., 2015). Aside its main function in cognitive processes, several studies conducted on different species suggested that the cortex is also an essential organ in producing noise-invariant presentations of communicating sounds (Khalighinejad., 2020). For instance, studies show that cortical processing and responses to conspecific vocalizations, and how they are discriminated by cortical neurons were greatly maintained in different modes of sound changes performed in the spectral and temporal domain (Souffi et al., 2020).

### **2.2.1 Inputs to the auditory Cortex**

The ear is where auditory information is processed, with hair cells positioned along the basilar membrane of the cochlea in the inner ear. They respond topographically to sound frequencies, i.e.

tones (Zhang & Gong, 2019). As a result, starting with a frequency that flows smoothly from higher to lower on the membrane (Stankovic & Guinan, 2000). As auditory information is processed and passed on from the auris interna through the brainstem, for example, starting from the cochlear nucleus to superior olive, then to medial lemniscus to inferior colliculus, to the medial geniculate nucleus (MGN) of the thalamus, and into Primary Auditory Cortex(PAC) this tonotopic (or cochleotopic) organization is maintained (Kaas & Hackkett, 2000). The PAC lies in the superior temporal gyrus (STG) and do extends into the lateral sulcus and the transverse temporal gyri (also called Heschil's gyri).The final sound processing is done by the parietal and frontal lobes of the cerebral cortex. From the basilar membrane to the auditory cortex, tonotopic organization is conserved, allowing for a common reference frame in this hierarchically organized sensory system (Kaas 1997, Nourski & Brugge, 2011).

**Fig 2.2** Primary auditory cortex (a) schematic of the human left cerebral hemisphere in lateral aspect. The white dotted line within this region indicates the extension of PAC into LS along Heschl's gyrus, which is not apparent in this view (b) schematic of the left cerebral hemisphere of a macaque monkey. Within the black dotted line, the overall position of PAC is again shown in red.



(From Maps of the Auditory Cortex by Brewer & Barton, 2016, <https://doi.org/10.1146/annurev-neuro-070815-014045> )

## **2.3 Tactile stimuli**

During manual interactions with an object, tactile signals are released and this provides precise and rapid feedback about the interface between hand and object. In our skin, several groups of mechanoreceptors convey detailed information about the timing, location, and nature of the contacts, and these signals are essential to our ability to dexterously handle and manipulate objects (Augurelle et al. 2003; Witney et al. 2004; Johansson & Flanagan 2009). While tactile signals received by the mechanoreceptors inform and elicit behavioral attitudes at various stages of information processing, the somatosensory cortex plays an essential role in dexterous manipulation. This is demonstrated by the fact that lesions of the somatosensory parts of the brain cause severe and lasting impairments in hand function. (Carlson 1990; Hikosaka et al. 1985; Xerri et al. 1998; Brochier et al. 1999; Duque et al. 2003; Schabrun et al. 2008).

### **2.3.1 Tactile stimuli processes**

Sensory events, particularly pain, can elicit a strong reaction and lead to neural alterations. Pain causes a change in behavior in the body that is proportionate to the severity of the pain (Von Korff et al., 1992). The experience is recorded by sensory receptors on the skin and conveyed to the central nervous system, which processes it and decides how to respond; if a response is required, a signal is sent down to a muscle, which responds appropriately to the stimulus (Nicholls et al., 2012). The major somatosensory area for the feeling of touch, is located in the postcentral gyrus (Bleyenheuf & Thonnard, 2009).

Pain receptors are called nociceptors. Group A-fiber nociceptors and group C-fiber nociceptors are the two basic types of nociceptors (Djouhri & Lawson, 2004). Myelinated group A-fiber receptors

conduct currents quickly. They are mostly employed to deliver quick and acute pain. G C-fiber receptors, on the other hand, are unmyelinated and transmit slowly. Slow, shearing, diffuse pain is sent by these fibers (Stucky et al., 2001).

The absolute touch threshold is the quantity of sensation required to elicit a response from touch receptors (Wellnitz et al., 2010). The force exerted by dropping a bee's wing onto a person's cheek from a distance of one centimeter is generally thought to be the absolute touch threshold. This value will alter depending on whatever portion of the body is being touched (Craig, 2003).

## **2.4 Tactile stimulation**

Starting from the hand, tactile information is passed on to the dorsal column of the spinal cord, to the dorsal column nuclei of the medulla, to the ventroposterior complex of the thalamus then finally to the cortex. In the hand, together with efferent (motor) fibers, afferents that innervate neighboring receptors bundle into fascicles, which eventually join other fascicles to form nerves. The palmar side of the hand and arm is innervated by the median and ulnar nerves, whereas the dorsal side of the hand and arm is innervated by the radial nerve. The nerve divides into dorsal and ventral roots as it approaches the vertebral column, with the former carrying sensory fibers and the latter motor fibers.

### **2.4.1 Spinal cord: Dorsal column**

The fibers in the Dorsal Root ganglia (D R G) terminate in a variety of places. For starters, this fibers can project straight onto  $\alpha$ - motor neurons at the same spinal cord level. Second, they can ascend or descend the spinal cord, projecting onto interneurons at neighboring levels. They can then rise (creating the dorsal column tract) and synapse onto neurons in the brainstem's dorsal column nuclei (DCN). Fibers in the dorsal columns are somatotopically arranged (Frohlich &

Meston, 2005), which means that afferents that innervate contiguous areas of the body tend to cluster together, providing a map of the body for both the upper and lower parts laterally and medially.

#### **2.4.2 Medulla: Dorsal column nuclei (DCN)**

The dorsal column nuclei (DCN) are made up of three nuclei that receive input mostly from first order neurons. The cuneate nucleus as well as external cuneate nuclei receive signals from the upper body, whereas the gracile nucleus receives impulses from the lower body. The trigeminal nerve supplies the major division of the trigeminal nucleus fibers from the upper part of the body. The input to the cuneate nucleus comes predominantly from cutaneous afferents, whereas the input to the external cuneate nucleus comes basically from or deep signals (Dykes, 1983). The DCN are organized starting from the lower limb through the medial and lateral axis to the head (Xu & Wall, 1996). Although the response qualities of DCN neurons appear to be fairly comparable to signals from the afferents, most research have been conducted in cats, while in primates the details are not clear. Sensorimotor cortices also send downward input to the DCN, that alter sensory signals before relaying them to upward regions. (Bentivoglio & Rustioni, 1986). The medial lemniscal route is formed by the extensions of neurons of the DCN sending axons contra-laterally to the ventral and posterior regions of the thalamus (Darian-Smith et al., 1990).

#### **2.4.3 Thalamus: Ventroposterior complex**

The medial lemniscal route brings signals from the contralateral dorsal DCN to the somatosensory thalamus. The main sections of the ventroposterior complex are ventroposterior nucleus (VP), ventroposterior superior nucleus (VPS) and ventroposterior inferior nucleus (VPI). (Krubitzer & Kaas, 1990). A lateral compartment (VPL) and a medial compartment (VMC) are separated into VP (VPM). VPL receives cutaneous input from the DCN, while VPM receives input from the

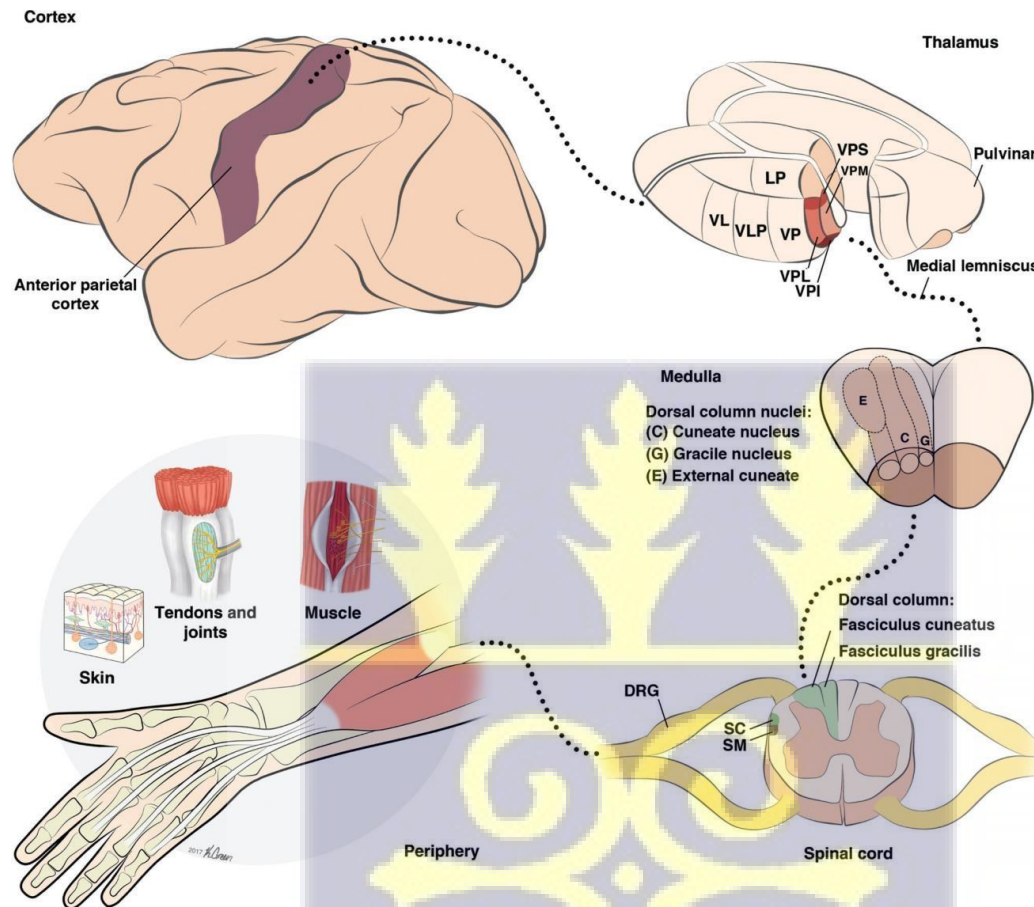
trigeminal nucleus; VPS receives input from proprioceptive fibers; and VPI receives significant input from the spinothalamic tract and is involved with thermoreception and nociception (Ashaber et al, 2014). The ventroposterior complex is divided into three main divisions (VP, VPS, and VPI), each of which is somatotopically organized and comprises a comprehensive map of the contralateral body (Padberg et al, 2009).

#### 2.4.4 Cortex

The anterior parietal cortex, APC, also known as the primary somatosensory cortex, is the primary receiver of inputs from the periphery. It is positioned along the anterior edge of the parietal lobe. Brodmann's areas 3a, 3b, 1, and 2 are cytoarchitecturally distinct areas in the APC, although only one of them, area 3b, may be termed primary somatosensory cortex proper due to its targeting of thalamocortical input (Kaas, 1983). The greater RFs and more complex response characteristics of Areas 1 and 2 indicate that they are higher cortical areas (Felleman & Van, 1991). APC, in turn, transmits projections, which have been compared to the visual system's ventrodorsal streams (Gardner, 2008). The secondary somatosensory cortex (S2) and the parietal ventral area (PV) are part of the ventral stream in the lateral parietal cortex (LPC), where neurons show greater sensitivity and more complex responses characteristics than their counterparts in the APC. This somatosensory route is associated with improved extraction (Fitzgerald et al, 2004) as well as cognitive activities including attention and decision-making (Jiang et al, 1997). The dorsal stream of the posterior parietal cortex (PPC) contains regions 5 and 7, which have significant and typically bilateral RFs (Leinonen et al, 1979) and is more closely connected to motor action, such as reach and grab (Andersen & Buneo, 2002).

**Fig 2.3** Pathways from somatosensory periphery to cortex. Afferent fibres at the periphery bundle in fascicles join to form the nerves. Afferent cell bodies are gathered in the dorsal root ganglia.

When entering the spinal cord through the dorsal root, afferent axons branch, sending one projection to the dorsal horn and one projection to the dorsal column nuclei through the dorsal column. The dorsal column projects contralaterally through the medial lemniscus to the ventroposterior complex of the thalamus, which in turns relays the information to cortex.



(From somatosensory pathways to cortex, <https://www.researchgate.net/figure/somatosensory-pathways>)

## 2.5 Visual Stimuli

Our brain can perceive as well as respond to changes occurring around the body through vision. Light-based information, or stimuli, enters the retina and stimulates a unique sort of neuron known as photoreceptor cell. Rods and cones are the two types of photoreceptor cells found in the retina. Scotopic vision, or low-light vision, is predominantly controlled by rod cells. Rods are the retina's

most prevalent cell type, and their density peaks at 15 to 20 degrees from the fovea, a small depression in the retina of the eye where visual acuity is strongest (O'Brien, 2008). In the human retina, there are around 90 million rod cells. Cones are the cell type most engaged at greater light levels when photopic vision predominates, and they confer color vision and good spatial acuity. The fovea is the most densely packed with cones and is devoid of rods. There are around 6 million cone cells in the human retina. It's worth noting that there's a "blind area" in the vision field around the optic nerve where photoreceptor cells are missing. Potentials do originates in the photoreceptor, where it brings about excitation of the cell sufficiently for the impulse to be transmitted to the central nervous system via a track of neurons. Action potentials must be generated as the signal do travels from a site of the photoreceptors to neurons in order for it to reach the Central nervous system ( Nicholls et al., 2012) .The stimulus does not reach absolute threshold if it does not deserve a strong enough response, and the body does not react. The brain would then process the information and also react correctly if the stimulus coming is strong enough to trigger or produced an action potential in neurons away from the photoreceptor. In addition, the main visual cortex is in the occipital lobe of the Central nervous system in which visual information is processed (Purves et al., 2012).

