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# Physiological Responses of Adults with Sensory Over-Responsiveness


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This thesis, written under the direction of the candidate's thesis advisor and approved by the program chair, has been presented to and accepted by the Department of Occupational Therapy in partial fulfillment of the requirements for the degree of Master of Science in Occupational Therapy. An electronic copy of the original signature page is kept on file with the Archbishop Alemany Library.

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**Physiological Responses of Adults with Sensory  
Over-Responsiveness**

by

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A culminating capstone project submitted to the faculty of Dominican University of  
California in partial fulfillment of the requirements for the degree of Master of Science  
in Occupational Therapy

Dominican University of California

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## Abstract

The purpose of this research study is to identify if there are physiological response patterns associated with self-reported sensory over-responsiveness (SOR) in typical adults. SOR is the most common sensory modulation disorder and negatively affects the daily experiences of those that report SOR. The first phase of the study consisted of phone interviews where participants were screened for any potential characteristics that could affect physiological function. Then, the SRQ and AASP were used in conjunction to identify low and high SOR, typical adults. The last phase utilized the Sensory Challenge Protocol, which is both standardized and randomized, to expose participants to auditory, olfactory and tactile stimuli while collecting electrodermal response (EDR) data. This research has three major findings. First, EDR differences between high and low SOR groups are not significant, however, the high SOR group had generally higher EDR for almost all stimuli. Second, there was a strong correlation for inter-stimuli EDR, informing us that each individual has a general response style to stimuli regardless of their self-report. Lastly, there is no correlation between self-reported SOR and EDR. It is hypothesized that self-reported SOR is shaped by habituation, coping skills and varying life experiences. EDR can help support the experiences of those with high SOR, however it is not sensitive enough for diagnostic/clinical purposes. Additionally, when an individual has sensitivity in one area, there is likely sensitivity in other sensory areas as well but may be masked by coping skills, habituation or modulation.

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## Introduction

All individuals respond differently to stimuli from the environment. However, for some, these responses can be greatly exaggerated and may result in a classification of sensory overresponsivity (SOR). The symptoms of this disorder can interfere with nearly every aspect of a person's life. Kinnealey, Oliver and Wilbarger (1995) did a qualitative study using in-person interviews with five adults who identified as sensory defensive, which is the term these researchers used to describe SOR. Interview questions addressed the adults' responses to sensory stimuli in six areas: tactile, vestibular, auditory, visual, olfactory, and oral. When describing their experiences to researchers, participants said that their sensory defensiveness disrupted their choice of activities, self-care routines, and intimacy. Furthermore, Abernethy (2010) found that symptoms of SOR can negatively impact the functional abilities, behavior, emotions, and mental health of subjects.

In 1963, Jean Ayres first used the term "sensory integration dysfunction" (Ayres, 1979). Since then, ample follow-up research has been conducted, with concepts and terminology branching off in a number of directions. In order to increase clarity, Miller, Anzalone, Lane, Cermak, and Osten (2007) proposed a nosology, or classification, for Sensory Processing Disorder (SPD). Utilizing this nosology, the term "sensory processing" is used to refer specifically to a disorder, as opposed to a theory (of sensory integration) or treatment (OT-SI). Miller et al, (2007) organize the sub-diagnoses under the umbrella diagnosis of SPD. The first pattern of SPD is that of Sensory Modulation Disorder (SMD). SMD occurs when the individual's response to sensory stimuli does not match in degree, nature and/or intensity to the information received. Responses are inconsistent with the situation and the individual is unable to adapt to the 'sensory challenges' that they encounter on a daily basis. Sensory

overresponsivity (SOR) is a subtype of SMD in which individuals overreact to harmless stimuli. Compared to those with typical sensory responsivity, individuals with SOR respond to sensation quickly, with more intensity, or for a longer duration of time. SOR is characterized by activation of the sympathetic nervous system, which may lead to inflated fight, flight, fright, or freeze responses.

Although SOR affects individuals of all ages, past studies have mainly focused on children (ASD) and mental health populations (psychiatric disorders). There is a lack of research on SOR focusing on typically functioning adults. This is likely due to the enhanced ability of adults, when compared to children, to create and use their own coping strategies. Therefore, overresponsivity in adults is often considered to be a less crucial issue. However, further research with this population is important. These individuals often experience feelings of hopelessness and despair when they are unable to determine a diagnosis that describes and validates their sensitivities and concerns (Abernethy, 2010). This study focuses on adults with no diagnosis, who self-report exaggerated or amplified sensory experiences. In addition to a lack of research on the subject, there is also a lack of available methods for capturing atypical sensory responsivity in adults. While other methods have been developed over the years, the Adolescent/Adult Sensory Profile (AASP), is currently the only published method that is widely available for this purpose.

For the purposes of this study, occupational therapy researchers will use physiological measurements to investigate sensory processing. DeBoth, Benevides, Lane and Reynolds (2015) report that, “connections between the ANS and observable outputs help to provide empirical support for the existence of sensory processing differences and guides the use of therapeutic interventions rooted in SI theory” (p.1). However, a majority of studies utilizing physiological

responses to validate Sensory Processing Disorder (SPD) focus on childhood populations. This study will aim to determine if physiological responses can also be used to assess sensory processing in adults who self-report as high SOR.

The feelings of individuals who self-report as high SOR may be validated if researchers are able to determine a unique pattern to their physiological responses to stimuli. This validation may enable these individuals to find better coping strategies, receive better intervention, and potentially improve their quality of life.

### **Problem Statement and Rationale**

Research and interventions for atypical sensory responses are often focused on individuals with defined diagnoses such as Autism Spectrum Disorders (ASD) and Sensory Processing Disorders (SPD). The population of adults with no official clinical diagnosis that report SOR are not frequently addressed in research or clinical practice. Due to a lack of research on this population, adults with sensory processing challenges cannot validate their experiences or receive adequate intervention or care. The purpose of this study is to examine physiological responses to various sensations in people who report increased responsiveness to sensation compared to adults who do not experience atypical sensory responses. This study will compare the response of typically functioning adults that self-report as high in sensory over responsivity to those that self-report as low in sensory responsivity. If a difference in physiological responses is found, this study will help to legitimize the experiences of these adults and assist practitioners in properly addressing them.

## **Background and Literature Review**

### **Sensory Integration**

Sensory Integration is an unconscious brain process that gives meaning to what we are experiencing in our environment through our senses. These experiences change the structure and organization of the brain allowing for active engagement through adaptive responses to challenges in the environment. These adaptive responses to sensation optimize function. Ayres (2005) defines sensory integration as “the organization of sensations for use” (p. 5). When the brain does a poor job of integrating sensations, this is known as sensory integration dysfunction. It is a term first used by Ayres, in 1963, which referred to the disorder as a whole. The original factors of sensory integration dysfunction documented by Ayres (1975) were dyspraxia (uncoordinated movement), poor bilateral integration (vestibular based), tactile defensiveness, form & space deficits, and auditory-language dysfunction. Sensory processing disorders affects 5-10% of children without disabilities and an estimated rate of 20-80% (Cheung & Siu, 2009) of individuals with developmental disabilities (Ahn, Miller, Milberger, & McIntosh, 2004).

