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From Touch to Perception: A Review of Tactile Sensitivity

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Abstract:

Tactile sensitivity is an increased sensitivity to light touch sensations. It can result in an over-responsive or under-responsive reaction to touch. Affecting nearly 20% of the world's total population, tactile sensitivity causes a different nervous system reaction to a touch sensation. Symptoms of tactile sensitivity can vary and begin at any stage of life. Tactile neurons below the epidermis receive and transmit touch stimuli through the spinal cord to the brain for interpretation. From there, thalamic nuclei send the signals to other parts of the brain for processing. Tactile sensitivity can be either inherited from family members,or developed neonatally or postnatally due to environmental factors. It is common for children or adults who experience tactile sensitivity to also have Autism Spectrum Disorder (ASD), or Asperger Syndrome (AS). People with ASD and AS may often experience some of the same symptoms as those who have tactile sensitivity. Tactile sensitivity is not something that can be cured, but there are many methods that can help people cope with it throughout their lifetimes such as occupational therapy. While occupational therapy is a reliable resource for those with tactile sensitivity, there needs to be more simple, short-term methods to help children and adults.

Keywords **—Tactile Sensitivity, ASD, Autism, Tactile Defensiveness, Thalamus**

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I.INTRODUCTION

Tactile sensitivity or tactile defensiveness is nervous system overreaction to a light touch sensation that makes the person feel uncomfortable or in pain. It is not a mental disorder, but rather a behavioral response to certain stimuli that can be overwhelming. Tactile sensitivity affects around 20% of the world's population with more women than men experiencing symptoms [1]-[2]. While age of symptom onset varies, children as young as a few months old can begin showing signs of tactile sensitivity. Children who are picky eaters, complain about uncomfortable material, or dislike getting their hands and feet dirty show signs of tactile sensitivity. These symptoms can affect the way people with tactile sensitivity interact with their environment and the people around them. For example, tactile sensitivity triggers can cause a rush of anxiety, distracting one from focusing on completing a task or having a conversation. People with sensory over-responsive (SOR) traits and sensory related motor dysfunction struggle more with social interactions or performance of every-day activities than those who do not suffer from sensory-related issues [3]. This gives children who suffer from tactile sensitivity a disadvantage in growing socially and emotionally. Without receiving help in the early stages of life, it is common for children to never grow out of their anxious tendencies, meaning they experience persistent symptoms of tactile sensitivity throughout the course of their lives. Tactile sensitivity affects adults as frequently as it affects children, sometimes impairing their ability to participate in the workforce or function properly in public settings. While tactile sensitivity is typically developed before birth, some people don't show signs until later on in life, often triggered by environmental stimuli. Since women are known to use more products on the skin and scalp, it increases the exposure to uneasy sensations, which can trigger tactile sensitivity. Moreover, symptoms of tactile sensitivity or SOR can be triggered in accordance with the female menstrual cycle, due to an increased hyper-response to factors such as weather conditions, strong smells or tastes, and uncomfortable touch [2]. Although symptoms of tactile sensitivity can remain with a person for theirwhole life, there is still a large need for cures and remedies for the issue.

II. MAIN

A.TOUCH INTERPRETATION AT THE LIMB

Sensory processing begins at the skin. Sensory receptors in the skin are activated upon touch and transmit signals to the brain. Skin, otherwise known as the epidermis, is a layer that protects the dermis; all of the veins, sweat glands, hair follicles, and nerves in the body. Within the dermis, there are several tactile neurons which are essential for transmitting touch stimuli to the brain. For example, Meissner's Corpuscles are receptors located closest to the skin's surface and are responsible for sending pressure signals [4]. Merkel's Disk receptors, located in the hair follicles, respond to texture, temperature, and are most sensitive to pain [4]. Ruffini Ending

receptors respond to stretching of the skin, temperature, and pressure [4]. Pacinian Corpuscle receptors pick up deep pressure and help with proprioception, the understanding of movement and action of the body in space [4]. The Krause End Bulb reacts to extremely cold temperatures, and Free Nerve Endings respond to all stimuli [4]. Most of these neurons are connected both to the epidermis, to receive tactile stimuli, and nerves, to send signals through the body (see in figure 1). When these cell receptors are functioning properly, our brains are able to correctly interpret touch signals. However, in people with tactile sensitivity, these cells can over be under or over-responsive contributing to the symptoms observed in tactile sensitivity.