### **2.5.1 Contrast**

The difference seen in luminance or color that distinguishes a visible object (or its representation either as in an image or display) is called contrast (Oliva & Schyns, 2000). The difference observed in color type and brightness level of a visible object and other things in same viewing field determines contrast in visual perception domain of the real world (Graham, 1989). The human

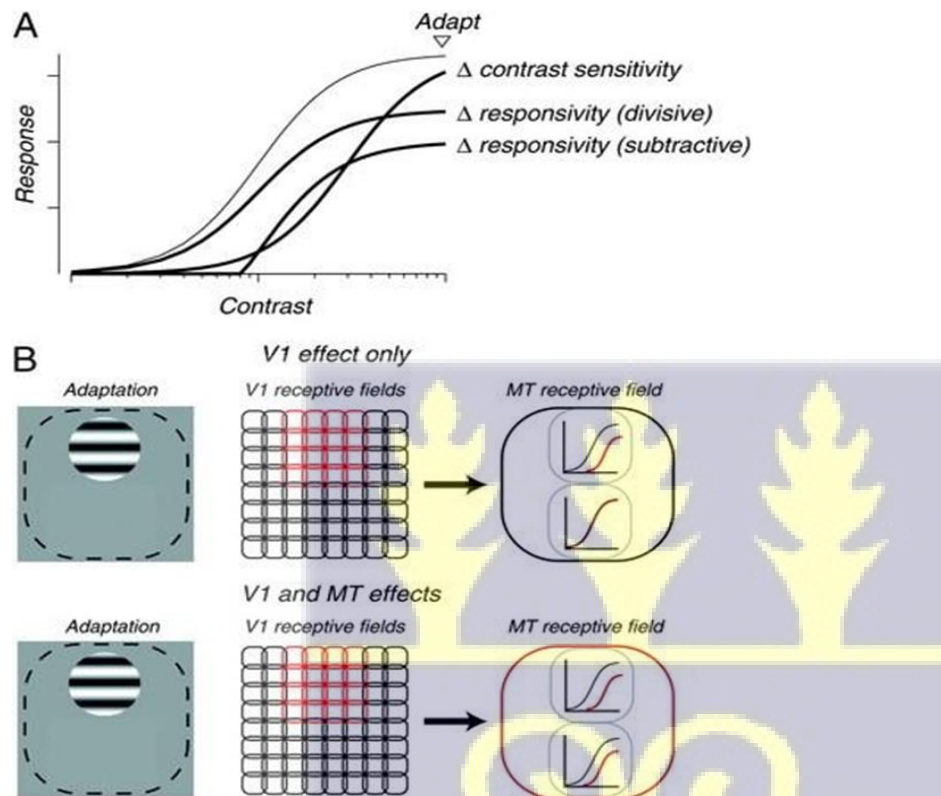
visual system has been identified as more sensitive to contrast than absolute luminance, eg humans can experience the world in the same way regardless of large variations in illumination throughout the day or from location to location( Baccus & Meister, 2004).

### 2.5.2 Contrast Adaptation

The visual system might theoretically adjust to new sensory information independently of one another within every step of processing, or possible anytime there are great volumes of neurons conveying nerve impulse to a synapse. (Hosoya et al., 2005). This could also apply changes quickly in the filtering stream and convey the resulting changed presentations to bottomward sections. Adaptation to a high-contrast stimulus reduces the apparent contrast of a test stimulus on a perceptual level (Sutter et al., 1989). Diminished contrast should be predicted to result from declined level of neuron sensitivity since reduced-contrast stimuli elicit low sensitivity in neurons of the visual system. This neuronal effect might be caused by a disruptive decrease in triggering rate (that diminishes the cells' effective range and hence present a type of detrimental exhaustion) or a decrease in contrast responsiveness (that results in a forward alter of the contrast reaction function). Each of these changes is evident in recordings from the primary visual cortex (V1), although the decline in contrast sensitivity is the most prominent (Albrecht et al. 1984). The cells' dynamic range is centered on the previously experienced average contrast after this sensitivity readjustment.

**FIG. 2.4** Adaptation's effects on contrast sensitivity A: Neuronal responses to increasing contrast stimuli are typically sigmoidal (thin line). High contrast adaptation (arrowhead indicates adapter contrast) can affect the contrast response function (thick lines) in one of three ways: a change in contrast sensitivity, a divisive change in responsivity, or a subtractive shift. B: in MT, determining the geographical specificity of adaptation A tiny adapter (left) will affect a subpopulation of V1

cells whose receptive fields (RFs) overlie the adapted region if adaptation increases contrast sensitivity of primary visual cortex (V1) but not MT cells (top row) (red, middle). In the modified region of an MT RF (right), a change in the contrast response function can be noticed, but not in a second site.



(From Adaptation's effects on contrast sensitivity by Kohn, 2007, <https://doi.org/10.1152/JN.00086.2007/ASSET/IMAGES/LARGE/Z9K0050781800003.JPEG>)

### 2.5.3 Mechanisms of visual sensitivity

The molecular mechanisms behind modifications in different sensitivity of neurons are possibly the well understood of all adaptation effects. Whole-cell recordings in the cortex have revealed that adaptation causes a substantial somatic hyperpolarization but no change in synaptic input (Carandini & Ferster, 1997). The  $\text{Na}^+$  influx which occurs when there is a synaptic process and the production of action potentials triggers the activation of a sodium-gated potassium channel,

which causes after hyperpolarization (Sanchez-Vives et al., 2000). These channels can also be activated through depolarizing current injection, resulting in alterations comparable to those seen after visual adaptation. The length of time it takes for the recovery of sodium channels from inactivation is curiously dependent on the length of the initial depolarization, implying that such mechanisms could be implicated in a other physiological based processes (Toib et al. 1998).Synaptic depression caused by the depletion of vesicles in the presynaptic terminal is a second mechanism that may be activated by adaptation. Unlike cat visual cortex research, other studies found no indication of alterations in cortical cell intrinsic features (e.g., hyperpolarization) (Chung et al, 2002). The role of synaptic depression in the rat barrel system may be explained by the low spontaneous and evoked firing rates of the relevant neurons. The thalamocortical synaptic depression caused by high spontaneous firing rates in the cat lateral geniculate nucleus (LGN) is considerable, leaving little room for further adaptation after adaptation (Boudreau & Ferster, 2005). Only when current activity is inhibited artificially in the cat primary visual cortex (V1) are corticocortical connections similarly decreased (Reig et al., 2006). Connections between pyramidal and some types of inhibitory cells in cortical brain slices become more fluid during repetitive driving, perhaps boosting the severity of recurrent inhibition (Thomson & Deuchars 1997). However, current in vivo evidence suggests that inhibition changes do not support adaptation's cortical effects.

Bicuculine methiodide iontophoresis, which lowers GABA-mediated synaptic inhibition, has minimal influence on adaptation in V1 but magnifies results in the Lateral geniculate nucleus, LGN (Yang et al. 2003). When neurons in Middle Temporal ( MT ) are exposed to a stimulus that shifts in the opposite direction of their preferred orientation, they get significant inhibitory input, providing a clear opportunity to investigate how synaptic inhibition is influenced by adaptation

(Kohn & Movshon, 2003). Using compound stimuli consisting of a preferred and null grating, researchers discovered that null adaptation reduces the strength of opponent inhibition (Kohn & Movshon, 2003). This result can be explained by a decrease in the contrast sensitivity of the inhibiting cells, but it contradicts the assumption that adaptation potentiates inhibition. Despite the fact that other research have revealed that a metabotropic glutamate receptor antagonist can block the cortical effects of adaptation, the role of metabotropic receptors has been largely ignored (McLean & Palmer, 1996). GABA agonists appear to enhance the LGN's adaptation effects as well (Yang et al. 2003). Given its ubiquity and kinetics, the significance of metabotropic receptors in adaptation needs more exploration. No synaptic mechanism is required for stimulus specificity or the efficacy of non-excitatory adapters since neurons are incorporated in recurrent networks. Hyperpolarization of these presynaptic cells would result in a stimuli-specific loss of responsiveness since other sensitive neurons control a cell's response to a given stimulus (Carandini & Ferster, 1997). The efficacy of adapters that fail to elicit a response in the recorded cell may be explained by the hyperpolarization of widely tuned presynaptic cells. Intracellular recordings demonstrate that synaptic input is retained throughout adaptation, which appears to contradict this (Sanchez-Vives et al. 2000). Postsynaptic hyperpolarization, which enhances the driving force for synaptic events while masking a decrease in the absolute but not relative amplitude of input given by the adaptor, explains the discrepancy (Nowak et al. 2005). In a recurrent model of V1 circuits, these researchers discovered that depending on which synapses are modified, both attractive and repulsive tuning alterations can occur. Narrow tuning and attractive shifts in tuning result from a drop in excitatory input to the adapted cell, whereas repulsive shifts in preference result from a decrease in both excitation and inhibition (with the latter

predominating). These models may be able to describe how adaptation alters tuning at different phases of the processing process.

## 2.6 LEARNING STYLES

Generally, learning style can be defined as a person's chosen method of receiving, processing, and making inference about a subject matter (Coffield et al, 2004). It has received a lot attention since the previous years as a result of the notion that identifying an individual's chosen learning style, likewise the chosen method to studying is essential in enlightening the student on how one can adjust and enhanced their learning (Ramsden, 2003). Often and widely classifications of learning styles is the type compiled by Fleming and Mills (1992) which is the VAK grouping. Its name is derived from the initials of the three learning modality, visual, auditory and kinesthetic.

Auditory modality study effectively by listening to and hearing materials presented through the audio format. These learners are able to derived novel thoughts and principles very well if a material is presented through the auditory modality. They require aural teachings and meetings, verbal based lectures and listening (Pashler et al., 2008). This group of learners are able to carefully understand teachings so very accurately just by hearing only once or twice what to do. Likewise, a document presented in a written format may have minute meaning till it is listened to. Because listening and communication are so very close, auditory learning modality always involve using voice and ears. Normally, auditory learners do often repeats a statement putting it in a question format for deliberation. It also lead to enhanced processing of information in their memory. Also, teaching style that involves playing of soft melodies at the backgrounds that helps to facilitate and accelerate the learning in this group of people (Dunn, 1993).

Visual learners study mainly using their sight, learning by visualizing. Most of them like to view or observe than listening to a description. Thus, watching illustrations and get it understood better

than listening to class sessions. They do not only need watching of pictures or materials presented through the graphical format but then learning from the teachers body language during the learning process displays such as facial expression( Zapalska & Dabb, 2002).

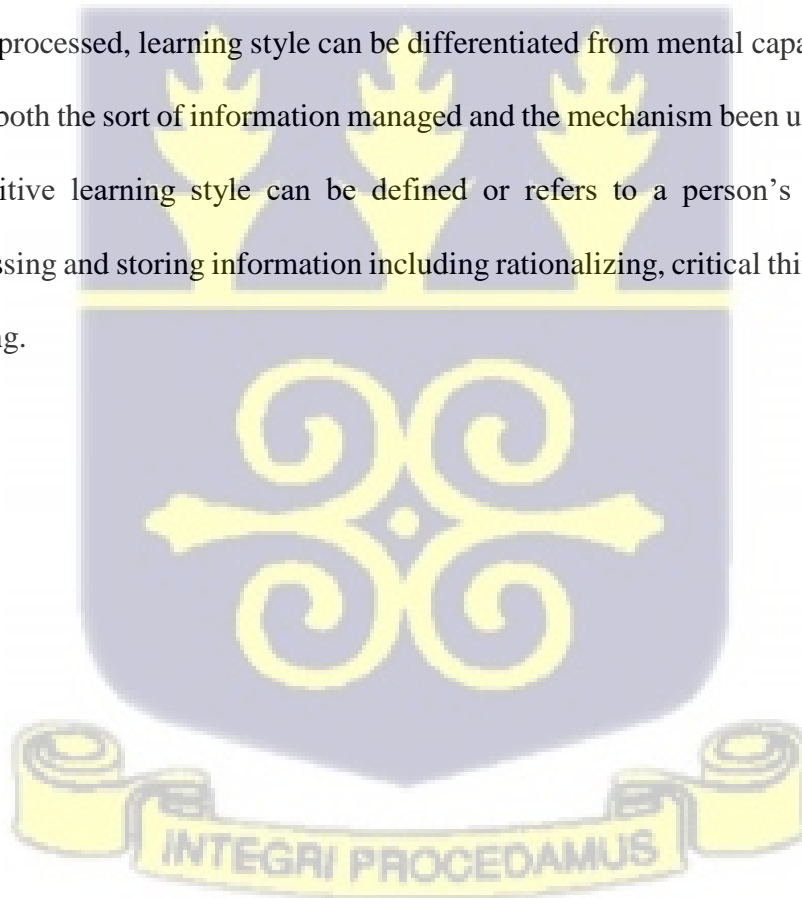
Kinesthetic learners study by the use of their hands to move and feel objects. These learners normally prefer to get involved in the learning through the use of their body in a practical demonstration rather than listening. They are learners that require active and interactive learning exercises (Cassidy & Eachus, 2000).