### **Sensory Modulation**

Sensory modulation is the neurological function and organization of sensory stimuli to meet environmental demands, and a necessary process for human functioning (Kinnealey, Koenig & Smith, 2011). Modulation is defined by Ayres (1979) as the “brain’s regulation of its own activity” (p. 182). Sensory modulation disorder (SMD) occurs when an individual's behavioral responses are not graded relative to the situational demand, degree, nature, or intensity of the sensory information (Wilbarger & Stackhouse, 1998). An individual with SMD may experience inconsistent responses to the demands of an activity, and an inability to adapt to sensory challenges seen in daily life. Miller et al. (2007) determined the three subtypes of SMD

to be sensory over-responsivity (SOR), sensory under-responsivity (SUR), and sensory seeking/craving. Individuals with SOR experience a disruption to the modulation of sensory input and results in an overreaction to harmless stimuli. Those with SUR do not react or appear to detect sensory information. The inaction of those with SUR is due to a failure to notice possibilities for action leading to responses of apathy, lethargy and a seeming lack of drive to socialize. People with the third subtype of SMD are sensory seeking/craving, these individuals crave large amounts of sensory input in their environment and “seem to have an insatiable desire for sensation” (Miller et al. 2007, p. 137).

SOR is the primary focus of this study. In current and past literature, SOR may be referred to as hypersensitivity, sensory defensiveness, sensory sensitivity and sensory avoiding (Ayres, 1972; Dunn, 1997; Miller, 1999; Wilbarger & Wilbarger, 1991). These terms are synonymous. However, for the purpose of this study, we will use the terminology high and low SOR. The term SOR is taken from “A Proposed New Nosology for Sensory Processing Disorder” by Miller et al. (2007). Individuals with SOR respond to sensation quickly, for a longer duration and with greater intensity than those who have typical sensory responsivity. SOR may be experienced in a single sensory system or in multiple, depending on the individual. This affects individual’s functional responses, particularly during transitions and in unfamiliar, unexpected situations. Responses to stimuli range from aggressive and impulsive to avoidant and withdrawn. The sympathetic nervous system is a marker of SOR, which may result in exaggerated fight, flight, fright or freeze responses (Ayres, 1972). Emotional responses of SOR can include poor socialization, moodiness, inconsolability or irritability.

## **Behavioral Measures of Sensory Responsiveness**

**Adolescent/adult sensory profile.** In order to determine which adults qualify as high or low SOR, and are therefore eligible for inclusion in the study, the Adolescent/Adult Sensory Profile (AASP) was used (Brown et. al, 2001). The AASP is a 60 item, self-report, behavioral measure based on Dunn's (1997) Model of Sensory Processing. The AASP yields four scores in the areas of sensory sensitivity, sensation avoiding, low registration, and sensation seeking. An individual who scores high in "sensory sensitivity" is characterized as easily distractible and likely experiences discomfort with sensation and difficulties with screening stimuli. An individual who scores high in "sensation avoiding" often avoids sensory stimuli because they are easily overwhelmed by most stimuli, even if it is low-intensity. This study will utilize an oversensitivity scale, created by researchers, that combines the total score from the "sensory sensitivity" and "sensation avoiding" areas to determine if an individual self-reports as SOR.

**Sensory response questionnaire.** The Sensory Response Questionnaire (SRQ) is a self-report measure of sensory sensitivity to stimuli encountered in daily life. Items ask participants if they are sensitive to sensations that are commonly considered innocuous or avoid common activities or environments because of sensory stimuli (Wilbarger & Cook, 2002).

## **Physiological Responses of Sensory Responsiveness**

When the human body interacts with stimuli from the environment, nerves transmit information to the brain where they are interpreted as a sense. The human body interprets incoming stimuli with seven senses: touch, auditory, vestibular, vision, olfaction, taste and proprioception (Constanzo, 2017). Stimulation from the environment affects an individual's senses. This causes automatic and unconscious changes, or physiological responses, in organs and organ systems. Most organs of the human body have both a sympathetic and



parasympathetic component that operates reciprocally or synergistically to produce physiological responses. Sympathetic responses tend to mobilize the body for activity, whereas parasympathetic activities conserve and restore energy. Examples of responses include increased or decreased heart rate, atrioventricular (AV) nodal conduction, and contractility. The skin's sweat glands may increase in activity and hair may contract, and eyes may dilate or constrict (Constanzo, 2017). This study will discern if physiological responses can be used as an objective measure for these SOR experiences.

### **Past Studies Using Measured Physiological Responses**

Several key occupational therapy researchers have examined physiological responses in individuals in response to various sensory stimuli. In 1999, a research study was conducted with 19 children with SMD and 19 control children (McIntosh, Miller, Shyu & Hagerman, 1999). The researchers created the Sensory Challenge Protocol (SCP) in which each individual participated in five sensory modalities with 10 trials each equaling 50 trials total. The five sensory modalities are (1) visual- strobe light, (2) olfactory- wintergreen oil, (3) auditory- fire engine siren, (4) tactile- feather touched from chin to ear and (5) vestibular- chair tilted back then returned to upright position. Their electrodermal activity was recorded and the results showed that children with clinically identified SMD had consistent differences in physiological responses to the sensory stimuli than the children without SMD including failing to respond to sensation, abnormal responses to sensation, more electrodermal responses and responses with greater magnitude.

In 2010, Lane, Reynolds and Thacker compared neuroendocrine, electrodermal and behavioral characteristics in 39 children ages 6-12 years old with attention deficit hyperactivity disorder (ADHD) and a control group of 46 typical children. Before the test, a saliva sample was

taken and five surface electrodes were attached to the child. Each child participated in the SCP and upon completion, another saliva sample was taken. The data indicates that ADHD and SOR can be linked. However, ADHD and SOR are also seen separately in children with ADHD without SOR and typical children with SOR.

### **Electrodermal Response (EDR): Physiological Measurement Method**

Considering the well-established nature of electrodermal response (EDR) measurements in the medical field, this study has selected EDR as the primary data collecting method (Quick, 2017). Electrodermal response is the term used for detecting involuntary changes through the electrical properties of the skin. Skin conductance measurements reflects an individual's arousal and alertness, which can increase or decrease depending on stressors and stimuli (DeBoth, Benevides, Lane, & Reynolds, 2015). In addition, EDR is as an indirect measure of sympathetic nervous system activity.

