5-2020

Interrelationship between Sensory Modulation, Altered Interoceptive Awareness, and Anxiety and Impacts on Quality of Life

Sara Laughter *Dominican University of California*

Vanessa Mitchell *Dominican University of California*

Natalie Nguyen *Dominican University of California*

Christine Kim *Dominican University of California*

https://doi.org/10.33015/dominican.edu/2020.OT.08

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.

Sara Laughter, Vanessa Mitchell, Natalie Nguyen, and Christine Kim
Candidate

Julia Wilbarger, PhD, OTR/L
Program Chair

Julia Wilbarger, PhD, OTR/L
First Reader

Interrelationship between Sensory Modulation, Altered Interoceptive Awareness, and Anxiety and Impacts on Quality of Life

by

Nhu Nguyen, Vanessa Mitchell, Sara Laughter, & Christine Kim

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

Dominican University of CA

San Rafael, CA

December 2019

Abstract

OBJECTIVE: The negative impacts of sensory modulation disorder (SMD), anxiety, and altered interoceptive awareness (AIA) on daily occupations reinforced the need for the study of the relationship between sensory modulation, anxiety, and interoception in typical adults. Understanding the relationship between the three constructs is the first step in the ultimate goal of developing effective intervention and treatment measures.

METHODS: This cross-sectional, exploratory study analyzed the relationship between scores on four self-report measures in an online survey: State Trait Anxiety Inventory (STAI), 36-Item Short Form Health Survey (SF-36), Sensory Responsiveness Questionnaire (SRQ), and Multidimensional Assessment of Interoceptive Awareness, Version 2 (MAIA-2). Participants were recruited via snowballing and a convenience sample of typical adults. Data was analyzed with Statistical Package for Social Sciences (SPSS) (version 22).

RESULTS: Data from 186 respondents showed moderately positive significant correlations between variables: (1) MAIA-2 and SRQ sum; (2) MAIA-2 and STAI state anxiety total; (3) MAIA-2 total and STAI trait anxiety total; (4) SRQ sum and STAI state anxiety total; and (5) STAI trait total and SRQ sum.

CONCLUSION: This correlational study shines light on the distinct interrelationship between SMD, AIA, and anxiety. Results indicate a significant interrelationship between SMD, AIA, and anxiety. Findings indicate that there is a relationship between co-occurring constructs: SMD and AIA; AIA and anxiety; SMD and anxiety. However, further research needs to be done to determine directionality.

Acknowledgements

The success of this project was achieved with guidance, supervision, and assistance from Julia Wilbarger, OTR/L, PhD. We are extremely privileged to have had her support all along the completion of this project. We would like to thank all of our participants without whom this research would not have been possible. We would like to thank our families and friends for supporting us throughout this process and Michael Pujals, our wonderful Dominican librarian for helping us insure that this was in fact the first study of its kind.

Table of Contents

List of Tables

List of Figures

Section I: Project Proposal

Introduction

At any given point throughout the day, the human body responds to stimuli from the body internally as well as externally from the environment. The human body has eight sensory systems: visual, auditory, tactile, gustatory, olfactory, vestibular, proprioception, and interoception. Sensory input from these systems is essential for human development because it shapes brain structure, influences function, and produces adaptive responses (Ahn, Miller, Milberger, & McIntosh, 2004). According to Ayres, the body integrates sensory input from the environment to create appropriate adaptive responses (Ayres, 1979). Disruptions in the process of sensory integration (SI) can significantly impact a person's life. The most commonly identified disruption is sensory modulation disorder (SMD), which is the inability to appropriately grade and valence responses to sensation from the environment (Wilbarger & Stackhouse, 1998).

The last decade has brought an increased awareness of the role that sensory processing disorders (SPD) play in adults with a range of mental health and developmental needs. Deficits in sensory processing have been clearly delineated in adults with mental health issues (Champagne & Koomar, 2011), trauma (Warner, Koomar, & Cook, 2013), and autism spectrum disorder (ASD) (Abernethy, 2010). Currently, attention is focused not only on responses to external stimuli, but also on the perception and response to stimuli that is internally generated, or interoception. Distortions in interoception have been associated with anxiety disorders and most recently with autism spectrum disorders (Ainley & Tsakiris, 2013; Dunn, Stefanovitch, Evans, Oliver, Hawkins, & Dalgleish, 2010; Garfinkel, Tiley, O'Keeffe, Harrison, Seth, & Critchley, 2016; Pile, et al., 2018; Pollatos et al., 2007).