## **2.7 IMPORTANCE OF LEARNING STYLES**

Studies have revealed that people display divergent strategies in the learning process and a singular strategy is not enough to produced stellar learning state for everybody (Brown et al., 2009). These might be linked to learners' divergent circumstances, puissance, shortcomings, delights, aspiration, degree of courage, and strategies to learning ( & Brent, 2005). To enhance college studies, instructors should pay more attention to these various strategies (Tanner, 2013). Learning styles can become more useful to improve students learners and instructors comprehend how to enhance the method through they study and instruct, correspondingly. Exploring learners' learning styles gives relevant insight about their unique chosen modalities. Comprehending learning styles may lead to easy creating, modification, and development of a more better syllabus and academic scheme. This can further improve learners' contribution in these projects and encourage them to get specialized insight ( Brown et al., 2009). Consequently, exploring learning style is a bit relevant in place to obtain a more efficient learning. Investigating learning styles gives insight on the way learners acquire knowledge and discover solutions to questions (Mountford et al.,, 2006). In consideration to the possibly issues experienced in the education of medical students, exploring

the learning style of individuals can enable the progress of methodologies to enhance the learning stages (Bokhari & Zafar, 2019).

Using the students's sensory modalities, they have been broadly categorize as visual, followed by auditory, then tactile and finally kinesthetic, stimulations are detected , encrypted and stored (Westman & Stuve, 2001). Ensuing from the divergence of cognitive learning modalities are synergistic acumen that learning styles are a representation of seperate and equally constant modes of answering and processing information (Romanelli et al., 2009). Furthermore, learning styles reveals to differ from one person to next and to go along with markings of genetics, environmental surroundings and previous event ( Kolb & Kolb, 2013). As a method that guides how sensory stimulations are processed, learning style can be differentiated from mental capability, an inherent ability to link to both the sort of information managed and the mechanism been used (Keefe, 1987). Generally, cognitive learning style can be defined or refers to a person's chosen mode for receiving, processing and storing information including rationalizing, critical thinking, and general mental processing.



## CHAPTER THREE

### 3.0 MATERIALS & METHOD

#### 3.1 Study Design

A cross-sectional design was used to collect quantitative data for learning style assessment and sensory sensitivity. Barsch learning style classification was used to group the study subjects into four groups; the visual, auditory, tactile and no/equal preference. Sensory sensitivity test were objective test used to analyze visual, auditory and tactile senses of the participants.

#### 3.2 Study Site

Department of Physiology, which is under the University of Ghana Medical School, on the Korle-bu campus of the University of Ghana was chosen as site for the research work.

#### 3.3 Study Subjects

The study population were 3rd year undergraduate medical students of the Korle-Bu campus of University of Ghana who were willing to avail themselves for this research.

#### 3.4 Sample Size

Using the 3rd year medical students with average population of 250, using a power of 80% and confident level of 95%, the minimum sample size for the study was calculated by the use of the formula below

$$n = \frac{2\sigma^2(Z_\beta + Z_\alpha)^2}{d^2}$$

INTEGRI PROCEDAMUS

With

$Z_{\beta}$  = value on the standard normal distribution at the power of 80% = 0.84

$Z_{\alpha}$  = value on the standard normal distribution at the 95% confidence level = 1.96

$d$  = mean difference between the three groups = 3  $\sigma$  = standard deviation = 6

$$n = \frac{2\sigma^2(Z_{\beta} + Z_{\alpha})^2}{d^2}$$

$$n = \frac{2 * 6^2 (0.84 + 1.96)^2}{32}$$

$$n = 62.3 = 63$$

### 3.5 Inclusion Criteria

Participants recruited were 3rd year undergraduate medical students aged between 17-28 years with normal hearing, and vision (with or without correction) and of no neurological or learning impairments.

### 3.6 Exclusion Criteria

It excludes persons outside this age range, who had a postgraduate degree, other medical student who were not in third year or those in third year with a history of neurological or learning disabilities or sensory impairments.

### 3.7 Learning Style Assessment

All the participants filled out the visual, auditory and tactile, (VAK), learning style questionnaire of the BLSI (Barsch, 1991). The Barsch Learning Styles Inventory (BLSI) assigns a score to each

of the three learning modalities: visual, auditory, and kinesthetic. This survey contains 24 three-point Likert-type scale items with response options of frequently, occasionally, and rarely. Each response was given a point value (5 for frequently, 3 for occasionally, and 1 for rarely), with a maximum score of 40 and a minimum score of 8 for each modality. The individual's learning style is determined by the highest score obtained among the three modality types. The five standardized memory tests were given out and graded in a consistent manner.

### **3.8 Sensory Modality Sensitivity**

For the measurement of each participant's sensory sensitivity, separate tests were conducted to measure sensitivity to visual, auditory and tactile stimuli.

#### **3.8.1 Contrast sensitivity using Pelli Robsin**

Visual sensitivity would be assessed using Pelli Robsin contrast sensitivity test. This is a standard test used for measuring visual contrast sensitivity. The Pelli-Robson chart displays forty-eight large Sloan letters of constant size, designed to work in conjunction with the Sloan acuity letters. The letters are organized in sets of triplets (Figure 1.4) on a 60 × 85 cm chart, each with the same contrast, with the log<sub>10</sub> contrast falling from top to bottom and left to right as you go from one triplet to the next. The contrast of each group of three letters is reduced by a factor of 0.71 (1/2) (log contrast 0.15) from the previous batch. At 3m, which is the testing distance advised by Pelli et al., the size of the letters on the chart subtend 0.5 degrees. The test is graded in Log CS units, with each pair of triplets progressing by 0.15 log units, ranging from a Log CS of 0.00 (about 100 percent contrast) to a Log CS of 2.25 (approximately 200 percent contrast) (approx. 0.56 percent contrast). However, Pelli and Robson suggested that the chart is to be used at a nearer testing distance in low vision patients. They also recommended putting the chart on a background that is as bright as the chart itself in order to detect any decrease in contrast sensitivity that may be due

to a disease resulting in wide-angle light scatter such as cataracts (Pelli & Robson, 1988). The test is administered by asking the subject to read the letters on the chart, starting with the highest contrast. The test ends when two out of the three letters in a group are read incorrectly. The subject's score in Log CS will be the preceding triplet read.

### **3.8.2 Auditory sensitivity test (Pure Tone)**

Pure tone air conduction audiometry determines the hearing levels at different frequencies at which one can only just hear a tone presented to the external ear canal. Step 1, the audiometer was connected to the power supply and switched it on. Step 2, the earphones were connected to the apparatus and it was placed on the client's head. It was done in a usual way to place them in such a manner that the blue phone covers the left ear and the red phone the right ear. Step 3: The tone was selected at 1000 Hz and the output switch was set to present the tone to the better ear. Because 1000 Hz is in the middle of the most sensitive portion of the hearing spectrum, it was chosen as the starting point for the test. For someone who has never been tested before, it is also a distinct tone to hear. Step 4: The sound was initially provided at 30 dB HL. If a response is given, it means that 30 dB sound is louder than the client's tolerance. If no response is elicited, the level is increased to 50 dB and subsequently increased in 10 dB increments until a response is elicited or the audiometer's frequency limit is reached. Step 5: Once the client responds, the volume is gradually reduced in 10dB increments until the participant stops replying. It is then increased in 5dB stages till he or she replies again. Step 6: At this point, the sound is boosted and dropped in 5dB steps until the participant determines that he or she hears the sound 50% of the time. The lowest intensity level in dB at which a person hears a sound 50% of the time is characterized as the hearing threshold for that specific frequency. The audiogram is then transcribed with this level. Repeat the frequency with 500 Hz and repeat the procedures above. In most circumstances, there isn't

much of a difference between the thresholds of surrounding frequencies. As a result, the starting point for Step 6 is the threshold level at 1000 Hz from Step 5. The test is repeated at 500Hz, 1000Hz, 1500 Hz and 2000Hz. As a control, the test is repeated at 1000 Hz. It is regarded that the accuracy is sufficient if the difference between the original and repeat measures is less than 5 decibels. If the difference in thresholds between the two tests at 1000 Hz is greater than 10 dB, the test's reliability is doubtful, and it should be repeated from the beginning. It was determined whether masking was required for each frequency. If the test ear's air conduction threshold and the non-test ear's bone conduction threshold differ by more than 40 decibels, the better ear must be masked so that only the answers from the worse ear are recorded. The reason for this is that air conduction has an intramural attenuation of about 40 decibels. To put it another way, a sound transmitted to the test ear must be 40 decibels louder than the non-test ear's bone conduction threshold before that ear hears it. Masking: A signal of substantial magnitude delivered to one ear may be heard by the other. This is referred to as signal crossover. Crossover or contralateralisation of the signal can cause problems in air conduction and bone conduction audiometry. When crossover occurs, it is necessary to isolate the ear being tested. Masking is a technique that involves presenting noise to the non-test ear (NTE) in order to keep it occupied while the test ear is being assessed.

### **3.8.3 Auditory sensitivity test (frequency discrimination)**

Frequency discrimination another psychoacoustic method was accessed using a software developed by the University of Southampton, department of hearing and vibration. The program is made of frequency of 500Hz, 1000Hz, 1500Hz, 2000Hz and a frequency difference values of 0.1%, 0.2, 0.25,0.5 Based on the frequency selected with the frequency difference value selected, two sounds of was heard. The participant's task was to identify which sound stimulus is having a

higher intensity. If a response was correct, it was recorded by the software, which remained visible on the left-hand side of the screen. An incorrect response too is also recorded at by the software and remains visible on the screen. Participants were given a just a one attempt trial for each of the five different sets, and the examiner initiated each new trial at a different frequency. For 500Hz task, frequency difference was at 0.1%. And for the 2000Hz task, the frequency difference was also at 0.1% .All participants put on headsets which was connected to the laptops through which the sound was heard.

### **3.9 Tactile sensitivity test using two point sensitivity**

Tactile sensitivity was assessed using two point sensitivity and vibration perception test. Two point discrimination tests were carried out with a pair of blunt dividers and a meter rule, on the right thumb (self-reported dominant hand). After demonstrating and explaining the test, participants had their eyes closed. The test was commenced with the points of the blunt divider opened greater than the normal values for the thumb, with application of light and equal pressure applied on the two points. The two points of the blunt dividers were moved closer together across consecutive attempts and the results corresponding to the inter-point distances at which the participants could no longer distinguish two points as separate were recorded.

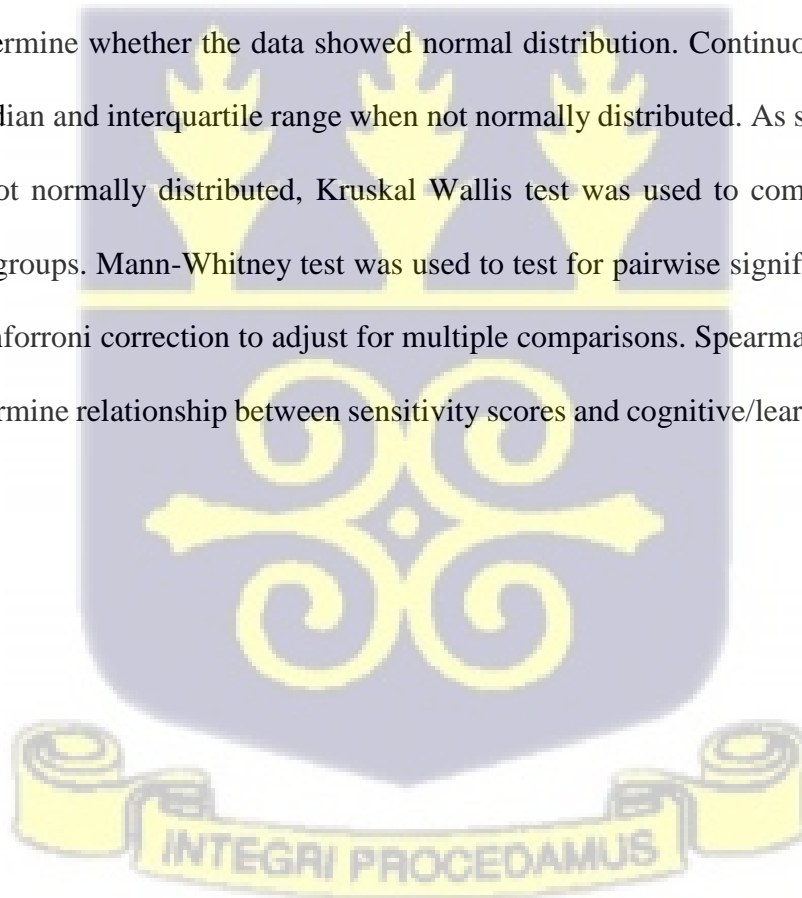
A modified Tira Vib vibration exciter (model TV51075, Schalkau, Germany) powered by a Voltcraft oscillator (model FG 506, Hirschau, Germany) was used to measure vibration thresholds. Vibration thresholds were measured in sitting condition. While seated, the subjects keep their thumb rested on a table not exert any pressure against the probe. Additionally, subjects used hearing protectors to avoid distracting noise. The vibration amplitude was gradually increased (at different speeds) from zero until vibratory stimulation was perceived by subjects.

### **3.10 Quality measures controls.**

All data collected were handled anonymously to ensure confidentiality. Participants were identified with number codes instead of their names. The investigator also ensured that all data/information about the study participants and completed code list was kept private and password protected.

### **3.11 Statistical analysis**

All data that was generated were entered into excel and analyzed using the statistical package for social sciences version 22 (SPSS). Descriptive statistics were presented as frequency and percentages for categorical variables. Analytical tools (Kolmogorov Smirnov/ Shapiro-Wilk test) was used to determine whether the data showed normal distribution. Continuous variables were presented as median and interquartile range when not normally distributed. As sensitivity score of students were not normally distributed, Kruskal Wallis test was used to compare performance among the four groups. Mann-Whitney test was used to test for pairwise significance differences by using the Benferroni correction to adjust for multiple comparisons. Spearman rank correlation was used to determine relationship between sensitivity scores and cognitive/learning styles scores.