### **Atypical Sensory Processing in Adults**

There are few studies on adults with sensory processing difficulties. Studies on populations of typically functioning adults who live with abnormal sensory experiences are even more scarce. In one of the earliest phenomenological studies on such a population, Kinnealey, Oliver & Wilbarger (1995), investigated the experiences of five adults who that had suspected sensory defensiveness to touch, movement, vision, smell, sound, and taste. The researchers found that there were two major themes across the participant's responses. The first theme was that there were six sensory areas that frequently had reports of abnormalities. These were the systems associated with tactile, visual, vestibular, oral, olfactory and auditory sensations. Second, the participants developed common coping mechanisms to reduce the abnormal experiences; these were avoidance, predictability, mental preparation, talking through, interaction and

confrontation. These early findings are significant because they support the notion that abnormal sensory experiences, like sensory defensiveness, can result in stress, anxiety, maladaptive behavioral patterns and require specialized coping techniques to overcome (Kinnealey, Oliver & Wilbarger, 1995). In a more recent study, Landon, Shepard & Lodhia (2016), studied adults with autism spectrum disorder (ASD), and found that loud piercing noises, anxiety, and coping are major components of noise sensitivity. This further supports the findings of Kinnealey, Oliver & Wilbarger's (1995) research. This study also highlights the need for additional studies to determine if sensory responses for both typically functioning adults and atypical adults cause specific physiological responses in all adult populations.

A study completed by Horder, Wilson, Mendez & Murphy (2014), found that neurotypical adults with higher levels of anxiety symptoms and ASD traits were correlated with higher sensory processing abnormalities. These findings support the notion that typically functioning adults with SOR can have abnormal sensory experiences that are similar to populations that have a clinical diagnosis. Furthermore, Singleton, Ashwin & Brosnan (2014), found that neurotypical adults that have a higher number of autistic traits experience a greater difference in physiological responses to nonsocial stimuli when compared with social stimuli. These findings suggest that different sensory experiences, such as SOR, do have an effect on physiological responses and the potential to be objectively measured with physiological measures.

Champagne & Stromberg (2004) effectively utilized a number of sensory approaches to improve the functioning of adults with psychiatric conditions in an inpatient mental health setting. This study supports the use and potential benefits of similar approaches across different populations and age groups. With the current state of literature, it is clear that there needs to be

more assessments and objective measures for typically functioning adults that have difficulties with sensory experiences. Furthermore, research is absent that concurrently examines parasympathetic and sympathetic physiological responses in adults.

### **Impact on Occupations**

Sensory over responsivity is the most common sensory modulation problem (Abernethy, 2010). In most adults, SOR begins in childhood but if not recognized or treated the child will not grow out of it and SOR will remain a problem (Wilbarger, 1995). As an one gets older, SOR often leads to more complications (Kinnealey & Koenig, 2004). This disorder “can have a detrimental effect on quality of life experiences. It can have an impact on functional abilities, behavior, emotions and mental health” (Abernethy, 2010, p. 210). Those with SOR may have negative experiences with everyday activities including self-care tasks such as: bathing, dressing, grooming and eating. As a result of this flight or fight response, individuals may have feelings of anxiety distractibility, restlessness, anger, fear, and emotional distress while performing daily tasks (Parham & Mailloux, 2015). People may develop coping strategies to manage their SOR that include; voidance, counteraction and confrontation, these strategies influence one’s choice of activity which negatively impacts their quality of life experiences (Abernethy, 2010).

The American Occupational Therapy Association (n.d.) defines an occupational therapist as a practitioner who “helps people across the lifespan to do the things they want and need to do through the therapeutic use of daily activities” (p. 2). Occupational therapists are best suited to treat the effects of SOR by identifying the characteristics of an individual's personal over responsiveness and help him or her find solutions to cope with the condition. Considering that SOR is the most common sensory modulation disorder it is important for occupational therapists

to find solutions to the activities and roles it impacts; thus, further research is necessary to improve assessment and treatment of individuals with SOR.

### **Statement of Purpose**

The concepts of sensory integration and sensory modulation are well established in the field of occupational therapy, as are the needs for interventions for individuals who experience difficulties in either of these two categories (Ayres, 1963; Miller, Milberger, & McIntosh, 2004). This literature review has established that there is a population of typically functioning adults that have high SOR experiences that are similar to those with conditions such as ASD, SPD or SMD. However, these individuals are unable to validate their experience because they do not fulfill the diagnostic criteria for any existing conditions in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition or International Statistical Classification of Diseases and Related Health Problems, 10th Edition. As a result, these typically functioning adults that report high SOR may be unable to obtain services needed to support their participation in meaningful occupations. The purpose of this study is to examine physiological responses to various sensations in people who report as high SOR. If a difference in physiological responses is found, this study will help to legitimize the experiences of these adults and assist practitioners in properly addressing them.

### **Research Question**

Researchers seek to determine if individuals who self-report as high SOR have different physiological responses to sensory stimuli. Due to what is known from previous studies and current literature, it is important to explore this question since SOR has negative effects on the daily lives of many adults. This study will gauge physiological responses using EDR measurements in response to auditory, tactile and olfactory stimuli. The physiological responses

of individuals who self-report as high SOR will be compared to those who self-report as low SOR.

### **Hypothesis**

Individuals who self-report as high SOR will have increased physiological responses to various sensory (auditory, olfactory, and tactile) stimuli, as measured by EDR, when compared to individuals who self-report as low in SOR.

## Theoretical Framework

This study uses the theory of sensory integration developed by Jean Ayres to guide the research question and methods. Sensory integration (SI) directly relates to an individual's ability to process and respond to sensory stimuli, which is the main premise of this research study. This section will describe key concepts of sensory integration and how it relates to this research study on physiological responses in adults who self-report as high or low in SOR.

Sensory integration is the process the body uses to organize sensory information from one's own body as well as from the environment. There are three levels of sensation that give individual's information about the world around them (Ayres, 2005). The first level of sensation gives the body information about what is coming from outside the body and include sight, sound, taste, smell and touch. The second level, which includes the vestibular and proprioceptive senses, tells the body where is in space and how it is moving. The third level is the visceral sense, which gives individuals a sense of what is going on inside the body. The brain is responsible for sorting, locating and ordering all of the sensory information that it receives so that the body can respond appropriately. When the brain successfully organizes and integrates the sensations that it is perceiving, the individual is able to use that information to form behaviors, perceptions and learning (Ayres, 2005). However, if there is dysfunction and disorganization experienced during the sensory integration process it can lead to difficulties in an individual's daily life, which can cause a number of challenges.

There are four main SI categories, adapted from Ayres' original work, that lead to successful processing and adaptive responses to stimuli. The components that encompass an individual's sensory integration are praxis, postural-ocular-vestibular control, discrimination and modulation (Ayres, 2005).