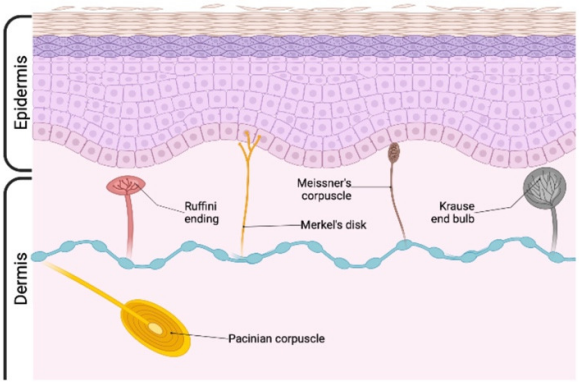

Figure 1: Graphical Representation of Touch Receptors: Neuron receptors lay just below the epidermis and receive touch stimuli from the surface of the skin. From there, they connect to nerves in the dermis (blue line in light purple section) and transmit signals to the rest of the body.

B. TOUCH SIGNALING TO THE BRAIN

From the touch at the skin, the signals are transmitted through the dorsal root ganglion (DRG) and trigeminal ganglion (TG) to the spinal cord, ultimately connecting the periphery of external skin to the central nervous system. The primary sensory neurons are what detect stimuli coming through the body and activate projection neurons to deliver information to the brain. Touch neurons and local interneurons in the spinal cord both give input to pain projection pathways. Touch signals are sent directly from the spinal cord to the brain, using 5 majorpathways: spinothalamic, spinoreticular, spinomesencephalic, corticospinal, and spinohypothalamic[5]. These pathways mainly react to and control painful sensations and motor functions. For example, the spinothalamic pathwaycarries conscious pain and temperature informationfrom theskin to the thalamus [6]. Most information is relayed directly from the external location point of the touch to the cerebral cortex, but pathways that carry information of pain signals first cross to the opposite side of the spinal cord (see Figure 2), then are transmitted to the brain with the help of the thalamus, which plays a big role in relaying sensory information [5].

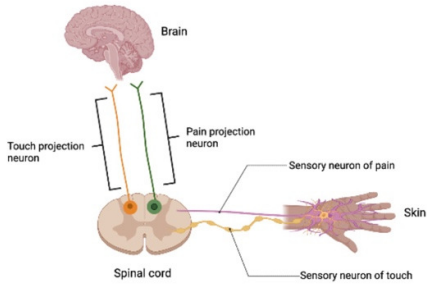

Figure 2: Graphical Representation of Projection Pathways: From the external touch of the skin, sensory neurons respond to touch signals (regular or pain), and transmit them to the spinal cord. From the spinal cord, projection neurons, also known as projection pathways, further transmit the signals to the cerebral cortex of the brain for processing. As shown, there are different sensory neurons and projection neurons that correspond with either pain or regular touch.

C. BRAIN INTERPRETATION OF SIGNAL

The thalamus takes on several important roles regarding brain functionality. Some of its bigger roles include relaying motor information, prioritizing attention, and retaining

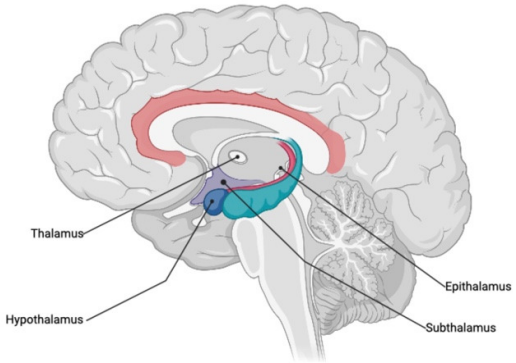

Figure 3: Graphical Representation of the Diencephalon: A side view of the human brain, with different colors representing the location of Diencephalon. As shown, the thalamus is found in the center, and slightly higher than the rest of the nuclei. The epithalamus is found to the side of the Thalamus. The hypothalamus and subthalamus are found below the thalamus.

memory. Additionally the thalamus receives and processes all sensory information and signals from the spinal cordinto the cerebral cortex, and from there, thalamic nuclei process and transmit the information to other parts ofthe brain. Sensory-specificthalamic nuclei process signals from different senses.The ventral posterior nucleus receives proprioceptive information and sends it to the somatosensory cortex for interpretation [7]. It has been shown that sensory-specific thalamic nuclei are "directly linked to behavioral performance," suggesting that the condition of the thalamus could be a factor that controls multi-sensory integration, and tactile sensitivity [8]. The thalamus extends to other areas of the brain that support the functionality of the thalamus. These include the hypothalamus, subthalamus, and epithalamus, which reside in the same relative area of the cortex (see Figure 3) [7].The hypothalamus is towards the base of the brain, and produces hormones that control body temperature, hunger, heart rate, and mood [9]. The subthalamus is a nucleus that regulates movement, found below the hypothalamus [6]. The epithalamus helps regulate motor pathways and emotions [10]. Everybody has a brain protective system that when triggered, can result in a fight, flight, or freeze response. Children and adults who suffer from tactile sensitivity's brains often have a greater reaction to any kind of touch, and may often feel pain resulting from an unfamiliar texture brushing against them. Sometimes even the slightest bit of uncomfortable external touch can trigger someone with tactile defensiveness, sending them into a fight, flight, or freeze reaction, which can explain the outbursts or meltdowns of children with tactile sensitivity.