## **CHAPTER FOUR**

## 4.0 RESULTS

### 4.1 Introduction

This chapter present the various results obtained from statistical analysis of the collected data. Its includes tables showing the demographic characteristic of respondents and the various performances of the subjects under the various sensory modalities. Furthermore it shows the relationship between sensitivity to the 3 sensory modalities and cognitive ability.

### 4.2 Demographic characteristics of respondents

This tables shows the results of the demographic characteristics of the respondents. This include age, gender, and level of education. It also includes their preferred learning style as students.

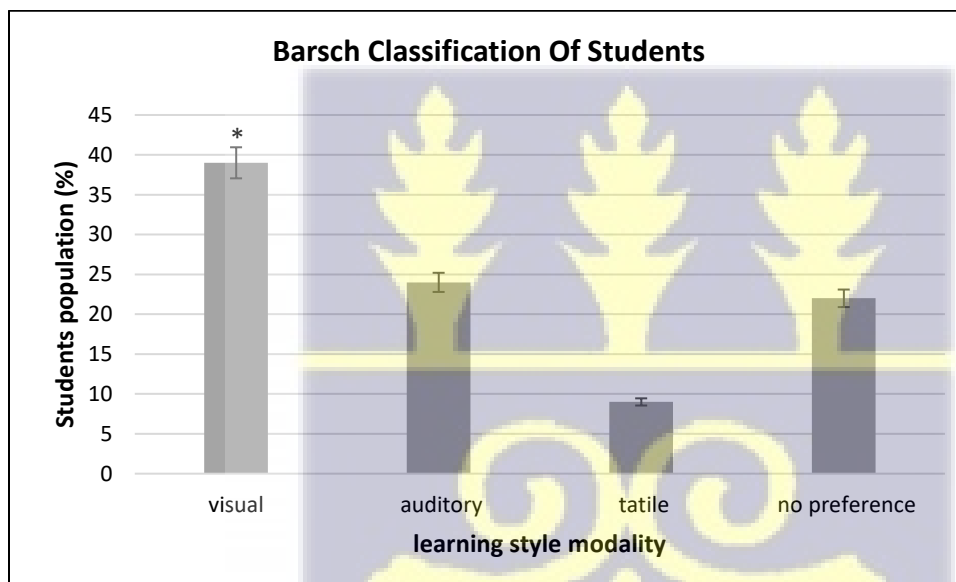
**Table 4.1: Demographics characteristics and learning style preferences of surveyed medical students**

N= 94		Number (n)	Percent ( % )
Gender	Female	54	57.45
	Male	40	42.55
Grade	1 <sup>st</sup>	20	21.28
	2 <sup>nd</sup>	42	44.68
	3 <sup>rd</sup>	12	12.77
Age	18-22	60	63.83
	22-26	22	23.40
	26-30	12	12.77
Learning styles			
	Visual	34	36.17
	Auditory	14	14.89
	Tactile	3	3.19
	No preference	43	45.74

### 4.3 Learning style classification of students using Barsch

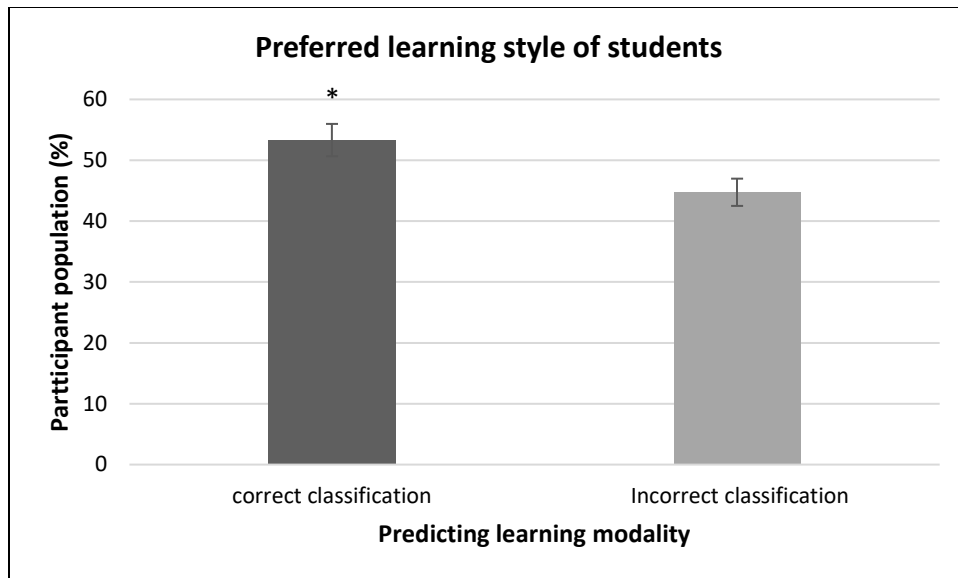
In the exception of demographics, all items on the Barsch questionnaire were measured in a 3-Likert response as follows, 1 (seldom), 2 (sometimes), and 3 (often).

Responses on the Barsch learning styles classifications are presented in fig 4.1 and that of the percentages of students who were able to accurately predict their preferred learning style modality which was found to be true after as the Barsch classification (55.36%) and untrue prediction (44.37%) are highlighted in fig 4.2. This percentage differences are indications of how correctly individuals were good at predicting their preferred learning styles.



**Figure 4.1: Showing the percentage of students scoring highest for each preferred modality under Barsch learning style classification.**





**Figure 4.2: Showing percentage of students in predicting their preferred learning style.**

#### **4.4 A Comparison of Pelli Robson, pure tone audiometry and two-point discrimination test.**

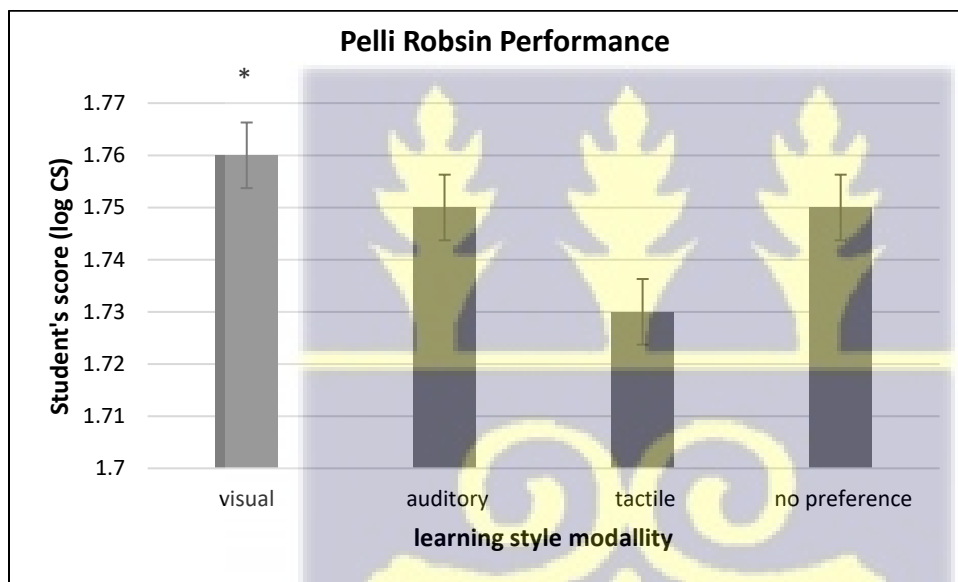
For the Pelli Robson score, visual learners had ( $1.76 \pm 0.30$  log CS). This was ( $1.75 \pm 0.2$  log CS) for auditory learners, ( $1.73 \pm 0.24$  log CS) for tactile learners and ( $1.75 \pm 0.26$  log CS) for no preference modality. These values were found not to be significantly different (A Kruskal – Wallis test revealed a statistically non-significant difference in Pelli Robsin test scores across the 4 learning styles, ( $\chi^2(2, N=94)=0.346, p=0.841$ )). This is highlighted in fig 4.3.

Visual learners had a Puretone right ear score of ( $20.1 \pm 5.0$ ) dB HL. This was ( $20.0 \pm 5.0$ ) dB HL for auditory learners, ( $20.3 \pm 5.0$ ) dB HL for tactile learners and ( $20.1 \pm 5.0$ ) dB HL for no preference modality. These values were found not to be significantly different (A Kruskal – Wallis test revealed a statistically non-significant difference in Puretone (left ear) test scores across the 4 learning styles, ( $\chi^2(2, N=94) = 1.389, p=0.499$ )). This is highlighted in fig 4.3

For Puretone left ear- visual learners had ( $19.51 \pm 5.0$ ) dB HL. This was ( $19.50 \pm 5.0$ ) dB HL for auditory learners, ( $19.52 \pm 5.0$ ) dB HL for tactile learners and ( $19.51 \pm 5.0$ ) dB HL for no preferenc

modality. These values were found not to be significantly different (A Kruskal – Wallis test revealed a statistically non-significant difference in Puretone (right ear) test scores across the 4 learning styles, ( $\chi^2(2, N=94) = 0.303, p=0.216$ )). This is highlighted in fig 4.3

Visual learners had a two point discrimination score of  $(1.40 \pm 0.23)$  mm. This was  $(1.50 \pm 0.23)$  mm for auditory learners,  $(1.20 \pm 0.17)$  mm for tactile learners and  $(1.40 \pm 0.21)$  mm for no preference modality. These values were found not to be significantly different (A Kruskal – Wallis test revealed a statistically non-significant difference in two point discrimination test scores across the 4 learning styles, ( $\chi^2(2, N=94) = 1.550, p=0.461$ )).



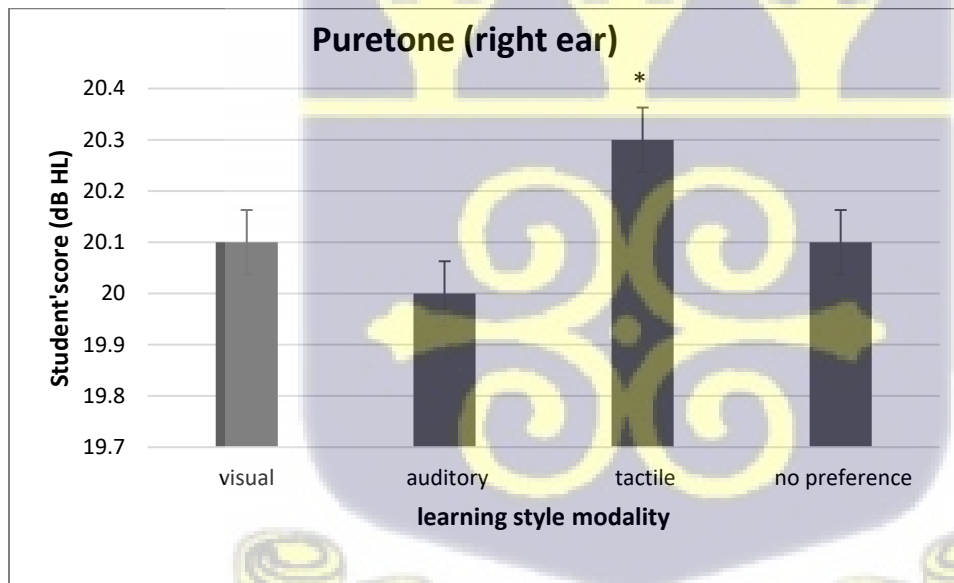
**Figure 4.3: Performances of the four different learning styles in the Pelli-Robsin contrast sensitivity test.**



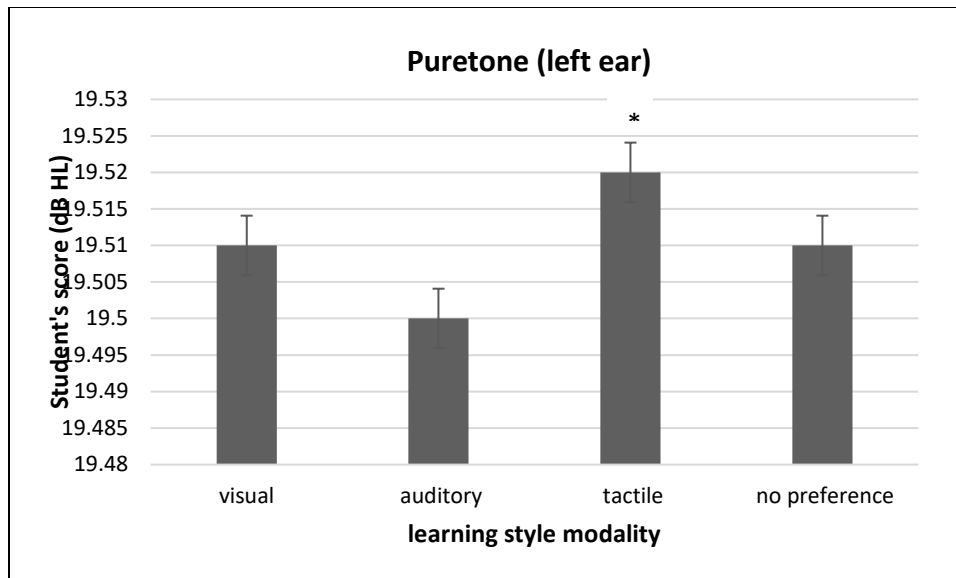
**Table 4.2: Comparison of Pelli Robsin, Puretone and Two-point discrimination task**