Praxis refers to the brain's ability to organize, plan and execute motor movements. There are five main aspects that contribute to praxis and motor movement: smooth muscle control, postural reactions, patterns of movement coordinated by the central nervous system (CNS), specific motor skills and motor planning. Smooth muscle control is important for providing jerky free movements, and postural reactions contribute to the ability to change position in space without losing balance. CNS movement patterns are pre-programmed, like walking and creeping, and typically do not require thinking to execute. Motor skills are movements that one had to initially learn, but can now be initiated spontaneously as long as the situation is familiar such as playing a piano or riding a bicycle. Lastly, motor planning is a complex form of functioning that requires conscious attention with sensory integration throughout the brain--the brain tells the body what to do and information from our senses enables to brain to do the telling (Ayres, 2005). Dysfunction in any of these five main areas affect praxis and ultimately the ability for an individual to organize sensations from the world in order move in an efficient or typical fashion.

The integration of the postural-ocular-vestibular systems allows an individual to form a perception of their body in relationship to the spatial surround. The vestibular system responds to the position of the head in relation to gravity and every change in head position stimulates vestibular receptors. So, when an individual moves in space by walking jumping, swinging or going upside down the body is receiving vestibular input. Of all the sense organs, the vestibular receptors are the most sensitive. The receptors process vestibular input along with information from muscles, joints, skin, auditory and visual receptors (Ayres, 2005).

When an individual has under reactive vestibular responses to stimuli they often have poor bilateral integration. Bilateral integration and sequencing (BIS), which is related to postural-ocular-vestibular control, allows the brain and body to coordinate the left and right sides



of the body, which is important for activities like riding a bike, playing sports, driving and playing an instrument. If an individual has an underactive vestibular system, it can interfere with specialization. Specialization happens when each side of the body and brain learns different functions. However, if specialization does not occur then the individual is less efficient and needs both sides of the brain and both hands to do tasks that typically only one side does like developing language and writing, respectively.

Discrimination is the ability to make fine distinctions in sensory information. Among the seven senses, sensory information that requires constant discrimination include tactile, visual (form and space), and auditory sensations. This function is important so that individuals can accurately perceive their surroundings and produce appropriate and functional behaviors. The body's use of discrimination works in partnership with sensory modulation for proper emotional regulation, social skills, and fine motor and gross motor skill development.

Sensory modulation is the brain's ability to regulate sensory input in order to meet environmental demands and achieve a range of optimal performance. Optimal performance is maintained when a person is neither over stimulated nor under-aroused from their surrounding environment and is able to successfully and efficiently engage in an activity. When an individual is unable to grade their behavioral responses to the situational demand, it is known as sensory modulation disorder (SMD). Miller et al. (2007) describe three subtypes within SMD; sensory over-responsivity (SOR), sensory under-responsiveness (SUR), and sensory seeking. Those with SOR have an over exaggerated response to harmless stimuli. Individuals with SUR, termed "low SOR" for the purposes of this study, have little to no response to sensory input and will appear apathetic to the surrounding environment. Those who are sensory seeking crave large amounts of sensory input from their surroundings.

Individuals with SOR often have negative experiences with daily life activities and describe them as irritating, overwhelming, disorganizing, and distracting (Kinnealey, Koenig & Smith, 2011). Avoidance or withdrawal from the stimuli may be developed as a coping strategy and feelings of isolation may arise. This influences one's ability to participate in meaningful activities and negatively impacts their quality of life. In this study, adults who self-report as SOR often have an exaggerated response to stimuli which will be reflected in their physiological measurements.

Sensory integration theory defines the parameters of the concepts this study measured. Sensory modulation was originally defined by Ayers in 1979. After these initial findings Ayers did not research further into the topic, this left room for other theorists to underline different mechanisms of sensory modulation disorders. Dunn (1999) theorized a high or low threshold of sensory responsiveness. Those with a neurological high threshold have low sensitivity and are often sensory seeking. Individuals in the low threshold range have high sensory sensitivities and require a small amount of stimuli to provoke a response. Shelly Lane further defined sensory modulation and proposed a limbic theory behind sensory modulation (Lane & Schaaf, 2010). She found sensory modulation to result in exaggerated sympathetic nervous system activity and reduced or unorganized parasympathetic activity.

### **Ethical and Legal Considerations**

This study was a continuation from Dominican University occupational therapy students who conducted research in 2016-2017. A modified formal proposal of the research study was sent to the Internal Review Board for the Protection of Human Subjects (IRBPHS) at Dominican University of California (DUC) prior to contact with participants. Dominican University of California gave researchers consent to use room 304 of Meadowlands as a testing room. Physiological testing equipment and procedures were obtained from a previous study by the faculty advisor.

The researchers complied with The American Occupational Therapy Association (AOTA) Code of Ethics (2015) throughout the study. All principles of the Code of Ethics were maintained and acknowledged. To protect participants, only harmless sensations were applied and a safe and secure testing location was used. Additionally, participants were made aware that they had the right to discontinue the study at any time. Accommodations for disabilities were acknowledged and addressed. Participants were thoroughly instructed on all procedures and conditions prior to testing. Confidentiality was maintained by storing all documentation in a secure location that was only accessible to the researchers and faculty advisor. All documentation will be destroyed one year after the study concludes. The researchers upheld commitments made with participants and provided equal and professional treatment.

## **Methodology**

### **Design**

Physiological responses to sensation were studied using a quasi-experimental design. The subjects were tested physiologically, utilizing the Sensory Challenge Protocol, to quantify responses to sensations. Scores from the AASP were assessed after the data collection to determine if the subject's scores were high or low on the sensory defensiveness composite scale. Based on their scores participants were then separated into the corresponding high SOR or low SOR group. The dependent variable was the individual's physiological response to various sensory stimuli. The independent variables, sensory stimuli, were presented during the physiologic testing. The study was approved by Dominican University of California IRB # 10530.

### **Participants**

The target population for this study were typical adults. For the purposes of this study, typical adults were defined as individuals without a sensory processing disorder diagnosis. Inclusion criteria for participation were typical, English speaking adults that were 18-64 years old. Exclusion criteria include individuals with a history of a developmental or neurological impairment such as an autism spectrum disorder, head injury, seizure disorder, taking medication that alters physiological responses, or allergies to adhesive tape. Participants were recruited with the use of flyers posted throughout Marin County, by word of mouth, and on social media. Interested participants contacted the researchers by phone or email. Researchers called prospective participants for an intake phone screening prior to beginning the study. Those that fit the criteria were invited to participate and given a welcome packet containing a consent form, a demographic questionnaire, the AASP, and SRQ. See Table 1 for further information on participant demographics.

## Data Collection Procedures

### Measures.

**Telephone Screening.** Data collection procedures began with a preliminary telephone screening. This six-question screening, as seen in Table 1, was used to ensure that participants were interested in partaking in the study and to determine if they met the eligibility requirements to participate.

Table 1

#### *Phone Intake Procedure*

Questions
1) Do you think you have sensory defensiveness? Would you say... 2) Do you think you avoid sensations others seem to enjoy or ignore 3) I love all kinds of sensations 4) I don't notice sensation much 5) I seek out intense sensations 6) Can you give examples? Probe for touch, sound, and smell
Answers
Extremely Untrue Quite Untrue Slightly Untrue Neither True nor False Slightly True Quite True Extremely True

**Demographic Questionnaire.** A basic demographic questionnaire was created for the purposes of this study. Information requested was date of birth, gender, ethnicity, highest level of education completed, current chronic medical conditions, and medications.