D. DEVELOPING SENSORY DISORDERS

Tactile sensitivity is often classified under a more widely known term, Sensory Processing Disorder (SPD). In 50% of cases, SPD is a hereditary trait, passed down from parent to offspring and encoded within the child's genetic material. In the other 50% of cases, SPD is developed prenatal, neonatal, or postnatal because of environmental stimuli [11]. A recent study was conducted to find genes associated with tactile sensitivity in developing children. Using the autism candidate gene, GABRB3, researchers found three single nucleotide polymorphisms (SNPs) associated with children experiencing tactile sensitivity [12].

SNPs are changes in a single nucleotide base of a DNA sequence. A typical DNA strand consists of several pairings using four nitrogen bases; adenine, guanine, cytosine, and thymine. In a normal DNA strand, thymine pairs with adenine, and guanine pairs with cytosine. However, genetic mutations may occur within a DNA sequence, which can alter the function of the gene [13]. For example, in DNA mismatches, adenine may accidentally be paired with guanine, or cytosine with thymine. DNA synthesis is the step in the cell cycle responsible for detecting and correcting mismatched bases, but sometimes they are either not caught or not fixed, leading to permanent genetic mutations [14].

The three SNPs associated with tactile sensitivity in the GABRB3 gene were rs11636966, rs8023959 and rs2162241. In the experiment, researchers conducted a behavioral touch test for children, and gathered parent reported information as well. Comparing the data from the experiment and information, three additional SNPs associated with GABRB3 were found. These SNPs can indicate different levels of tactile sensitivity in a child, whether it be higher or lower, and the condition may change overtime. While it is common for tactile sensitivity to be genetically transferred from parent to offspring, there are several prenatal and neonatal risk factors that can cause sensory processing symptoms in a newborn. Exposure to alcohol or stress while in the womb can affect the fetus, but have been shown to be a non-hereditary cause of tactile sensitivity. On the other hand, neonatal environmental conditions have shown to cause sensitivity to environmental stimuli, including those of external touch [15]. Children who have birth complications such as cord wraps, premature birth, prolonged delivery, or jaundice are more likely to develop tactile sensitivity than children who are born under normal, less stressful conditions [16]. In the moments post-birth, babies are extremely vulnerable, and it is important that they are not exposed to any sort of negative stimuli, as even the slightest offset can result in major brain development issues. Even in the days and months following birth, it is crucial that newborns are receiving proper nutrients, physical touch, and sleep so their brains and bodies can grow appropriately. For example, if an infant is left in a stroller, strapped into a car seat for too long, or experiences frequent accidental falls or bumps on the head, it can result in developmental dysfunction [17]. This especially pertains to the influence of tactilesensitivity on a child later on in life, as these activities involve touch

perception. In addition, allowing newborn babies to crawl and explore their bodily functions helps them to develop their sensory functions, but if they aredeprived of that physical freedom, their sensory development can be stunted.

E. COMORBIDITY WITH AUTISM

Children and adults who experience tactile sensitivity often also suffer from Autism Spectrum Disorder (ASD). This is because Autism is associated with hypersensitivity to sensory information, especially concerning tactile stimuli. Up to 90% of people with ASD are either sensory over- responsive, or sensory under-responsive [18]. In a 2018 study done in Indonesia testing the relations between children with ASD and responses to tactile stimulus, it was found that children with ASD are more sensitive to touch and pain, than children who did not have ASD [19]. These findings support the theory that many children with ASD also experience tactile sensitivity, whether it be soon after birth or later on in childhood. The autism candidate gene, GABRB3, has multiple SNPs that indicate genetic variation in that gene, however there were 3 SNPs that were also associated with tactile sensitivity [12],[20].

A study on the relationship between ASD and Asperger Syndrome (AS) conducted 6 tests to find similarities in SNPs [21]. These tests consisted of the Empathy Quotient (EQ), a measure of empathy, the Autism Spectrum Quotient (AQ), a measure of autistic traits, the Systemizing Quotient-Revised (SQ-R), and a few others [21]. Many SNPs were associated with all tests, but three were significantly associated with the EQ and AQ tests: the same SNPs associated with both Autism Spectrum Disorder and tactile sensitivity. This shared genetic association further confirms the behavior similarities in children with Aspergers and children with ASD, as it is common for them both to experience tactile sensitivity, or hypersensitivity [22].