Variable	Visual n = (39) Median $\pm$ IQR	Auditory n = (24) Median $\pm$ IQR	Tactile n=(9) Median $\pm$ QR	No preference n = (22) Median $\pm$ IQR	P – value
<b>Pelli Robsin</b>	1.76 $\pm$ 0.3	1.75 $\pm$ 0.2	1.73 $\pm$ 0.24	1.75 $\pm$ 0.26	0.841
(log CS)					
<b>Puretone -right ear(dB HL)</b>	20.1 $\pm$ 5.0	20.0 $\pm$ 5.0	20.3 $\pm$ 5.0	20.1 $\pm$ 5.0	0.216
<b>Puretone – left ear(dB HL)</b>	19.51 $\pm$ 5.0	19.50 $\pm$ 5.0	19.52 $\pm$ 5.0	19.51 $\pm$ 5.0	0.499
<b>Tactile(mm)</b>	1.30 $\pm$ 0.23	1.50 $\pm$ 0.23	1.20 $\pm$ 0.17	1.40 $\pm$ 0.21	0.461

\*Significant at  $p < 0.05$  n = number of participants, IQR = Interquartile range



**Figure 4.4: Performance of the four different learning styles in the pure tone test for the right ear.**



**Figure 4.5: Performance of the four different learning styles in the pure tone test for the left ear.**

#### 4.5 Comparison of Frequency discrimination and frequency modulation scores

Visual learners had a frequency discrimination, 500Hz, score of  $(0.67 \pm 0.17)$ Hz. This was  $(0.83 \pm 0.33)$ Hz for auditory learners,  $(0.59 \pm 0.30)$ Hz for tactile learners and  $(0.62 \pm 0.23)$ Hz for no preference modality. These values were found to be significantly different (A Kruskal – Wallis test revealed a statistically significant difference in frequency discrimination(500Hz) test scores across the 4 learning modalities,  $(\chi^2(2, N=94)=17.348, p=0.000)$ ). A Mann – Whitney U test revealed that frequency discrimination (500Hz) score were significantly lower in the tactile learners group (Median,  $Md=0.5900\text{Hz} \pm 0.30, n=9$ ) compared to the visual learners group ( $Md=0.6700\text{Hz} \pm 0.17, n=39$ ),  $U=260.50, z=-1.45, p = 0.003$  with a small effect size  $r = 0.199$ . Also, frequency discrimination (500Hz) score were significantly lower in the visual learners group ( $Md=0.6700\text{Hz} \pm 0.17, n=39$ ) compared to the auditory learners group ( $Md=0.8300\text{Hz} \pm 0.33, n=24$ ),  $U=31.000, z=-3.968, p = 0.001$ , with a large effect size  $r = 0.612$ .

Frequency discrimination (500Hz) score were significantly lower in the no preference group (Md=0.6200Hz  $\pm$  0.23, n=22) compared to the visual learners group (Md=0.6700Hz  $\pm$  0.17, n=39), U=51.000, z=-2.968, p = 0.000, with a large effect size r = 0.522. Also, frequency discrimination (500Hz) score were significantly lower in the tactile learners group (Md=0.8300Hz  $\pm$  0.30, n=9) compared to the no preference group (Md=0.6200Hz  $\pm$  0.23, n=22), U=72.000, z=-2.438, p = 0.000, with a large effect size r = 0.712. Also, frequency discrimination (500Hz) score were significantly lower in the no preference group (Md=0.6200Hz  $\pm$  0.23, n=22) compared to the auditory learners group ( Md=0.8300Hz  $\pm$  0.33, n=24), U=84.000, z=-2.128, p = 0.005, with a large effect size r = 0.832. Finally, frequency discrimination (500Hz) score were significantly lower in the tactile learners group (Md=0.5900Hz  $\pm$  0.30, n=9) compared to the auditory learners group (Md=0.8300Hz  $\pm$  0.33, n=24), U=34.000, z=-3.111, p = 0.000, with a large effect size r = 0.559. Fig 4.6

For the frequency discrimination, 2000Hz, visual learners had (0.68  $\pm$  0.16)Hz. This was (0.84  $\pm$  0.33) Hz for auditory learners, (0.62  $\pm$  0.36)Hz for tactile learners and (0.64  $\pm$  0.46) Hz for no preference modality. These values were found to be significantly different (A Kruskal – Wallis test revealed a statistically significant difference in frequency discrimination (2000Hz) test scores across the 4 learning modalities, ( $\chi^2(2, N=94) = 6.915, p=0.032$ )). A Mann – Whitney U test revealed that frequency discrimination (2000Hz) score were significantly lower in the tactile learners group (Md=0.6200Hz  $\pm$  0.36, n=9) compared to the auditory learners group (Md=0.8400Hz  $\pm$  0.33, n=24), U=63.00, z=-1.812, p = 0.007, with a moderate effect size r = 0.325. Frequency discrimination (2000Hz) score were significantly lower in the visual learners group (Md=0.6800Hz  $\pm$  0.16, n=39) compared to the auditory learners group (Md=0.8400Hz  $\pm$  0.33, n=24), U=75.00, z=2.518, p = 0.012, with a moderate effect size r = 0.393. Also, frequency

discrimination (2000Hz) score were significantly lower in the no preference group ( $Md=0.6400Hz \pm 0.46$ ,  $n=22$ ) compared to the visual learners group ( $Md=0.6800Hz \pm 0.16$ ,  $n=39$ ),  $U=49.000$ ,  $z=-1.918$ ,  $p = 0.021$ , with a moderate effect size  $r = 0.322$ . Frequency discrimination (2000Hz) score were significantly lower in the tactile learners group ( $Md=0.6200Hz \pm 0.36$ ,  $n=9$ ) compared to the no preference group ( $Md=0.6400Hz \pm 0.46$ ,  $n=22$ ),  $U=62.000$ ,  $z=-2.028$ ,  $p = 0.020$ , with a large effect size  $r = 0.659$ . Also, frequency discrimination (2000Hz) score were significantly lower in the no preference group ( $Md=0.6400Hz \pm 0.46$ ,  $n=22$ ) compared to the auditory learners group ( $Md=0.8400Hz \pm 0.33$ ,  $n=24$ ),  $U=38.000$ ,  $z=-1.128$ ,  $p = 0.015$ , with a large effect size  $r = 0.692$ . Frequency discrimination (2000Hz) score were significantly lower in the tactile learners group ( $Md=0.6200Hz \pm 0.36$ ,  $n=9$ ) compared to the visual learners group ( $Md=0.6800Hz \pm 0.16$ ,  $n=39$ ),  $U=266.00$ ,  $z=-1.144$ ,  $p = 0.031$ , with a small effect size  $r = 0.159$ .

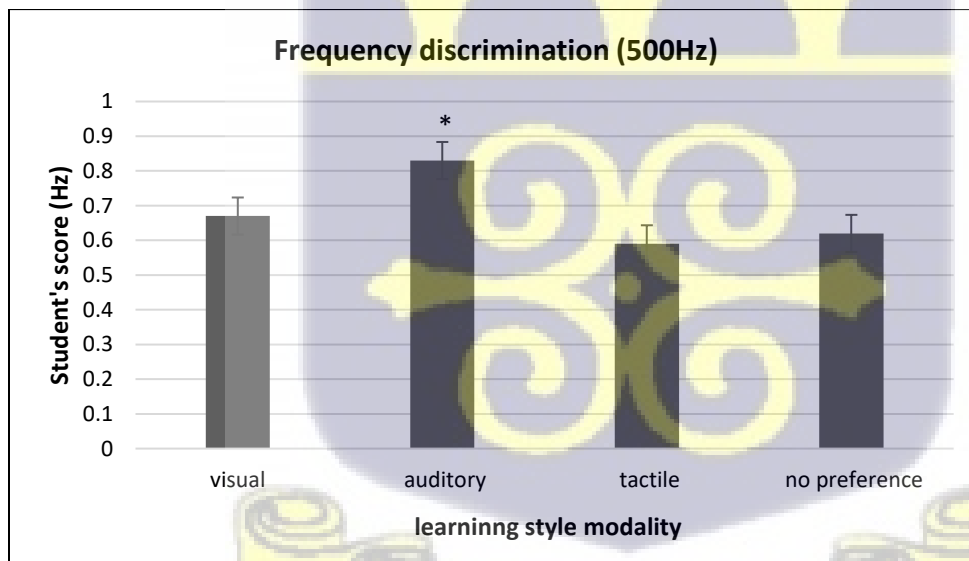
#### 4.7

Visual learners had a frequency modulation, 500Hz, score of ( $0.66 \pm 0.17$ ) Hz. This was ( $0.82 \pm 0.33$ ) Hz for auditory learners, ( $0.63 \pm 0.13$ ) Hz for tactile learners and ( $0.65 \pm 0.23$ ) Hz for no preference modality. These values were found to be significantly different (A Kruskal – Wallis test revealed a statistically significant difference in frequency modulation(500Hz) test scores across the 4 learning modalities, ( $\chi^2(2, N=94)=13.475$ ,  $p=0.001$ )). A Mann – Whitney U test revealed that frequency modulation (500Hz) score were significantly lower in the tactile learners group ( $Md=0.6300Hz \pm 0.13$ ,  $n=9$ ) compared to the visual learners group ( $Md=0.6600Hz \pm 0.16$ ,  $n=39$ ),  $U=320.00$ ,  $z=-0.291$ ,  $p = 0.022$ , with a small effect size  $r = 0.034$ . Frequency modulation (500Hz) score were significantly lower in the visual learners group ( $Md=0.6600Hz \pm 0.16$ ,  $n=39$ ) compared to the auditory learners group ( $Md=0.8200Hz \pm 0.33$ ,  $n=24$ ),  $U=44.00$ ,  $z=-3.532$ ,  $p = 0.000$ , with a large effect size  $r = 0.545$ . In

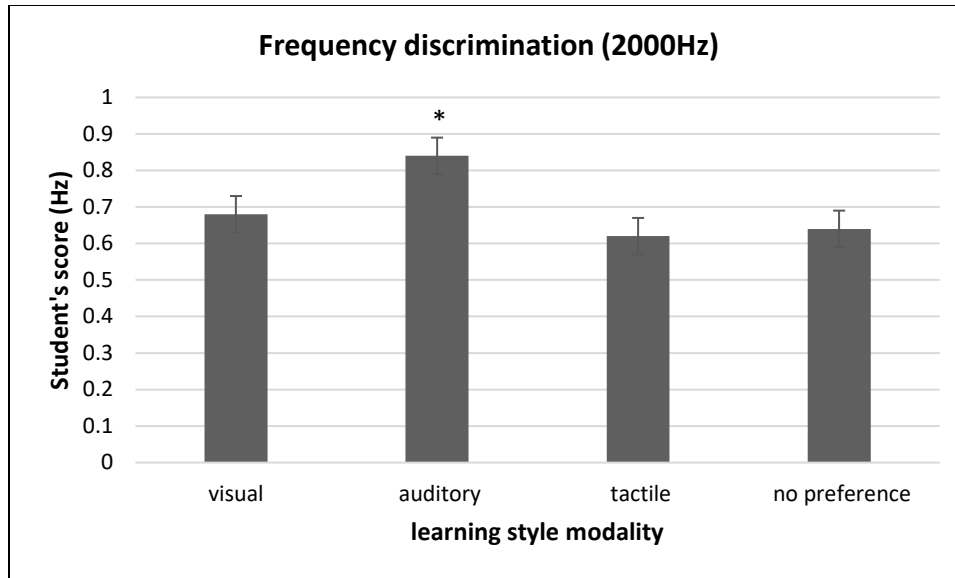
addition, frequency modulation (500Hz) score were significantly lower in the no preference group (Md=0.650Hz  $\pm$  0.23, n=22) compared to the visual learners group (Md=0.6600Hz  $\pm$  0.13, n=39), U=63.000, z=-2.118, p = 0.010, with a large effect size r = 0.544. Frequency modulation (500Hz) score were significantly lower in the tactile learners group (Md=0.6300Hz  $\pm$  0.13, n=9) compared to the no preference group (Md=0.6500Hz  $\pm$  0.23, n=22), U=64.000, z=-3.438, p = 0.030, with a large effect size r = 0.612. Also, frequency discrimination (500Hz) score were significantly lower in the no preference group ( Md=0.6500Hz  $\pm$  0.23, n=22) compared to the auditory learners group ( Md=0.8200Hz  $\pm$ 0.33, n=24), U=54.000, z=-1.128, p = 0.000, with a large effect size r = 0.539. Frequency modulation(500Hz) score were significantly were significantly lower in the tactile learners group ( Md=0.6300Hz  $\pm$ 0.13, n=9) compared to the auditory learners group (Md=0.8200Hz  $\pm$  0.33, n=24), U=31.00, z=-3.178, p = 0.001, with a large effect size r = 0.571. Fig 4.8 For the frequency modulation, 2000Hz, visual learners had (0.69  $\pm$  0.16)Hz. This was (0.85  $\pm$  0.33) Hz for auditory learners, (0.65  $\pm$  0.23) Hz for tactile learners and (0.67  $\pm$  0.46) Hz for no preference modality. These values were found to be significantly different (A Kruskal – Wallis test revealed a statistically significant difference in frequency modulation(2000Hz) test scores across the 4 learning modalities, ( $\chi^2(2, N=94)=0.346, p=0.000$ )). A Mann – Whitney U test revealed that frequency modulation(2000Hz) score were significantly were significantly lower in the tactile learners group ( Md=0.6500Hz  $\pm$  0.23, n=9) compared to the visual learners group( Md=0.6900Hz  $\pm$  0.16, n=39), U=63.00, z=-1.812, p = 0.040, with a moderate effect size r = 0.325. Frequency modulation (2000Hz) score were significantly were significantly lower in the visual learners group (Md=0.6900Hz  $\pm$  0.16, n=39) compared to the auditory learners group ( Md=0.8500Hz  $\pm$  0.33, n=24), U=75, z=2.518, p = 0.012, with a moderate effect size r = 0.393. Also, frequency modulation (2000Hz) score were significantly lower in the no preference group