**The Adolescent/Adult Sensory Profile.** The Adolescent/Adult Sensory Profile (AASP), based on Dunn's (1997) Model of Sensory Processing, and developed by Brown and Dunn, was used as a classifying tool for this study. The AASP is a 60 item, self-reported, behavioral

assessment that gives individuals specific information on their own sensory processing. The AASP yields four scores in the areas of sensory sensitivity, sensation avoiding, low registration, and sensation seeking. An individual who scores high in “sensory sensitivity” is characterized as easily distractible and likely experiences discomfort with sensation and difficulties with screening stimuli. An individual who scores high in “sensation avoiding” often avoids sensory stimuli because “he or she perceives even low-intensity stimuli and easily is inundated or overwhelmed by the input” (Brown, Tollefson, Dunn, Cromwell, & Filion, 200, p. 76).

Reliability and validity of the AASP is established. For reliability, the values of alpha for the various age groups and quadrant scores ranged from .639 to .775, with 0 representing no consistency and 1 representing perfect consistency (Pearson Education, 2008). Validity for the AASP was established through the use of an expert panel and data collected for pilot studies. Convergent validity was established through a study which compared scores of the AASP to those of the NYLS Adult Temperament Questionnaire and through comparisons with skin conductance responses (Pearson Education, 2008).

***Sensory Response Questionnaire.*** The Sensory Response Questionnaire (SRQ) is a measure constructed by Dr. Julia L. Wilbarger, OTR/L. The questionnaire contains 56 statements on taste, smell, movement, auditory, visual, and touch processing and yields scores of exhibited behaviors based on a Likert scale of 1-7, from “Extremely Untrue” to “Extremely True”. The SRQ was adapted and derived from established sensory questionnaires: (1) *Sensory Profile*, (2) *ADULT-SI*, and (3) *Temperament and Personality* (Dunn, 1999; Kinnealey & Oliver, 2002; Rothbart, Ahadi, & Evans, 2000). The SRQ was successfully utilized as the main outcome measure in a past study by Wilbarger and Cook (2002), however, validity and reliability of the SRQ have not yet been established.

***Electrodermal Response (EDR)*** The Sensory Challenge Protocol was used to measure the subject's physiological responses to sensation. EDR was used to quantify an individual's response to particular stimuli and to measure sympathetic nervous system activity (McIntosh et al., 1999).

**Procedures.** Interested participants were contacted by a researcher and were asked questions as part of a telephone screening. Participants who met the requirements of being either high SOR or low SOR were invited to participate in the study. If the invitation was accepted, the participant was sent a welcome packet which included a welcome letter with instructions, a consent form, a demographic questionnaire, the AASP and SRQ. During a scheduled appointment, participants met the researchers in Meadowlands Room 304 at Dominican University of California for testing. Each subject was tested with one researcher administering the stimuli and a second researcher assisting from an observation room. Consent was obtained prior to testing for participation in the study.

***Sensory Challenge Protocol.***

Once participants were oriented to the study and connected to the sensors, the researcher left the testing room and a neutral screensaver appeared on the monitor. The E-Prime and AcKnowledge programs were started, and data collection began in order to establish a baseline. After three minutes of collecting baseline data, participants were exposed to three different sensory modalities: auditory, tactile, and olfactory. Each sensory stimuli varied in intensity and pleasantness of sensation. The following procedures were adapted and expanded from research by Baranek et al., (2002), McIntosh, Miller and Shyu (1999), and Wilbarger, Wagner and Riccioli-Wilcox (2011) in preparation for this study.

To record the electrodermal responses, small sensors with conducting gel were placed on the third and fourth digit of the non-dominant hand. Each stimulus was presented eight times for 2-4 seconds each. There was a 10-25 second interval between each stimulus and a period of 1-3 minutes between each different sensory category. After the application of each stimuli, participants were asked to rate their experience of pleasantness on a nine-point Likert-type scale.

***Auditory.*** Participants listened to pure tones and real sounds from everyday life. Sounds were presented at 75 db through high quality sound attenuating headphones. The real sounds, came from a collection of International Affective Digital Sounds (IADS) and consisted of a baby crying, crickets, and a lawn mower.

***Tactile.*** The tactile stimuli included three different texture: a feather, a cotton puff and a firm brush presented on the left cheek. The stimuli were presented in a three-inch stroke with approximately two ounces of pressure. The stroke began below the earlobe, went along the jawline, and ended at the chin.

***Olfactory.*** Three milliliters of each concentrated scent were placed in a vial with approximately a ½ inch opening. Stimuli included orange extract, camphor extract, and butyric acid. The researcher presented each vial under the participant's nose. Participants were instructed to breathe in fully.

***Stimulus Presentation.*** The E-prime program (version 2) controlled all stimuli presentations through a PC computer. Stimulus presentation procedures were adapted and expanded from research by McIntosh and colleagues (1999). The categories of stimuli were presented in the same sequence for each participant and followed the order: pure tones, real sounds, tactile, and olfactory. For tones, real sounds, and tactile modalities, each stimulus within the sensory category was presented in a random order. However, for olfactory stimuli, the order



was always presented in the same way: orange extract, camphor extract, and butyric acid.

Participants were offered a five-minute break after the auditory stimuli portion was complete; if a subject took the break, they would need to take a one-minute baseline period before resuming.

### **Data Analysis Plan**

First, demographics were analyzed using descriptive statistics. A comparison of groups, was completed using self-report measures from the AASP, using t-tests. Additionally, researchers analyzed the correlation between the self-report scores and EDR.