Given the co-occurrence of SMD, altered interoceptive awareness (AIA), and mental health issues, the study examined the correlation between SMD, AIA, and anxiety in the typical adult population. The purpose of this study was to identify and begin to understand correlations between the impacts of SMD, anxiety disorders, and AIA on quality of life. Understanding the relationship between the three constructs is the first step in developing effective intervention and treatment measures.

Background and Review of the Literature

Limited literature exists between these pairs of relationships: (1) SMD and anxiety, (2) SMD and AIA, and (3) AIA and anxiety. The inter-relationship between SMD, AIA, and anxiety has not been found in any literature. Defining these three concepts first as separate entities will provide a platform for understanding correlations between them.

Sensory Integration (SI)

The SI theory was created by Jean Ayres to describe how the central nervous system (CNS) organizes incoming sensory stimuli from the environment and interprets the information to influence functional motor or behavioral responses (Ayres, 2005). According to Ayres (1989, p. 11), SI is "the neurological process that organizes sensation from one's own body and from the environment and makes it possible to use the body effectively within that environment". SI is integral to engaging in meaningful occupations, social interaction, and activities of daily living (ADLs). The term sensory integration (SI) is often used interchangeably with sensory processing in occupational therapy (OT) practice.

Sensory processing disorder (SPD). Difficulties with SI can lead to SPD, a condition where the CNS does not organize sensory input into appropriate responses. Children who have ASD, attention deficit disorders, language disorders, learning disabilities, post-traumatic stress disorders, and fragile X syndrome also experience SPD (Ascent Children's Health Services, 2018). In typically developing children in the US, about 5-16% of children are affected by SPD the typical pediatric population (Ahn, et al., 2004; Ben-Sasson, Carter, & Briggs-Gowen, 2009). Although children diagnosed with SPD carry the same sensory issues with them into adulthood, limited research has been established linking SPD to adults. Three categories of SPD include

sensory modulation disorder (SMD), sensory discrimination disorder (SDD), and sensory based motor disorders (SBMD) (Miller, Anzalone, Lane, Cermak, & Osten, 2007). People with SMD have difficulty responding to sensory stimuli, often with behaviors that are not equivalent to the intensity, degree, and nature of those stimuli (Miller et al., 2007). SDD presents as difficulty interpreting and discriminating sensory stimuli, while SBMD affect posture and movement due to sensory issues (Miller et al., 2007). Since this research only studies sensory modulation, the following section is focused on exploring the subcategories of SMD.

Sensory modulation disorder (SMD). Two main categories of SMD include sensory over-responsivity (SOR) and sensory under-responsivity (SUR) (Wilbarger & Wilbarger, 2019).

Sensory over-responsivity (SOR). SOR impacts 16% of the typical children population in the US (Ben-Sasson et al., 2009). **"**Miller et al. (2004) proposed sensory over-responsivity as a new label for a combination of sensory defensiveness and increased sensory sensitivity within discrete sensory systems. This term subsumes defensiveness, hypersensitivity, and aversive responses to sensory input" (Schoen, Miller, & Green, 2008, p. 394). SOR occurs when a person overreacts to benign external stimuli and encompasses sensory defensiveness, aversion to sensory input, and hypersensitivity (Knickerbocker, 1980; Miller et al., 2007; Schoen, Miller, & Green, 2008; Wilbarger & Wilbarger, 1991b). Sensory defensiveness is an exaggerated fright, fight, or flight response to innocuous sensory input involving the tactile, auditory, and olfactory systems, and can result in withdrawal, avoidance, isolation, anxiety, and anger (Miller et al., 2007; Knickerbocker, 1980; Kinnealey & Fuiek, 1999; Wilbarger & Wilbarger, 1991b; Wilbarger & Wilbarger, 2019). Ayres (1972, 1979) described gravitational insecurity as well as atypical autonomic reactions to movement as guidelines of SOR influencing the vestibular system.

Sensory under-responsivity (SUR). Individuals diagnosed with SUR usually fail to react to typically stimulating input from the environment or lack the knowledge of how to react to stimuli from the environment (Miller, Anzalone, Lane, Cermak, & Osten, 2007).

Occupational impact of SMD. Individuals with SMD experience autonomic responses such as sensory shutdown and sensory seeking to help them cope their conditions. Sensory shutdown occurs in the presence of excessive sensory stimuli (Cullen & Barlow, 2002) and acts as a protective mechanism to defend against SOR (Demopoulos, 2009). Sensory seeking is when an individual with SOR intentionally provides stimuli to one of their sensory systems to drown out excessive stimuli from one of their other sensory systems. Similar to SOR, people with SUR also show sensory seeking tendencies to satisfy cravings for external stimuli. These coping strategies employed by individuals with SI disruptions have the potential to negatively affect occupations and quality of life (QOL) throughout the lifespan, including ADLs, self-care, social participation, and work (Bar-Shalita & Cermak, 2016; Kinnealey, Koenig, & Smith 2011).