(Md=0.6700Hz  $\pm$  0.46, n=22) compared to the visual learners group (Md=0.6900Hz  $\pm$  0.16, n=39), U=55.000, z=-2.008, p = 0.018, with a moderate effect size r = 0.302. Frequency modulation (2000Hz) score were significantly lower in the tactile learners group (Md=0.6500 $\pm$ 0.23, n=9) compared to the no preference group (Md=0.6700Hz  $\pm$  0.46, n=22), U=42.000, z=-1.438, p = 0.021, with a moderate effect size r = 0.312. Also, frequency modulation (2000Hz) score were significantly lower in the no preference group (Md=0.6700Hz  $\pm$  0.46, n=22) compared to the auditory learners group (Md=0.8500Hz  $\pm$  0.33, n=24), U=94.000, z=-2.028, p = 0.000, with a large effect size r = 0.692. Frequency modulation (2000Hz) score were significantly were significantly lower in the tactile learners group

(Md=0.6500Hz  $\pm$  0.23, n=9) compared to the auditory learners group (Md=0.8500Hz  $\pm$  0.33, n=24), U=266.00, z=-1.144, p = 0.003, with a small effect size r = 0.159. This findings can be found table 4.9



**Figure 4.6: Performance of the four different learning styles in the auditory frequency discriminatory test (500Hz).**

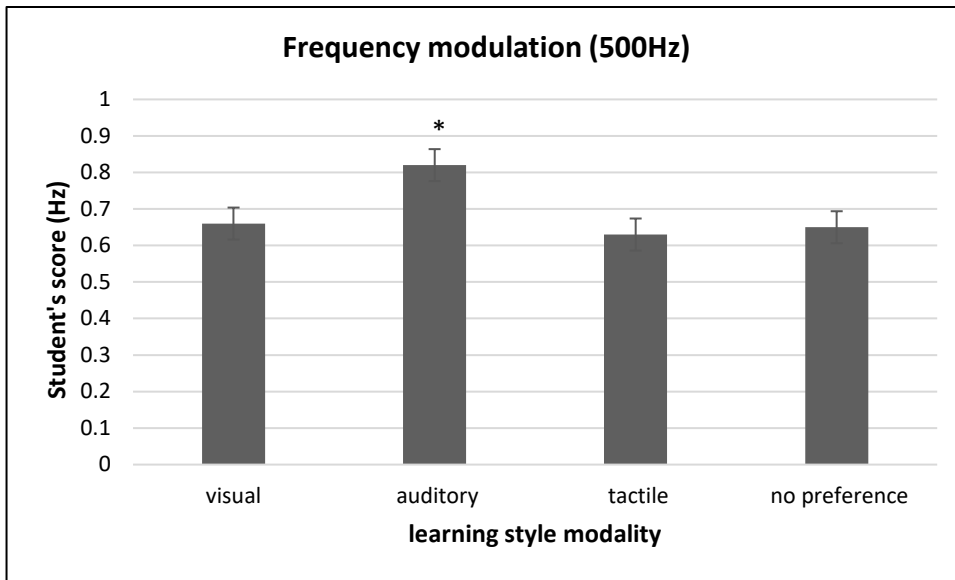


**Figure 4.7: Performance of the four different learning styles in the auditory frequency discriminatory test (2000Hz).**

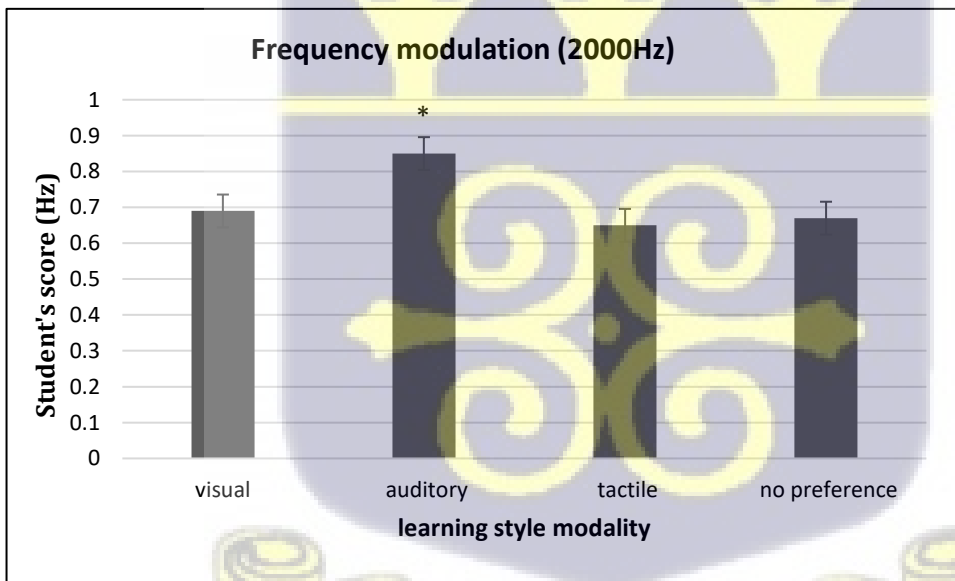
**Table 4.3: Showing frequency discrimination and frequency modulation test performance of participants among groups**

Values (Hz)	Visual n = (39) Median ± IQR	Auditory n = (24) Median ± IQR	Tactile n= (9) Median ± IQR	No preference n = (22) Median ± IQR	P – value
Frequency discrimination (500Hz)	0.67 ± 0.17	0.83 ± 0.33	0.59 ± 0.30	0.62 ± 0.23	<0.000
Frequency discrimination (2000Hz)	0.68 ± 0.16	0.84 ± 0.33	0.62 ± 0.36	0.64 ± 0.46	<0.032
Frequency modulation (500Hz)	0.66 ± 0.16	0.82 ± 0.33	0.63 ± 0.13	0.65 ± 0.23	<0.001
Frequency modulation (2000Hz)	0.69 ± 0.16	0.85 ± 0.33	0.65 ± 0.23	0.67 ± 0.46	<0.000

\*Significant at p <0.05 n = number of participants, IQR = Interquartile range



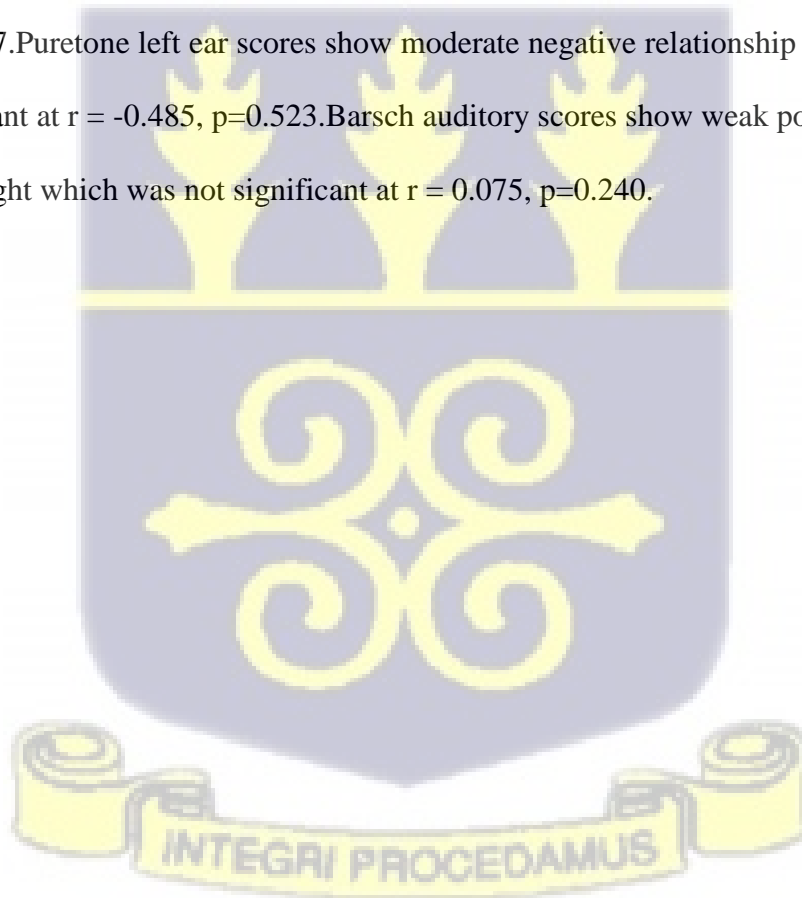
**Figure 4.8: Performance of the four different learning styles in the auditory frequency modulation test (500Hz).**



**Figure 4.9: Performance of the four different learning styles in the auditory frequency modulation test (2000Hz).**

**4.6** Spearman correlation matrix of the sensory sensitivity test scores and Barsch learning style assessment scores for visual learners.

Spearman ranked test analysis between sensitivity to sensory processing pathways and cognitive processing pathways for students classified as visual learners by barsch learning style show no significant relationship between both pathways i.e. Barsch visual show moderate positive relationship with batch auditory which was not significant,  $r = 0.338$  at  $p=0.42$ .Pelli Robsin score show negative weak relationship with barsch visual, which was not significant,  $r = -0.083$  at  $p=0.673$ .Frequency discrimination at 500Hz show weak positive relationship with barsch visual at  $r = 0.083$ ,  $p=0.647$ .Puretone left ear scores show moderate negative relationship with tactile which was not significant at  $r = -0.485$ ,  $p=0.523$ .Barsch auditory scores show weak positive relationship with puretone right which was not significant at  $r = 0.075$ ,  $p=0.240$ .



**Table 4.4 Spearman correlation matrix of the sensory sensitivity test scores and Barsch learning style assessment scores for visual learners.**

	Barsch Visual	Barsch Auditory	Barsch Tactile	Pelli Robsin	FD 500Hz	FD 2000Hz	Puretone Right	Puretone Left	tactile
Barsch Visual		.386	.775	-.083	.083	-.084	.126	.230	-.364
Barsch Auditory			.347	.033	.184	.215	.075	.205	-.047
Barsch Tactile				-.136	-.220	-.041	-.037	-.223	-.463
Pelli Robsin					.393	.353	.210	-.126	.196
FD 500Hz						.347	.196	-.130	.169
FD 2000Hz							.271	.013	-.114
Puretone Right								.440	-.160
Puretone Left									-.485
Tactile									

\* Correlation is significant at 0.05 level

\*\* Correlation is significant at 0.01 level



#### 4.7 Spearman correlation matrix of the sensory sensitivity test scores and Barsch learning style assessment scores for auditory learners

Spearman ranked test analysis between sensitivity to sensory processing pathways and cognitive processing pathways for students classified as auditory learners by Barsch learning style show significant relationship between both pathways. i. e Barsch auditory score show moderate positive relationship with frequency discrimination(2000Hz) score which was significant at  $r = 0.538$ ,  $p = 0.03$ . Barsch auditory show weak positive relationship with frequency puretone right ear scores which was significant at  $r = 0.03$ ,  $p = 0.04$ . Barsch auditory show weak positive relationship with pure tone left ear scores which was significant at  $r = 0.163$ ,  $p = 0.014$ . Barsch visual show weak positive relationship with pure tone right ear that was not significant  $r = 0.117$ ,  $p = 0.614$ . Barsch visual show weak negative relationship with pure tone left which was not significant at  $r = -0.119$ ,  $p = 0.608$ .