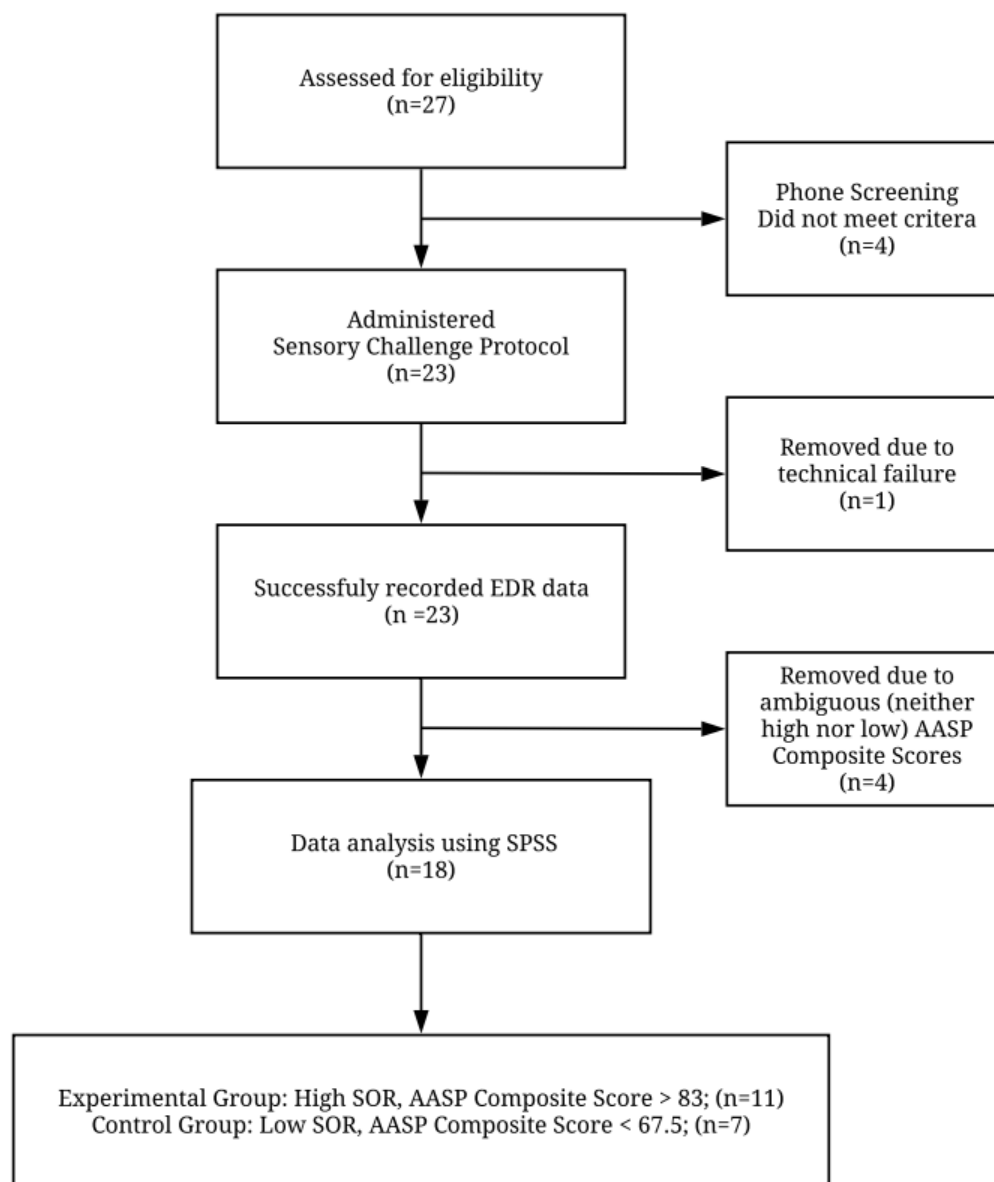
Electrodermal response (EDR) was measured in microsiemens. EDR magnitude was determined using the first trial of each stimulus presentation. EDR measures reported are the natural log transformation of the difference between the lowest point of the peak to highest point of the peak (P-P) within the first eight seconds after exposure to the stimuli. The EDR data was transformed to a natural log in order to normalize the distribution of EDR data since they were positively skewed, a common occurrence with such data. The relationship between EDR response and the self-report measures were compared with Pearson's Product Moment Correlations. The relationship of EDR responses between each of the stimuli were compared with Pearson's Product Moment.

Data was collected using AcKnowledge software and transferred into SPSS (v.20) software for analysis. The groups were compared for the magnitude of response using an Independent Samples *t*-test. A significance level of  $p = .05$  will be set.

## Results

The study collected data from 27 participants that self-reported as either high or low in SOR. The 27 participants were screened before participating in the study. Figure 1 shows the flow of inclusion in the study and categorization into groups. As displayed in Figure 1, four participants did not meet screening criteria, one was removed due to technical failure, and four were eliminated due to ambiguous (neither high nor low) AASP scores. The sensory defensiveness composite, made by summing “sensory sensitivity” and “sensation avoiding” scores from the AASP, was used to determine if an individual were categorized into high or low SOR groups. Participants who scored  $> 83$  in the sensory defensiveness composite were placed in the experimental group (high SOR,  $n = 11$ ). Participants who scored  $< 67.5$  in the sensory defensiveness composite (low SOR,  $n = 7$ ) were placed in the control group. The final data analysis was completed on the remaining 18 participants.

Figure 1

*Group Inclusions and Exclusions*

*Note. All subjects were screened and then tested using the Sensory Challenge Protocol. Group determination was completed last.*

The demographics of the remaining 18 participants included in the study are displayed in Table 2. Demographics obtained include gender, age, and ethnicity. Seven females and four males made up the high SOR group ( $n = 11$ ), while six females and one male made up the low SOR group ( $n = 7$ ). Ages ranged from 18-64, with a mean age of 28 in the low SOR group, and

34 in the high SOR group. The groups did not differ in age ( $t_{(16)} = .98, p > .05$ ). Fifteen participants identified as white, one participant identified as Asian, and two participants identified as other.

Table 2

*Participant Demographics*

	Experimental (n = 11)	Control (n = 7)
<u>Gender</u>		
Female	7	6
Male	4	1
<u>Age</u>		
18-29	5	6
30-49	4	0
50-64	2	1
<u>Ethnicity</u>		
White	9	6
Black	0	0
Asian	0	1
Other	2	0

The AASP and the SRQ were used as measures to categorize participants into high or low SOR groups; a series of t-tests were used to compare the results of the self-report measures. As seen in Table 3, the high SOR group had significantly higher scores on both measures, and the SD of the composite of the AASP. The scores from the AASP, the SD composite and the SRQ were strongly and significantly correlated.

Table 3

*Comparison of Adult and Adolescent Sensory Profile (AASP) and Sensory Response Questionnaire (SRQ) Data*

	AASP Sensory Defensiveness Composite		AASP Total Scores		SRQ Total Scores	
	Mean	SD	Mean	SD	Mean	SD
High SOR (n=11)	104.45*	9.18	190.00*	14.21	263.27*	38.92
Low SOR (n=7)	61.71	5.09	142.00	19.71	153.14	26.15

*Note.* \* Groups differ significantly  $p < .05$ . SOR = Sensory over responsiveness.

Table 4 shows the correlation between the AASP total, sensory defensiveness composite score, and SRQ total. All three correlations are significant at the 0.01 level.