The negative impact of SMD on social skills may begin early in life. Children with disabilities are often excluded from social participation due to the nature of their diagnoses, which can inhibit social play with typically developing peers and impair social skill development (Elksnin & Elksnin, 1995; Panacek & Dunlap, 2003). Pfeiffer, Kinnealey, Reed, and Herzberg (2005) discovered an association between delayed social skills and limited community engagement in adults with SOR, suggesting social exclusion carries into adulthood. Adults with SOR endure higher symptoms of social-emotional issues, depression, and anxiety (Kinnealey & Fuiek, 1999).

Anxiety

Fear and anxiety exist as unconscious defense mechanisms to anticipated threats and serve to protect the organism from danger (Grillon, 2008). Fear and anxiety can sometimes last beyond their usefulness and become pathological (Leal, Goes, da Silva, & Teixeira-Silva, 2017). Preclinical data indicates that anxiety can exist as a situation-specific psychophysiological reaction (state anxiety) and an inherent personality trait (trait anxiety), with the latter one being pathological (Leal et al., 2017; Spielberger, Gorsuch, & Luschene, 1970).

State anxiety. State anxiety is a temporary psychological and physical response to the existence of an imminent threat, causing increased activity in the autonomic nervous system (ANS) as portrayed by outward behaviors such as stress and nervousness (Horikawa & Yagi, 2012; Leal et al., 2017). Levels of state anxiety may differ in intensity and can determine the level of performance of occupations, including effectiveness and efficiency (Eysenck & Calvo, 2012; Horikawa & Yagi, 2012). Worry increases motivation to decrease the aversive anxiety state (Eysenck & Calvo, 2012).

Trait anxiety. Trait anxiety refers to excessive apprehension of fear and constant hypervigilance in response to the anticipation of a potentially nonexistent future threat (Grillon, 2008; Leal et al., 2017), and is categorized as anxiety disorders in the Diagnostics Statistical Manual (DSM-5) (American Psychiatric Association (APA), 2013). Anxiety disorders are the most common mental illness affecting from 28.8% to 29.5% of the adult population in the United States (US), however less than half received medical attention (Kessler, Berglund, Demler, Jin, & Walters, 2005; Nepon, Belik, Bolton, & Sareen, 2010). The five subcategories of anxiety disorders include generalized anxiety, social anxiety, panic disorder, agoraphobia, and phobia (APA, 2013).

Generalized anxiety disorders (GAD). The prevalence of GAD ranges from 5.7% to 7.7% in the US (Kessler, et al., 2005; Nepon et al., 2010). Diagnosis of GAD requires that symptoms of persistent and excessive worry last at least 6 months (APA, 2013). Several studies established that people with GAD are predisposed to elevated emotional awareness, altered interoceptive states, intolerance of unpredictability, expectation of future harm to self, autonomic imbalance, and decreased prefrontal cortex activity (Ainley & Tsakiris, 2013; Paulus & Stein, 2010). The connection between anxious behaviors to cognitive traits suggests that the cause of anxiety disorders might be linked to other CNS-related disorders.

Occupational impact of anxiety. Despite the high prevalence of GAD in US adult populations, up to 75% have not utilized mental health treatment (Wang, Lane, Olfson, Pincus, Wells, & Kessler, 2005). A positive correlation exists between untreated GAD and secondary comorbidities such as other anxiety, mood, substance use disorders (Ruscio et al., 2007), dementia (Gallacher et al., 2009), and cardiovascular disease (Carriere et al., 2013; Martens, Jonge, Na, Cohen, Lett, & Whooley, 2010). Mantella et al. (2007) measured a significant impairment in short-term memory and delayed memory in elderly adults with GAD. Due to physical and emotional difficulties, GAD significantly impacts ADL performance and health-related QOL (Bourland et al., 2000; Henning, Turk, Mennin, Fresco, & Heimberg, 2007; Hoffman, Dukes, & Wittchen, 2008; Paulus & Stein, 2010).

Additionally, individuals with GAD also experience impairments in social, work, and functional roles (Alonso et al., 2011; Hoffman et al., 2008; Kessler, Greenberg, Mickelson, Meneades, & Wang, 2001; Wetherell, Thorp, Patterson, Golshan, Jeste, & Gatz, 2004). As a consequence, these individuals suffer from an “economic burden” which describes the lack of healthcare resource affordance due to lost work (Hoffman et al., 2008). Given the similarity

between profound health impacts caused by GAD and those caused by SMD, establishing a link between anxiety and sensory modulation can potentially ameliorate crucial insights into mental health, SI diagnosis, and treatment.