**Table 4.5: Spearman correlation matrix of the sensory sensitivity test scores and Barsch learning style assessment scores for auditory learners**

	Barsch Visual	Barsch Auditory	Barsch Tactile	Pelli Robsin	Frequency 500	Frequency 2000	Puretone Right	Puretone left	Tactile
Barsch Visual		.867	.249	.207	.005	.526	.117	-.119	.147
Barsch Auditory			.302	.041	.031	.538*	.033*	.163*	.080
Barsch Tactile				-.336	.156	.206	-.072	-.114	-.026
Pelli Robsin					-.314	.003	.267	.030	.213
Frequency 500						.137	-.202	.118	-.089
Frequency 2000							.283	-.100	-.028
Puretone Right								.431	.104
Puretone Left									-.059
Tactile									

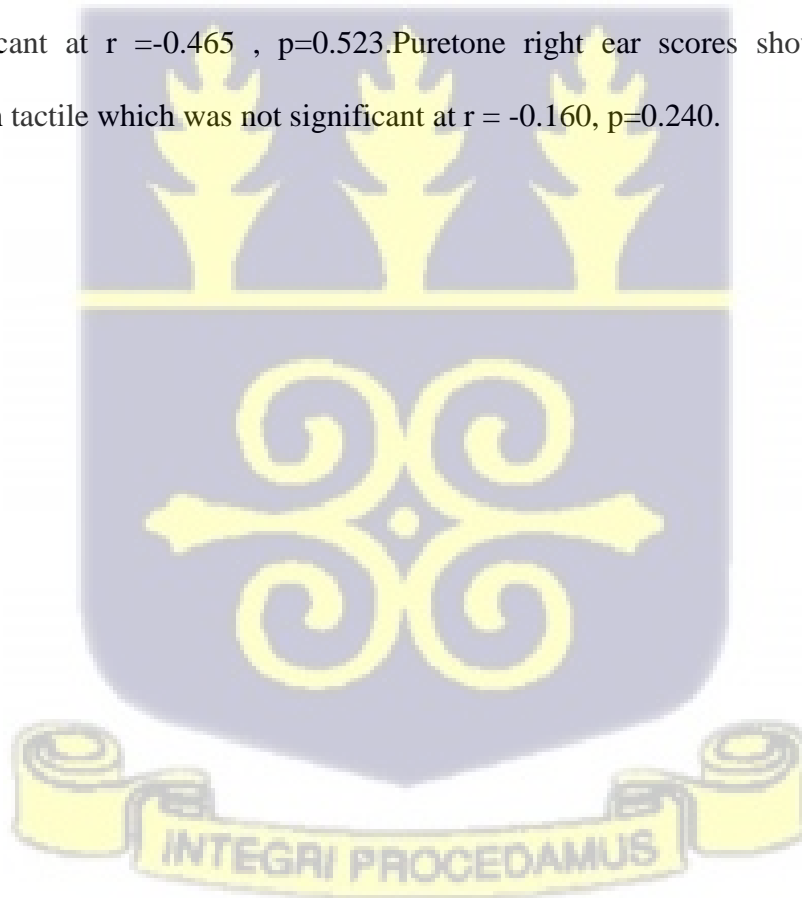
\* Correlation is significant at 0.05 level

\* \*Correlation is significant at 0.01 level



#### **4.8 Spearman correlation matrix of the sensory sensitivity test scores and learning style assessment score for tactile learners**

Spearman ranked test analysis between sensory processing pathways and cognitive processing pathways for students classified as multimodal learners by barsch learning style show no significant relationship between both pathways i.e. Barsch visual show moderate positive relationship was not significant barsch auditory,  $r = 0.376$  at  $p=0.52$ .Pelli Robsin score show negative weak relationship with barsch visual, which was not significant,  $r = -0.083$  at  $p = 0.673$ .Frequency discrimination at 500Hz show weak positive relationship with barsch visual at  $r = 0.073$ ,  $p=0.417$ .Puretone left ear scores show moderate negative relationship with tactile which was not significant at  $r = -0.465$  ,  $p=0.523$ .Puretone right ear scores show weak negative relationship with tactile which was not significant at  $r = -0.160$ ,  $p=0.240$ .



**Table 4.6: Spearman correlation matrix of sensory sensitivity test scores and Barsch learning style assessment scores of multimodal learners.**

	Barsch Visual	Barsch Auditory	Barsch Tactile	Pelli Robsin	FD 500Hz	FD 2000Hz	Puretone Right	Puretone Left	tactile
Barsch Visual		.376	.675	-.083	.073	-.074	.126	.240	-.354
Barsch Auditory			.447	.033	.284	.215	.075	.105	-.047
Barsch Tactile				-.236	-.220	-.051	-.037	-.243	-.463
Pelli Robsin					.363	.353	.220	-.146	.176
FD 500Hz						.327	.196	-.130	.169
FD 2000Hz							.271	.013	-.114
Puretone Right								.440	-.160
Puretone Left									-.465
Tactile									

\* Correlation is significant at 0.05 level

\*\* Correlation is significant at 0.01 level



## CHAPTER FIVE

### 5.0 DISCUSSION

#### 5.1 Introduction

Cognitive processing pathways as defined by learning styles means individual chosen best method of learning. In this study and according to Barsch classification of learning styles, we employed the visual, auditory and tactile learning styles (Kratzig & Arbuthnott, 2006). In this study, we have a sizeable portion of the participants (23.40%) falling under multimodal modality, that is they show equal preference for two or more learning styles. Sensory sensitivity is how we are able to use our senses to interact with the environment using our sensory channels: sight, sound, touch and pain (Molnar & Gair, 2013). We all have varying degrees of sensitivity and different ways of responsiveness to various stimuli.

#### 5.2 Sociodemographic characteristics of the study participants

The average age of the participants in this study was (18-22) years, with no significant differences between the four groups. In the study, the participant gender distribution (male to female ratio) was 1:1.3. This is to be expected, given the unequal gender ratio among the University of Ghana medical school's student population, for example. Females account for approximately 65 percent of the total population, while males account for approximately 35 percent.

#### 5.3 Learning styles assessments of students.

Students can employ diverse modalities to learn, nevertheless, one mode can be predominant and preferred (unimodal) or they can show equal/no preference for two or more modalities (multimodal) (Ojeh, et al., 2017). From our study, using the Barsch classification, the unimodal modality, where students show preference for one learning style were the majority (76.6%). Our findings are in line with a study done on learning styles among tertiary students at the University

of Peradeniya, Sri Lanka that reported unimodal preferences (Dissanayaka, 2014). Begum & Jabeen, 2017, have reported 80.27% unimodal preference and 19.73% multimodal classification among 148 first year medical students of Mahavir Institute of Medical Sciences. Also, Meehan-Andrews, 2008, indicated a dominance of 54% for unimodal modality among 86 undergraduate health students in La Trobe University Bendigo Campus, Australia. However, our findings also differs from a few other reports such as the reports of Breckler et al., 2009 who had multimodal/no or equal preference styles forming 60% among undergraduates and postgraduates.

Similar findings to Breckler and co-workers were observed in studies done in Malaysia( Sinha et al, 2013) Saudi Arabia(Nuzhat et al, 2013) Turkey(Baykan & Nacar, 2007) and China (Ding et al., 2012). Similar observation has been made by Shah et al, 2011 which found 70% of their participant being multimodal and preferred kinesthetic. These differences in learning modality preferences of medical students across the world could be due to variations in teaching methodologies been employed (Kharb et al., 2013).

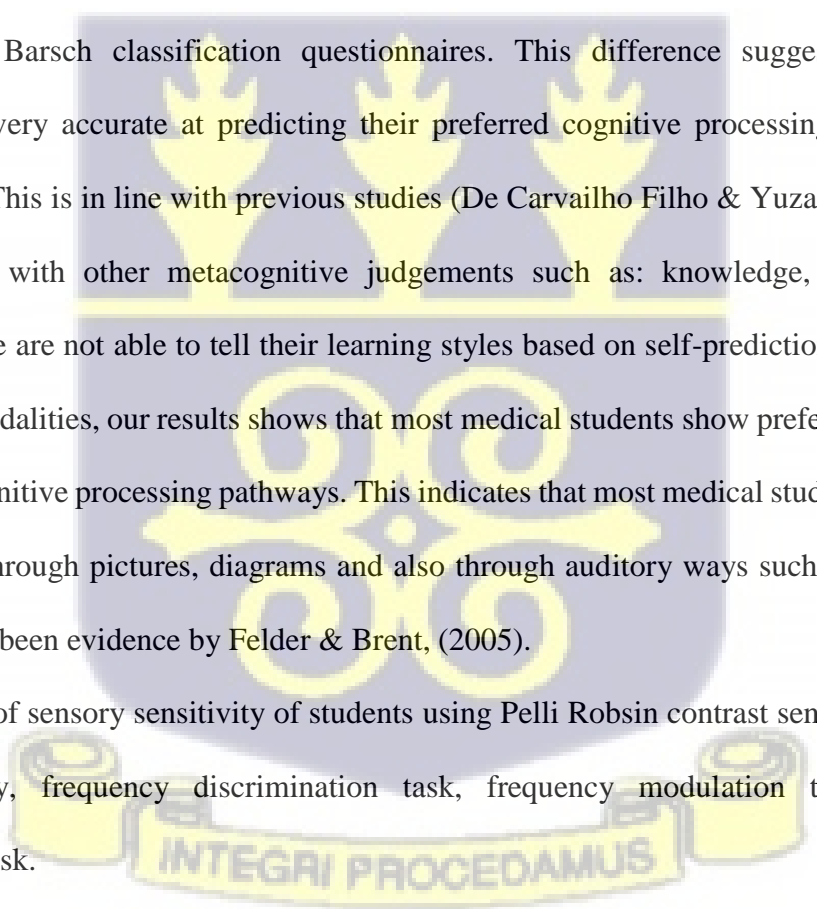
In our study, the most predominant and preferred learning styles was visual. Visual learners were 41.5% followed by auditory (25.5%), then no preference (23.4) and tactile (9.6%) Though the preclinical studies is a mixture of teaching modes, the predominant mode of teaching students is the normal didactic lectures which has been adopted by so many tertiary institutions in Ghana. This form of presenting information aids both the visual and auditory learners as teaching slides are made of written format with pictures and diagrams. Furthermore, Traditional teaching in our secondary schools which is also common in Accra and other parts of Ghana make use of visual and auditory modalities. Therefore, there is a high possibility that most of our study participants are already used to the visual and auditory modalities from secondary school through to the University level. As such it is not a surprise that most unimodal students are visual and auditory learners. This few

numbers of tactile learners identified can be explained by the fact that teaching in most of our secondary school across the country have a less chunk of it being practical based ( Millar, 2004).

As such most students are not accustomed with the tactile form of learning.

In this study, we also compare the perceived learning styles (self-report) and the actual preferred learning styles (Barsch classification self-assessment questionnaire) of the students. The participants were asked to initially indicate their preferred learning style before completing the Barsch questionnaire to avoid bias in the experiment. It was found out that performance of self-report and Barsch classification of the cognitive processing pathways (learning styles) of students were not the same. Thus, 55.31% of the students were able to classify themselves correctly on the self-report and Barsch classification questionnaires. This difference suggests that not all individuals are very accurate at predicting their preferred cognitive processing pathway as in learning styles. This is in line with previous studies (De Carvailho Filho & Yuzawa, 2001) which suggest that as with other metacognitive judgements such as: knowledge, experience and strategies, people are not able to tell their learning styles based on self-prediction. In general, for the unimodal modalities, our results shows that most medical students show preferences for visual and auditory cognitive processing pathways. This indicates that most medical students in our study prefer to learn through pictures, diagrams and also through auditory ways such as listening and hearing as it has been evidence by Felder & Brent, (2005).

**5.4** Assessment of sensory sensitivity of students using Pelli Robsin contrast sensitivity test, pure tone audiometry, frequency discrimination task, frequency modulation task, two point discrimination task.



#### 5.4.1 Visual Sensitivity using Pelli Robsin Contrast Sensitivity Chart.

In our study, the tactile learners had a lower visual sensitivity compared to visual, auditory and no/equal preference group. The auditory and no/equal preference group also had a lower sensitivity compared to the visual learners. So based on our study, visual learners have higher sensory sensitivity for vision. These findings are in line with other studies done on the relationship between learning styles (visual, auditory and tactile) and objective memory test performances for these various modality (Kratzig & Arbutnott, 2006). However, Kratzig & Arbutnott, 2006 used the Osterrieth line drawing test for the assessment of visual performance, while we assessed visual performance using Pelli Robsin contrast sensitivity chart. Pelli Robsin contrast sensitivity test, is a standard test that deals with visual sensitivity (using difference in contrast between objects and their background). It is an indicator of how sensitive a person's visual system works using luminance and distance as key major factors. Studies have shown that frequent utilization of the photoreceptors have resulted into increase adaptive response (Schulze & Bosman, 2018). This may account for the higher sensitivity seen in visual learners. Also, contrast sensitivity is an indicator and predictor of visual influence on real life task such as facial and picture recognition. As such, higher performance in it might explain why visual students preferred to study using pictures and diagrams compared to the other unimodal modalities. In addition, research suggests that contrast sensitivity measurements is also an indicator in detection of ocular diseases such as cataract, glaucoma, age related macular diseases and diabetic retinopathy (Pramanik et al., 2020). Therefore it suggests that visual learners have got very healthy eyes thereby increasing their chances of having better vision abilities.

Performance in the visual sensitivity test among the three unimodal learning styles and the multimodal modality show comparable high sensitivity across all groups with visual learners

leading with 88% sensitivity (representing 1.76 out of 2), followed by auditory learners having 87.5% sensitivity (representing 1.75 out of 2), as well as the no/equal preference group having 87.5% sensitivity (representing 1.75 out of 2) and finally tactile learners having 84% (representing 1.68 out of 2). According to Parede et al, 2013 a Pelli Robsin chat score of 2 indicates a 100percent contrast sensitivity ability. Therefore the sensitivity scores found in this work, which ranges from 84%-88%, is an indication that all the four classes of our sensory groups of students were having a very high visual sensitivity irrespective of their preferred modality.

#### **5.4.2 Auditory sensitivity using pure tone audiometry, frequency discrimination and frequency modulation.**

The sensitivity (which is inversely related to values, i.e. low value of hearing threshold implies higher sensitivity) to pure tone audiometry was lower in tactile learners compared to visual learners, no/equal preference group and the auditory learners for the left ear. The visual learners as well no/equal preference group had lower sensitivity than the auditory learners. The findings in this research are in agreement with works done in Nigeria and other parts of Africa on learning styles among students and academic performance (Zapalska & Dabb, 2002). These studies reported that auditory learners perform better when a material is presented through the spoken or sound stimuli compared to other sensory modalities such as visual and tactile learners. Higher sensitivity in auditory learners can be explained by homeostatic plasticity at the cellular and molecular in the ear. In which a form of cellular gain control allows neurons found in the ear to adapt for increased activity leading to increase sensitivity ( Auerbach et al., 2014). Also, other findings done on pure tone audiometry had indicated that speech detection threshold, which is the lowest speech intensity an individual can detect speech at least 50% of time, has an influence on pure tone performance. Auditory learners have been reported to have better speech detection threshold leading to higher

performance (Schadler et al., 2020). Likewise, word recognition, which is the ability to repeat correctly an open set of monosyllabic words at suprathreshold intensity, is found to be high among auditory learners (Hoover et al., 2017). It has been reported to show positive correlation with puretone performance in people. Furthermore, good performance in puretone audiometry test is an indication of low susceptibility of the ear to conditions such as occlusion of the external auditory system by serumen or mass, perforation of the tympanic membrane and ossicular abnormalities (Voss et al., 2007). As such a better working ear leads to better hearing.