Table 4

*Correlations between the Adult/Adolescent Sensory Profile (AASP), Sensory Response Questionnaire (SRQ), and Sensory Defensiveness Composite Score*

	AASP Total	Sensory Defensiveness Composite
SRQ Total	.824*	.941*
AASP Total		.920*

*Note.* \*Correlation is significant at the 0.01 level (2-tailed)

### **Electrodermal Responses**

The mean EDR of the high SOR group was compared to that of the low SOR group using a series of independent t-tests to determine if there were differences between groups. Table 5 reports the means and standard deviations of the natural log transformed, peak to peak (P-P) EDR data for both groups. Natural logs were used to normalize the distribution of the EDR data. Table 5 also reports the results of the t-test and the effects sizes comparing the mean responses between groups. Figure 2 shows the same comparison of the participants' peak to peak (P-P)

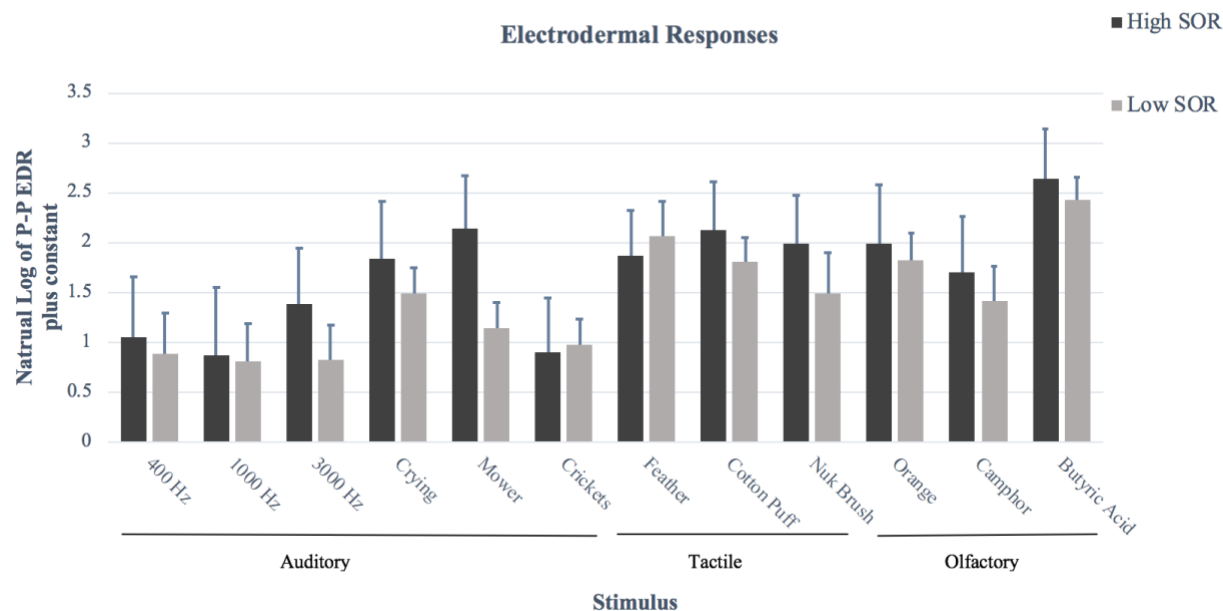
EDR results for the high and low SOR groups as in Table 5, however for ease of interpretation a constant of two was added to the raw values. The participants in the high SOR group had larger mean EDR than participants in the low SOR group for all sensory stimuli except Crickets and Feather. However, as illustrated by Table 5, the differences between groups were not significant for any stimuli. One stimuli trended towards significance Mower with a p-value of .084 and a large effect size of Cohen's  $d = .866$ . EDR responses to two other stimuli had moderate effect sizes including 3000 Hz Cohen's  $d = .428$  and Nuk Brush Cohen's  $d = .378$ .

Table 5

*Electrodermal Response Data*

Sensory Measures	Experimental Group (n = 11)		Control Group (n = 7)		df	t	p	Cohen's d
	M	SD	M	SD				
400 Hz	-.945	1.36	-1.12	1.60	16	-.256	.801	0.118
1000 Hz	-1.13	1.19	-1.20	1.81	15	-.095	.926	0.0496
3000 Hz	-.614	1.14	-1.18	1.48	16	-.918	.372	0.428
Crying	-.161	.876	-.519	1.50	16	-.642	.530	0.294
Mower	.136	.818	-.867	1.42	15	-1.85	.084	0.866
Crickets	-1.10	1.08	-1.03	1.48	16	.122	.904	0.054
Feather	-.136	1.14	.059	1.20	16	.347	.733	0.167
Cotton Puff	.118	.784	-.20	1.28	15	-.620	.545	0.299
Nuk Brush	-.015	1.35	-.51	1.27	16	-.772	.451	0.378
Orange	-.013	.892	-.176	1.56	16	-.284	.780	0.128
Camphor	-.299	1.13	-.593	1.48	15	-.465	.649	0.223
Butyric Acid	.641	.741	.428	1.33	16	-.438	.667	0.198

Figure 2

*Electrodermal Responses***EDR and Self-Report Correlations**

The relationship between scores on the self-report measures and EDR were analyzed to determine if there was relationship between the two measures. No significant or meaningful correlations were found between physiological responses and self-report measures.

**Inter-Stimuli Correlations**

Moderate to strong positive inter-stimuli correlations were found between all stimuli, except for butyric acid. The correlations, ranging from .47-.93, were all significant. This pattern indicates that each individual participants' EDR is similar in intensity across all stimuli. In other words, the way an individual responds to one stimulus predicts how they will respond to the other stimuli.



## Discussion

The aim of this study was to compare the physiological responses to sensory stimuli of individuals who self-report as high SOR to those who self-report as low SOR. Researchers hypothesized that those who experience high SOR would exhibit higher EDR to sensory stimuli than participants with low SOR. The hypothesis was not confirmed. EDR did not differ significantly between the high and low SOR groups. However, an examination of the differences in effect sizes across stimuli reveals some interesting findings. Additional findings included a lack of correlation between EDR and self-report measures, and strong intercorrelations between stimuli across stimuli. Each of these findings will be discussed below.

As predicted, individuals with high SOR had higher EDR to all sensory stimuli except the crickets and feather, however none of these differences were statistically significant. Although, differences were not found in the mean responses between groups, there are some interesting patterns in the effect sizes. Effect size represents the amount of influence that the independent variable has on the dependent variable, in this case, how SOR status influences EDR responses. The stimuli with the largest effect sizes included the mower, 3000 Hz, and Nuk Brush. These stimuli could be predicted to yield higher reactions in people with high SOR--each of these stimuli represents common complaints in daily life. The lawn mower is an intense, alerting sound, similar to a blender or vacuum. These noises are commonly reported as bothersome and offensive by individuals with high SOR. The Nuk Brush provides a scratchy tactile sensation, that is alerting and uncomfortable such as scratchy clothing. The 3000 Hz tone represents the primary frequency of the human voice, a sound that is alerting for purposes of communication. Some individuals with high SOR report challenges with some people's voices or tones of voice (Kinnealey, Oliver and Wilbarger, 1995). A heightened response to these stimuli may be

attributed to the potential association with danger signals from the environment. Individuals with high SOR may experience negative reactions to stimuli that signal “danger” or demand “alerting”. These responses serve as a biological function for survival. People with SOR may be more sensitive to these survival signals. Participants with high SOR would be expected have larger EDR to potential danger or alerting signals in stimuli as opposed to neutral or pleasant stimuli. In fact, the stimuli that can be categorized as neutral or pleasant were found to have very low effect sizes. For example, the effect size of the sound of crickets and the smell of orange, stimuli generally appreciated as pleasant, were very small. Although the findings were non-significant, the trends found in this study support that typical adults, with self-reported high SOR, have physiological responses that can help validate their experiences.