Interoception

Interoception refers to the integration of internal bodily signals in the CNS that influence cognition and behavior, with or without awareness (Ainley & Tsakiris, 2013; Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015; Sherrington, 1948). Interoceptive states include pain, sensual touch, temperature, itch, tickle, muscle tension, stomach discomfort related to pH, intestinal tension, and air hunger (Paulus & Stein, 2010). Although proprioceptive signals arise from joints and muscles within the body, they belong to SI rather than interoception (Miller et al., 2007; Sherrington, 1948).

Dimensions of Interoception (Fig. 1). Garfinkel and Critchley (2013) proposed three distinct dimensions of interoception including interoceptive accuracy, interoceptive sensibility, and IA. Interoceptive accuracy reflects objective precision in reading interoceptive signals, while interoceptive sensibility measures subjective sensitivity to internal sensations (Garfinkel et al., 2015; Mehling, Price, Daubenmier, Acree, Bartmess, & Stewart, 2012). IA is defined as the "metacognitive awareness of interoceptive sensibility" or the ability to identify and perceive interoceptive signals (Garfinkel et al., 2015; Mehling et al., 2012).

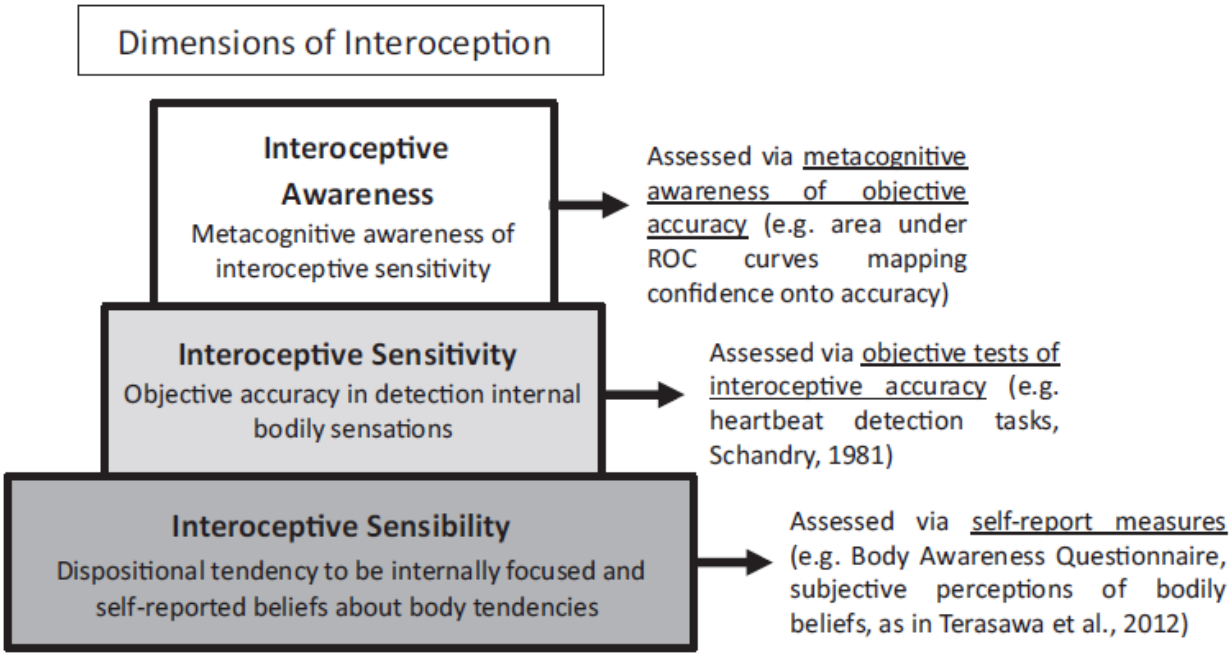

Figure 1 Dimensions of interoception schema depicting layered representations of interoception proposed by Garfinkel and Critchley (2013). These facets may have distinct and dissociative effects on behavior. Suggestive assessments for these facets are located on the right hand side (used with permission, appendix A).

Altered interoceptive processing (AIA). In psychology and neuroscience, terms such as body awareness or somatic awareness can be used interchangeably with IA to describe the cognitive rumination on exaggerated physical symptoms in anxiety and panic disorders (Mehling et al., 2012). Paulus and Stein (2010) proposed that individuals with high anxiety have enhanced ability to detect sub-threshold afferent interoceptive signals, and that these "noisily amplified" signals can be interpreted as aversive signs, causing the body to go into fight or flight. Altered interoceptive processing can influence one's emotional state (anxiety, depression, social fear) and cognitive state (decision making, judgment, behavior, memory retention) (Garfinkle & Critchley, 2013). Measuring IA could help to predict relationships to mental health conditions.