Also for the right ear, pure tone audiometry sensitivity was lower in tactile learners compared to visual, no/equal preference and auditory learners. The visual and no/equal preference group had lower sensitivity than the auditory learners. This findings are similar with other researches done in other parts of the world notably on students' academic performance based on learning styles (Elliot & Katz, 1980). In addition, other studies have reported that environmental sound localization on the vertical plane can influence output on an individual performance on puretone audiometry test (Tabry et al., 2013). So better sound localization have been implicated as a measure that leads to decrease hearing threshold in individuals. This might account for higher sensitivity found in the auditory group. Also, if the impedance between the outer ear and the inner ear is reduced, higher sensitivity is observed (Frear et al., 2018).

However, performance in pure tone audiometry revealed interesting patterns. From the results, all four groups of students performed or had higher sensitivity in the left ear compared to the right ear. This auditory sensitivity asymmetry is represented as visual learners scoring  $(20.1 \pm 5)$ dB, auditory learners scoring  $(20.0 \pm 5)$ dB, tactile scoring  $(20.3 \pm 5)$  dB and no preference group scoring  $(20.1 \pm 5)$ dB for the right ear whilst performances in the left ear were as follows, for visual learners;  $(19.51 \pm 5)$ dB, auditory;  $(19.50 \pm 5)$ dB, tactile;  $(19.52 \pm 5)$ dB and no preference group having

(19.5±51)dB respectively. This asymmetry seen are generally presumed to occur as a result of hemispheric asymmetry at some level of processing and an advantage conferred upon contralateral ear-cortex pathways that are transmitted along ipsilateral routes(O'Regan & Serrien, 2018). This findings shows that the students had better sensitivity for the left than the right ear. According to Minton & Giannarelli, 2019, the left ear and the right ear process sound differently i.e. while the right ear responds to speech and logic, the left ear is more tuned into emotion and intuition. It is believed that speech is processed in left hemisphere of the brain whiles other creative functions are processed in the right hemisphere (Proverbio et al., 2009). And this might have accounted for differences observed in performance for left and right ears. However, the values obtained from the pure tone test for left and right ears shows quite high sensitivity across all groups because according to Majumder et al, 2018, upper limits of sensitivity to normal hearing in puretone audiometry test is 25db to 30db.

For auditory frequency discrimination at 500Hz, sensitivity was lower in tactile learners compared to visual, no/equal preference group and auditory learners. The visual learners and no/equal preference group had a lower sensitivity compared to the auditory learners. This observations are in line with other studies done on VAK classification of learning styles among students in Australia, that found out that students who fall under auditory learners perform well using the sound stimulus modality ( Schulze & Bosman, 2018). This findings can be explained by improved performance in the medial olivocochlear efferent neurons that innervate the cochlea. This improved performance is attributed to frequent use of ear for sensing information as observed in auditory learners. (Greaves, 2018). For the auditory frequency discrimination at 2000Hz, the trend was similar to observations made in 500Hz, i.e. sensitivity was lower in tactile learners compared to visual, no/equal preference and auditory learners. The no/equal preference group had a lower

sensitivity than the visual learners and visual learners had a lower sensitivity than the auditory learners. This is an indication that auditory learners were sensitive than the other learning styles at both higher and lower harmonics and noise levels. Therefore, an increase in test frequency from 500Hz to 2000Hz did not produce a difference in the trend of sensitivity auditory learners were having. This can explain our observations i.e. the repeated pattern at 500Hz and 2000Hz.

For auditory frequency modulation (500Hz), sensitivity was lower in tactile learners compared to visual, no/equal preference group and auditory learners. The visual learners as well as no preference group had a lower sensitivity than the auditory learners. These findings are in line with reports from studies done in South Africa which suggest that performance in frequency modulation is observed to be high in students who are auditory learners. Studies reveal that functions of aquaporin - 4 (AQP4) have been implicated in increased sensitivity of the inner ear observed in auditory learning (Duffy et al., 2013). This may explain the above observations. For auditory frequency modulation at 2000Hz, the trend was similar to performance in 500Hz. i. e. sensitivity was lower in tactile learners compared to no preference group, visual and auditory learners. The visual learners and no preference group had a lower sensitivity value than the auditory learners. Superior sensitivity observed at high and low frequency for auditory learners indicates that sound pitch and intensity had less impact on their sensitivity (Deroche et al., 2012).

#### **5.4.3 Tactile sensitivity using two point's discrimination task**

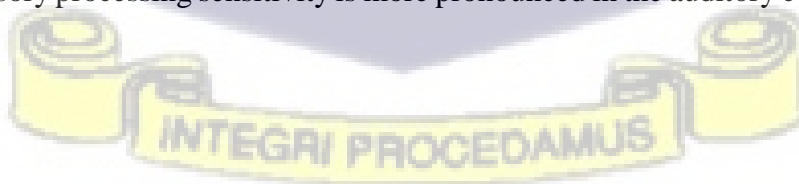
For two point discrimination task, sensitivity was higher (inverse relationship-lower values implies higher sensitivity) in tactile learners compared to visual, no preference group and auditory learners. The visual learners had higher sensitivity than the auditory learners and no preference group. This findings are in line with others studies done in other parts of the world that supported the learning style hypothesis that individuals do perform better when a material is resented through ones

preferred modality (Aslaksen & Loras, 2018). The functional upregulation of piriform cortex has been implicated in cross modal plasticity leading to increase tactile sensitivity (Ye et al., 2012). And this can explain the observed performance in this our study. However, students were very sensitivity as visual learners score 1.30mm, auditory learners score 1.40mm, tactile learners score 1.20mm and no preference group score 1.40mm on average. This high sensitivity experienced in tactile based tasks could be as a result of the sharpness of the custom designed aethiesiometer used as compared to a blunt pair of divider as used by Won et al., 2017. In the same vein, findings by Shimokata and Kuzuya reported age related changes in tactile sensitivity for the elderly, but high sensitivity for adolescents due to loss of cutaneous mechanoreceptors in the elderly (Shimokata &Kuzuya, 1995).

### **5.5 Relationship between sensory processing pathways and cognitive processing pathways**

One the goals of this study was to investigate if cognitive processing pathways as in learning styles reflect varied abilities to retain data presented in different sensory modalities. Thus to ascertain if there is any relationship between both properties. According to the learning style hypothesis, individuals who are classified as visual learners, in particular, should be able to show more sensitivity, thus perform best when materials are provided in a graphical or visual format. Whereas those that are evaluated as auditory learners should be able to do well when auditory based task are given and tactile learners should be able to do well when task are given through the tactile modality (Zapalska & Dabb, 2002). This was not the case observed in the visual and tactile cognitive modality of this study. Likewise, were individuals who show no/equal preference for all modalities had any correlation between their cognitive processing pathway and sensory processing pathways. The findings of this research show that only the auditory cognitive modality impacted performance in auditory sensitivity as there was a positive correlation between both pathways. The

auditory results in particular contradict Kratzig & Arbuthnott, 2006, findings indicating no correlation with the learning modalities and their sensory objective test. Jiraporcharoen et al., (2015) discovered no link between learning styles and academic achievement in their research. There were no statistically significant variations between Turkish students' first semester grade point averages and learning methods (Baykan & Nacar, 2007). Similarly, Ramirez, 2011 found no correlation between MCQ grades and students' preferred learning techniques for both unimodal and multimodal learning. Thus, it was interesting to note that though students show clear preferences for visual, auditory, tactile, multimodal cognitive processing pathways, it didn't impact their performance in their sensory processing pathways in exception of the auditory modality. This implies that cognitive processing pathways for both visual and tactile modality process information independently of their sensory processing pathways. Likewise, multimodal based students had their cognitive processing pathways process information independently from their sensory processing pathways. However, positive relationship seen in the auditory modality indicates the interconnection between the auditory cognitive and auditory sensory pathways. As attributed by other studies, auditory cognitive processing pathways are associated with the white matter of the temporary and parietal lobe and auditory sensory information is also processed by the same temporal lobe of the brain ( Gray et al., 2020). Accordingly, knowledge of cognitive processing pathways for an individual is helpful to understand himself or herself better, however its impact on sensory processing sensitivity is more pronounced in the auditory cognitive modality.



## CHAPTER SIX

### 6.0 SUMMARY, CONCLUSION AND RECOMMENDATION

#### 6.1 Conclusion

1. The present study suggests that intuition of people about their learning styles may be incorrectly attributed and does not correlate with objective measures of learning styles.
2. Sensory sensitivity of students assessed showed high values in both modalities (unimodal and multimodal) indicating no sensory deficit within the study population and a relatively high measure of sensory processing abilities.
3. Finally, there was a significant relationship between only the auditory cognitive processing pathways and sensitivity to auditory sensory modalities.

#### 6.2 Recommendations

Based on the various outcomes of the study, the following recommendations were made:

1. Individuals have preferred learning styles (either unimodal or multimodal) used or adopted in their learning process. .
2. Some sensory sensitivity pathways of students are not influenced by their cognitive processing pathways, eg, visual and tactile, while others are. i.e. auditory
3. Future studies of this study should consider replicating this study using other learning instruments.



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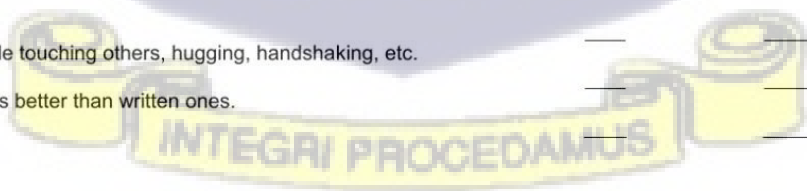


**APPENDIX**

**BARSCH LEARNING STYLE INVENTORY**

Please check the appropriate line after each statement.

	Often	Sometimes	Seldom
1. Can remember more about a subject through listening than reading.	—	—	—
2. Follow written directions better than oral directions.	—	—	—
3. Like to write things down or take notes for a visual review.	—	—	—
4. Bear down extremely hard with a pen or pencil when writing.	—	—	—
5. Require explanations of diagrams, graphs or visual directions.	—	—	—
6. Enjoy working with tools.	—	—	—
7. Are skillful with and enjoy developing and making graphs and charts.	—	—	—
8. Can tell if sounds match when presented with pairs of sounds.	—	—	—
9. Remember best by writing things down several times.	—	—	—
10. Can understand and follow directions on maps.	—	—	—
11. Do better at academic subjects by listening to lectures and tapes.	—	—	—
12. Play with coins or keys in pocket.	—	—	—
13. Learn to spell better by repeating the letters out loud than by writing the word on paper.	—	—	—
14. Can better understand a news article by reading about it in the paper than by listening to radio.	—	—	—
15. Chew gum, smoke or snack during studies.	—	—	—
16. Feel the best way to remember is to picture it in your head.	—	—	—
17. Learning spelling by "finger spelling" the words.	—	—	—
18. Would rather listen to a good lecture or speech than read about the same material in a book.	—	—	—
19. Are good at solving and working on jigsaw puzzles and mazes.	—	—	—
20. Grip objects in hands during learning period.	—	—	—
21. Prefer listening to the news on the radio rather than reading about it in a newspaper.	—	—	—
22. Obtain information on an interesting subject by reading relevant materials.	—	—	—
23. Feel very comfortable touching others, hugging, handshaking, etc.	—	—	—
24. Follow oral directions better than written ones.	—	—	—







**UNIVERSITY OF GHANA**  
**COLLEGE OF HEALTH SCIENCES**  
**ETHICAL AND PROTOCOL REVIEW COMMITTEE**

EPRC/JULY/2021

July 28, 2021

Ref. No.: .....

**Ms. Valentina Adjei**  
**Dept. of Physiology**  
**University of Ghana Medical School.**  
**College of Health Sciences**  
**Korle-Bu.**

**ETHICAL CLEARANCE**

Protocol Identification Number: **CHS-Et/M.6-5.1/2020-2021**

**FWA: 000185779**

**IORG: 0005170**

**IRB: 00006220**

The College of Health Sciences Ethical and Protocol Review Committee (EPRC) on July 28, 2021 reviewed and approved your research protocol.

Title of Protocol: **"Investigating the relationship between sensitivity to sensory modalities and cognitive ability"**

Principal Investigator: **Ms Valentina Adjei**

This approval requires that you submit six-monthly review report(s) of the study to the Committee and a final full review report to the EPRC at the completion of the study. The Committee may observe, or cause to be observed, procedures and records of the study before, during and after implementation.

Please note that any significant modification(s) to this project/study must be submitted to the Committee for review and approval before its implementation.

You are required to report all serious adverse events related to this study to the EPRC within seven (7) days verbally and fourteen (14) days in writing.

As part of the review process, it is the Committee's duty to review the ethical aspects of any manuscript that may be produced from this study. You will therefore be required to furnish the Committee with any manuscript for publication.

**This ethical clearance is valid until July 28, 2022.**

Please always quote the protocol identification number in all future correspondence in relation to this protocol.

Signed: .....

**Professor Andrew Anthony Adjei**  
Chair, Ethical and Protocol Review Committee

cc: **Provost, CHS**  
**Dean, UGMS**  
**Head, Physiology**

**INTEGRI PROCEDAMUS**