An additional finding was that EDR did not correlate with self-report scores. This finding may be attributed to a number of reasons. Despite their self-report identification, individuals may actually have a higher or lower tolerance to stimuli due to habituation, differences in experience, or not noticing their responses in daily life. With habituation, individuals may have a diminished response to stimuli that they frequently experience. Furthermore, due to life experiences, individuals may respond differently than the expected response. For example, the feather was expected to be an alerting, ticklish sensation that would elicit a higher EDR than the data demonstrated. This could be due to the fact that people associate feathers as soft and comforting thus creating a calming response despite its light-touch nature. Finally, individuals may not report responses to subtle stimuli that they interact with in daily life. Speculatively, when individuals are under stress or experiencing fatigue, established coping mechanisms or habituation may break down, possibly resulting in their responses to these every day stimuli to be heightened and reactions may be stronger.

The second additional finding was strong correlations between all stimuli responses for an individual, which demonstrates that each individual has a generalized response style. McIntosh, et al, (1999) found a similar pattern of EDR responses with children with SMD. If a person responds higher to one stimulus, they will respond higher to other stimuli or vice-versa. EDR data was found to be individualized to the person and their pattern of responsivity was found to carry over to all stimuli regardless of their self-report data. The generalized response pattern might explain the lack of correlation between EDR and self-report. On the self-report measures, adults generally report some types or modalities of sensation as more bothersome. Self-reports of SOR vary across sensory modalities while the EDR responses are more consistent across those same modalities. If researchers want to determine a person's response pattern using the Sensory Challenge Protocol, they may need to only use a few key stimuli.

## **Conclusion and Other Considerations**

In conclusion, our results did not support our hypothesis that EDR for those that self-report as high SOR would differ significantly than those with low SOR. The differences did trend in the expected manner for all stimuli, except for crickets and the feather, indicating that greater power may have yielded significant differences. However, there were additional findings that the results unveiled. Although self-reported SOR did not correlate to EDR, it informs us that coping, habituation, and life experience may have shaped the way that individuals respond to or are aware of the stimuli in their day-to-day environment. Lastly, the second additional finding highlighted that each individual has a generalized response pattern in EDR regardless of specific sensory modality reports. Collectively, these findings add value to the field of occupational therapy and enhance practice.

## **Clinical Implications**

The results have four main implications for occupational therapy practice. First, typical adults that identify sensitivity in one sensory area will likely be at risk for sensitivities across all stimuli. A second finding is that EDR is a valuable measure to justify the experiences of typical adults with SOR for practitioners, but is not sensitive enough for clinical/diagnostic purposes. Results also demonstrated the AASP and SRQ used in conjunction offer clinicians with a powerful tool to determine participants' low/high SOR status for future studies. Finally, findings support that that occupational therapists continue to be best suited to work with this population through holistic evaluation, task analysis on education and appropriate coping mechanisms.

In this study, individuals displayed a generalized response style across all sensations. For typical adults who identify sensitivity in one sensory area, they will likely be at risk for sensitivities across all stimuli. Sensory modulation adapts regulation of sensory input. When

there is a breakdown, as is common with stress and fatigue, individuals will have a higher response to stimuli in the environment that would normally not affect them. Therefore, typical adults who self-report as both high and low SOR may be more vulnerable than reported and occupational therapists can be instrumental in educating them on recognizable signs/symptoms and can offer coping strategies.

While EDR is a valuable measure of physiological responses, it is not sensitive enough to be used for clinical and diagnostic purposes. The data found in this study can help justify the reactions to sensation of an individual with high SOR and supply practitioners with evidence to accommodate these sensory experiences. EDR can be used as a tool to provide further information regarding an individual's physiological responses to sensation, but should not be used as a means for diagnoses.

When used in conjunction, the AASP and SRQ can be used to distinguish between adults that are high or low SOR. Using these questionnaires as determinants, the differences between groups was found to be significant ( $p < .001$ ). In regards to olfactory sensitivity, the AASP only has two questions, while the SRQ incorporates six. Therefore, inclusion of the SRQ is helpful in capturing information about the participant's olfactory sensitivities, which were targeted in this study. The high correlations found between scores of the AASP and the SRQ help to validate the use of the SRQ supporting the use of these methods to determine high and low SOR status for future studies.

These findings do support the notion that occupational therapists continue to be uniquely suited to work with individuals with high SOR through holistic evaluation, task analysis and education on appropriate coping strategies. Clinicians should continue to search for an objective measure that can be used to further validate the experience of typical adults who report as SOR.

## **Limitations and Recommendations**

The major limitation of this study was the small sample used in both the high and low SOR groups. The power of a study depends on sample size; therefore, a larger number of participants is needed for future studies in order to detect significant group differences and correlations. Additionally, the sample lacked diversity in gender, age, and ethnicity. To make the results more generalizable across populations, participants should be recruited from a wider pool outside of Marin County. The participants of the study were only typical adults, with no cognitive or mental diagnoses, and therefore cannot be generalized to the larger population. This study captured observable trends validating the use of EDR as an objective measure, however, did not capture significant group differences. Therefore, further research is required using other physiological measures such as blood pressure, heart rate variability, and electroencephalogram waves. Finally, the group determination criteria could be stricter to enhance the homogeneity of high and low SOR data.

## **Conclusion**

As hypothesized, this study found that individuals who self-report as high SOR had higher EDR to sensory stimuli than those with low SOR to all stimuli tested except the crickets and feather. However, these differences were not significant, which may be attributed to the small sample size. As researchers predicted, stimuli with the largest effect sizes that trended towards significance included the mower, 3000 Hz, and Nuk Brush. The mower and Nuk Brush stimuli are bothersome sensations and results showed expected responses for the high SOR group. Stimuli like the feather demonstrated an unexpected response pattern, which may be related to habituation, life experiences, and lack of awareness.

Through the use of the Sensory Challenge Protocol, researchers found that participants display a unique response style across sensations, regardless of group status. This suggests that future studies can obtain information about a participant's sensory response style through the testing of only a few sensations.

EDR may not be sensitive enough to determine a person's SOR status and additional physiological measures, such as EKG and heart rate variability, may aid in providing more robust results. It would be beneficial to further explore the physiological responses of neurotypical adults that report as high SOR to determine the feasibility of using EDR as an objective measure.

This study is important for the field of occupational therapy because abnormal sensory responses are common occurrences in populations of all ages and current OT interventions are only currently tailored for those with diagnoses. This evidence may expand the use of and provide the needed rationale for OT to provide intervention for neurotypical adults with SOR, allowing for greater occupational participation for these individuals.

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