Relationships between SMD, anxiety, and AIA

A gap in the literature exists exploring the interrelationship between all three constructs of SMD, anxiety, and AIA, but some connections have been made between pairs of factors: (1) SMD and Anxiety, (2) SMD and IA, and (3) Anxiety and AIA. Connections made between the pairs indicate negative impacts on occupation.

SMD and anxiety. Studies examining the relationship between SMD and anxiety found that difficulties modulating sensation may be a risk factor for anxiety (Bar-Shalita & Cermak, 2016; Kinnealey & Fuiek, 1999). In a sample of 204 participants, typical adults were compared to adults experiencing SOR or SUR in one or more sensory systems (Bar-Shalita & Cermak, 2016). The group experiencing SOR or SUR displayed significantly higher symptoms of psychological distress than the comparison group (Bar-Shalita & Cermak, 2016).

Kinnealy, Koening, and Smith (2011) also discovered a direct correlation between SOR and anxiety (2011). The study compared 14 adults with SOR to 14 adults without SOR by comparing scores on multiple self-report measures, which established a negative correlation between anxiety and SOR (Kinnealy et al., 2011). The fight, flight, or freeze reactions manifested by people who are SOR have been associated with anxiety (Kinnealey & Fuiek, 1999; Kinnealey, Oliver, & Wilbarger, 1995), hyperactivity and inattention (Parush, Sohmer, Steinberg, & Kaitz, 1997). Interference with engagement in social interactions and participation in home and school routines have been reported by individuals experiencing SOR (Cohn, Miller, & Tickle-Degnen, 2000; Wilbarger & Wilbarger, 2019).

Impacts of SOR on occupation can be detrimental in the area of work. Sensory overstimulation in a work environment may cause alienation (Kobasa, 1979) and emotional detachment leading to decreased productivity (Evers, Rasche, & Schabracq, 2008). People who

are unable to change situations can become anxious and overwhelmed by over-stimulation, leading to low self efficacy, anxiety, and ultimately less success at work, further supporting the link between SMD and anxiety (Evers et al., 2008).

SMD and AIA. The connections are tenuous between SMD and AIA. Herbert and Pollatos (2012) compiled a literature review on the topic of AIA, highlighting the integral role sensory modulation has on creating one's sense of self-awareness. "Being aware of our internal state is relevant for modulating approach and avoidance behaviors that help us to maintain and regain homeostasis, that is, the regulation of internal body state" (Herbert and Pollatos, 2012, p. 694). Feelings experienced inside of the body gives individuals the markers to interpret emotions. Internal feelings aid in deciphering emotions. Inaccuracies about interpreting bodily sensations can lead to misperceptions in emotional state and responses in the environment. Potential connections between specific brain regions include more somatic and interoceptive processing capabilities than were previously believed to exist (Craig, 2003).

One recent study and a literature review explain findings of heightened IA in populations diagnosed with ASD (Schauder, Mash, Bryant, and Cascio, 2015; DuBois, Ameis, Lai, Casanova, and Pushpal Desarkar, 2016). DuBois et al. (2016) provided a review of the literature, highlighting a potential connection between atypical sensory processing and AIA, in addition to suggesting a link between anxiety and AIA. According to DuBois et al. (2016), atypical sensory processing (a current criterion when diagnosing ASD) is most generally associated with SOR and SUR to pain and touch, which places focus on the relationship to external sensory information. DuBois et. al (2016) suggests that populations with an ASD diagnosis experience heightened IA as well as interruptions to their sensory modulation processing functions. According to DuBois et al. (2016), AIA potentially plays an important role with the presentation

of clinical symptoms, though this prospective connection remains poorly understood by the research community.

A wider variety of studies show that adults with ASD express SOR in reaction to external sensations, and express SUR in reaction to internal sensations (Elwin, Ek, Schroder, & Kjellin, 2012). For instance, people experiencing hyposensitivity expressed in their diaries that “I rarely feel any hunger or thirst” and “I was given a punch in the stomach, every day,... Perhaps I wasn't much fun to hit because I had a very high pain threshold, and even when I did hurt I never showed what I felt. I didn't know that was what you should do" (Elwin et al., 2012, p. 425). Consequently, Elwin et al. (2012) established a link between low IA and SUR. While this research supports the potential link between SMD and AIA in adults with ASD, there is no evidence supporting this link in typical adults.