For people with Autism, they may interpret touch stimuli in a different manner than people without ASD would. For example, receiving a hug from someone who is trying to show love or affection may cause a person with ASD slight pain or discomfort [23]. Similarly for people who have Asperger Syndrome, sensory processing is different from those in the control group. One difference between those with Autism and those with Asperger's is what sensation they feel when touched. While people with ASD can feel more pain or discomfort from external touch, people with Asperger's may feel more of a tickle with either self touch, or external touch [24]. With comparisons in genetic mutations regarding the SNPs rs11636966, rs8023959 and rs2162241, along with similar behavioral responses to tactile stimuli, there are evident phenotypic and genotypic links between people with Autism Spectrum Disorder, Asperger Syndrome, and tactile sensitivity.

F. CURRENT SOLUTIONS TO COPE WITH TACTILE SENSITIVITY

Like many disorders, tactile sensitivity is life-long, and cannot be permanently cured. The best thing for a child with tactile sensitivity to do is seek occupational therapy, which helps them cope with their behavioral issues, and learn how to live with them. Occupational therapists (OTs) treat people of all ages, ranging from babies to seniors, and work to reduce the severity of many health problems [25]. For example, occupational therapists can help people with mild tactile sensitivity, and it may only take a few months to a year to see beneficial changes. After working with the OT, they may recommend physical or mental exercises and games to practice and play at home. Daily or weekly exercises allow people with tactile sensitivity to practice improving their life skills on their own, further improving independence and intellectual growth.

Some activities OTs may encourage children to do at home are firm pressure massaging of the skin, animal walks around the house on hands and feet, and baking [26]. All of these activities help children get used to engaging with materials in their environment, and helps them become less sensitive to touch stimuli. Occupational therapy won't cure tactile sensitivity, but it gives children and adults who suffer from it coping mechanisms that reduce the severity. With a necessary amount of therapy sessions and continual practice of therapist-recommended activities, people with tactile sensitivity are able to live life to their full potential, without the stress of environmental stimuli. Occupational therapy is a great way to set children up for success in the workforce, social interactions, and a bright future.

G. FUTURE STEPS TO HELP TACTILE SENSITVITY

Since children with Autism Spectrum Disorder and tactile sensitivity share similar tendencies, medication that helps symptoms of autism may be able to treat those with tactile sensitivity as well. Among these medications are selective serotonin uptake inhibitors, tricyclics, stimulants, and anti-anxiety medications. Selective serotonin uptake inhibitors can help reduce the intensity of anxiety, irritability, and aggressive behavior, as well as improve social skills such as eye contact [27]. This medication could be used to help people with tactile sensitivity respond more normally to external touch, and decrease some of the stress associated with it. Tricyclics serve mainly as antidepressants but can be used to treat obsessive-compulsive disorder (OCD), anxiety, and neuropathic pain [28]. Many types of tricyclics can have side effects that increase with the dosage, with the exception of nortriptyline and desipramine, which are found to have the least amount of side effects. Stimulants are used to decrease hyperactivity for those with Autism, but are also used to speed up connections between the brain and the body [29]. Therefore, larger doses of stimulants can cause overstimulation and anxiety, but small

doses can help autism-specific symptoms. Anti-anxiety meds come in different forms, but the one that could be most beneficial to tactile sensitivity is antihistamines. Antihistamines treat mild cases of anxiety, and work to decrease performance and social interaction anxiety, which are often outcomes of tactile sensitivity [30]. These medications are used to treat generalized disorders, and are not specific to tactile sensitivity, and therefore should not be taken without proper consultation from a medical professional. However, because these medications are used to treat ASD symptoms, they could potentially be beneficial to people who suffer from tactile sensitivity.

III. CONCLUSION

A cure has yet to be found for tactile sensitivity. It is not a disorder, disease, or disability, but rather a behavior that can only be treated. Since it affects around 20% of the worlds' population, it is important for those who suffer from tactile sensitivity to understand what it is, and how to cope with it. There is also no definite cause for tactile sensitivity. What has been found, however, is that it can be inherited, or developed neonatally or postnatally, depending on environmental factors. Common symptoms that come with tactile sensitivity include picky eating, complaining about uncomfortable material, or dislike of getting their hands and feet dirty. These symptoms can also be found in children with Autism Spectrum Disorder and Asperger's Syndrome. Furthermore, there have been genetic links found between tactile sensitivity, ASD, and AS with SNPs in the GABRB3 gene.

These similarities suggest that treatment for ASD or AS, could also improve the symptoms of those with tactile sensitivity. Medications such as SSUI, tricyclics, stimulants, and anti-anxiety medications could possibly reduce stress and neuropathic pain, while improving social interaction skills. Though these medications have not been proven to help treat symptoms of tactile sensitivity, there are already specific treatments that have proven effective. Occupational therapy is a reliable resource that not only helps people with tactile sensitivity, but several other disorders that affect motor and social development. Through one-on-one sessions with therapists and at-home practices, symptoms of tactile sensitivity can be reduced significantly. With OT and advancements in medication, finding a cure to tactile sensitivity may be sooner than we think.

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