Anxiety and AIA. Several neuroimaging studies established that interoceptive awareness (IA) and interoceptive sensitivity, as well as experiences of anxiety are linked to anterior insular cortex activity (Garfinkel & Critchley, 2013; Pollatos, Traut-Mattausch, Schroeder, & Schandry, 2007). According to Seth (2013), anxiety is explained by a mismatch between arriving interoceptive information to the anterior insular cortex with that from the anterior to posterior insula toward several thalamocortical regions. Dorsal and anterior cingulate cortex relates to both interoceptive sensibility and emotional awareness (Lane, Reiman, Axelrod, Yun, Holmes, Schwartz, 1998; Pollatos et al., 2007). These findings indicate the potential causal relationship between altered interoceptive processing and anxiety disorders (Dubois et al., 2016).

Recent research established conflicting results correlating AIA and anxiety. Paulus and Stein (2010) found that altered interoceptive processing influences anxiety. Higher interoceptive accuracy, higher IA, and higher interoceptive sensibility are associated with trait anxiety and

lower QOL in typical adults and those with ASD (Dunn, Stefanovitch, Evans, Oliver, Hawkins, & Dalgleish, 2010; Garfinkel et al., 2016; Pile, et al., 2018; Pollatos et al., 2007). Lower interoceptive accuracy and lower IA correlate with anxiety in individuals with ASD and typical adults (Ainley & Tsakiris, 2013; Garfinkel, 2016). Several studies found no correlation between AIA and anxiety (Antony, Brown, Craske, Barlow, Mitchell, & Meadows, 1995; Barsky, Cleary, Sarnie, & Ruskin, 1994; Ehlers, Margraf, Roth, Taylor, & Birbaumer, 1988). Overall, the lack of general consensus on the relationship between anxiety and AIA in adults warrants the need for future research.

Summary of Literature Review

Given the fact that SPD affects up to 16% of typical children (Ahn et al., 2004; Ben-Sasson et al., 2009) and anxiety affects about 30% of the typical adult population (Kessler, Berglund, Demler, Jin, & Walters, 2005; Nepon, Belik, Bolton, & Sareen, 2010), the two disorders may affect a substantial amount of the population and potentially overlap. The statistical prevalence of AIA is not present in current research. Due to the relationships between SMD, anxiety, and AIA as proposed in this study, a large percentage of the US adult population could be affected by one or more of the conditions.

Review of the current literature revealed connections between (1) SMD and anxiety, (2) SMD and AIA, and (3) AIA and anxiety, but literature has not been found examining the interrelationship of all three topics in any populations. There is no literature addressing the occupational impacts between the pairs of constructs: AIA and anxiety; SMD and AIA, but the potential negative impacts of SMD, anxiety, and AIA on occupations and QOL reinforce the need for further research. Necessity for future research on the interrelationship between the constructs is further supported by the fact that a significant number of relevant research articles were published more than ten years ago.

Statement of Purpose

This study hypothesized there would be a significant correlation between SMD, anxiety, and AIA in the typical adult population in the US. Additionally, there would be significant relationships between the following pairs of constructs: (1) SMD and anxiety, (2) SMD and AIA, and (3) AIA and anxiety.

Theoretical Framework

SI Theory (Ayres, 1979)

SI theory was instrumental to this study in providing a platform for understanding how the brain processes and responds to sensory information. SI is the process by which the brain organizes sensations from the body and environment to function efficiently within that environment. To function efficiently, the brain creates appropriate adaptive responses to stimuli. The brain begins to do this as early as in the womb as the fetus senses a mother's body movements and responds to them. Up until age seven, the brain is primarily sensing things and gathering meaning from those sensations without very many abstract thoughts. Adaptive responses at this age tend to be more motor based rather than mental and continue to mature and become more refined into adulthood. As the body matures, mental and social responses replace some of the motor activity. According to Ayres (1979), if a child is able to efficiently organize sensory responses, they will have an easier time learning mental and social skills later on as an adult. Furthermore, when there are deficits in the brain integrating sensation, activities are difficult and require more effort, leading to less success and satisfaction.

Insular Model of Anxiety (Paulus & Stein, 2010).

The insular model of anxiety proposes the causal relationship between AIA and anxiety. The model emphasizes the process of allesthesia. Positive allesthesia occurs when repeated stimuli create an intensifying effect, for example repetitive dangerous signals will pose more threat; whereas negative allesthesia constitutes a diminishing effect, for example intense smells may become dull over time. Positive and negative allesthesia are synonymous to sensitization and habituation, respectively.

Individuals experiencing anxiety tend to have increased anterior insular cortex function which causes them to be more responsive to recognizing and interpreting interoceptive input, regardless of whether these signals are aversive or innocuous. These people experience anxiety due to positive allesthesia as their CNS over-registers interoceptive signals and assigns a threat significance to these signals. In response to perceived threat, the body activates fight or flight which presents through outward symptoms like increased heart beat or perspiration, which are also symptoms of anxiety. The insular model of anxiety describes the similar neurological etiology and physical symptoms for AIA and anxiety, suggesting the potential causal relationship between these two constructs.

Methodology

Study Design

This exploratory, cross-sectional study examined correlations between three independent and dependent variables: SMD, anxiety, and AIA. Preliminary analysis of quantitative data collected from online self-report surveys completed by typical adults residing in California indicates a significant interrelationship between SMD, AIA, and anxiety. The advantages of this study design were access to a large sample size and the objectivity of the data, while the disadvantages are the screen time requirement, the accessibility to a computer device with internet access, and the participant's necessity of technology knowledge to navigate the questionnaire.

Participants

Characteristics. Participants were [110] typically functioning adults from a convenient, snowball sample from California.

Inclusion and exclusion criteria. All participants were 18 years of age or older. All genders, ethnicities, and races were welcome to participate.

Sampling method. Participants were recruited using a snowball sampling method via social media, fliers posted on public bulletin boards, and word of mouth.

Compensation or incentive. No direct reimbursement or compensation was given to participants, however participants had the option to be entered into a lottery to receive one of two $50 Visa gift cards via email. There were no direct benefits to participants in this study, but participants may have self-reflected and developed increased insight into the interaction of their

own anxiety and sensory system. Participants may also have felt satisfaction in contributing to research in the area of OT.

Procedures for obtaining informed consent. An informed consent form was the first page of the online survey(s) and was signed electronically by all participants prior to beginning.

Ethical and Legal Considerations

Researchers were granted approval from the Dominican University of California Institutional Review Board (IRB) to recruit participants. There were no known physical risks to participants, but some participants may have found the questions on the survey anxiety provoking. Participants were informed that they could skip any question that made them uncomfortable. If a participant became anxious or otherwise emotionally uncomfortable, the participant also had the option to withdraw from the study at any time without adverse consequence. All participants were informed of potential psychological risk in the informed consent form. Additionally, numbers to the National Alliance on Mental Illness (NAMI) Helpline (call 1-800-950-NAMI (6264)) and the Crisis Text Line (text "CONNECT" at 741741) were provided. Participants were provided with a primary contact email for the researchers if they had any follow up questions upon completion of the survey.

Assessments

State Trait Anxiety Inventory (STAI; Spielberger et al., 1970). The State Trait Anxiety Inventory (STAI) is an instrument designed to identify a person's feelings of anxiety, delineating between the temporary condition of state anxiety and the long term condition of trait anxiety. The STAI is composed of 40 self-report questions answered via a four point frequency scale response. Higher scores are positively correlated with higher levels of anxiety. Internal

consistency is excellent among the general adult population with scores of .95 on the state scale and .91 on the trait scale. The STAI has been compared to the Beck Anxiety Inventory (BAI) and proved to have positive convergent validity scores ranging from .44 to .68.

36-item Short Form Health Survey (SF-36; Ware, Snow, Kosinski, & Gandek, 1993). The Medical Outcome Survey - Short Form 36 (SF-36) is a generic self-report health survey that examines health related QOL in eight areas of physical and mental health via self-report questions answered on a Likert scale. Higher scores indicate a more favorable QOL. Physical health scores include general physical functioning, role-physical, bodily pain, and general health scales. The mental health scores include social functioning, role-emotional health, vitality, and mental health scales. Reliability of scores of the SF-36 has been widely researched and all estimates equal or exceed .80.

Sensory Responsiveness Questionnaire (SRQ) (Wilbarger & Cook, 2011). The Sensory Responsiveness Questionnaire is a self-report measure of sensory sensitivity to typically encountered stimuli. The questionnaire consists of 56 items measuring sensory processing among five categories (taste/smell, movement, auditory, visual, touch). Questions are answered on a seven-point scale ranging from “extremely untrue of you” to “extremely true of you.” Items ask participants if they are bothered by sensory stimuli that do not typically irritate people or if they find themselves avoiding situations because of sensory stimuli. Higher score indicate more sensory responsiveness. The SRQ scale demonstrates good internal consistency with an excellent Cronbach alpha score of .94.

Multidimensional Assessment of Interoceptive Awareness (MAIA; Mehling et al., 2012). The 32-item self-report instrument measures five overarching dimensions of interoception: (1) awareness of body sensations, (2) emotional reaction and attentional response

to sensations, (3) capacity to regulate attention, (4) trusting body sensations, and (5) awareness of mind-body integration. Eight sub-dimensions include (1) noticing, (2) not distracting, (3) not worrying, (4) attention regulation, (5) emotional awareness, (6) self-regulation, (7) body listening, and (8) trusting. The national sample of 325 adults (mean age 48 years) was predominantly female (79%) and Caucasian (85%). Internal-consistency reliability ranged from .70 to .93. Construct validity was measured in comparison to mainstream measures of body/mindful awareness, measures of anxiety, measures of dissociation, and measures of emotion regulation ranging from -.54 to .53.

Data Collection and Management

Four questionnaires were compiled into one online survey using Google Forms and were used to assess sensory modulation, AIA, anxiety, and health related QOL in the typical adult population: State Trait Anxiety Inventory (STAI), Short Form Health Survey (SF-36), Sensory Responsiveness Questionnaire (SRQ), Multidimensional Assessment of Interoceptive Awareness (MAIA). The survey took approximately 30 minutes to complete.

Only demographic data and codes were placed on the questionnaires and the survey did not ask for any identifying information. A coding scheme was used to identify each participant. Given that online surveys do not guarantee complete anonymity, participants were informed that the data was confidential and any reference to personal URLs was deleted as soon as the survey was downloaded. Only the researchers from DUOC Occupational Therapy department saw the data. The outcomes of the research will be disseminated to a wider audience, but at no time will actual names of participants be entered onto the survey or disclosed in the results. Only demographic data was used when analyzing results.

A coding method was used to organize the data and maintain the confidentiality of the participants. All questionnaires were administered online. The master list of codes was kept separate from the questionnaires in a password protected file on a desktop computer in the office of the researchers. The questionnaires were stored in a separate, password protected file. Only the researchers saw the coded questionnaires. Raw data was retrieved, computed, and stored on a secure computer in possession of the researchers in password protected files. All other data was kept in a locked cabinet in the office of the researchers' advisor. All of the data will be destroyed one year following completion of the study.

Data Analysis

Descriptive statistics were used to describe the characteristics of our participants, the means, and the standard deviations. Correlation between all constructs was measured using the Pearson's correlation coefficient. All results were analyzed using SPSS (version 22).

Section II: Project Manuscript

Introduction

At any given point throughout the day, the human body responds to internal stimuli from the body and external stimuli from the environment. The human body has seven well established sensory systems: visual, auditory, tactile, gustatory, olfactory, vestibular, and proprioception. Recently, research has focused not only on responses to external stimuli but also on the lesser known eighth sensation: interoception, which describes the integration of internal bodily signals in the central nervous system (CNS) that influence cognition and behavior, with or without awareness (Ainley & Tsakiris, 2013). Sensory input from all eight systems is essential for human development because it shapes brain structure, influences function, and produces adaptive responses (Ahn, Miller, Milberger, & McIntosh, 2004; Garfinkel, Seth, Barrett, Suzuki, & Critchley, 2015). A. Jean Ayres defines sensory integration as a process where the CNS organizes incoming sensory stimuli from the environment and interprets the information to influence functional motor or behavioral responses (Ayres, 2005). Disruptions in integration of any of the sensory systems can significantly impact an individual's quality of life (QOL), occupational performance, and mental health. The most commonly identified disruption is sensory modulation disorder (SMD) (Wilbarger & Stackhouse, 1998). The last decade has brought an increased awareness to the role that sensory modulation difficulties plays in adults with a range of mental health and developmental needs. This connection has been clearly delineated in adults with mental health issues (Champagne & Koomar, 2011), trauma (Warner, Koomar, & Cook, 2013), and autism spectrum disorder (ASD) (Abernethy, 2010). Currently, attention has focused on disrupted responses to internal stimuli or altered interoceptive awareness (AIA). Distortions in interoception have been associated with anxiety disorders, trauma, and most recently with ASD (Ainley & Tsakiris, 2013; Dunn, Stefanovitch, Evans,

Oliver, Hawkins, & Dalgleish, 2010; Garfinkel et. al., 2016; Pile, et al., 2018; Pollatos et al., 2007). Due to the large percentage of the US adult population that may be affected by one or more of these conditions, this study examined the correlation between three variables in the typical adult population: SMD, AIA, and anxiety.

1. *SMD*: inability to appropriately grade and valence responses to sensation from the environment (Wilbarger & Stackhouse, 1998).
2. *AIA*: cognitive rumination on exaggerated physical symptoms including pain, sensual touch, temperature, itch, tickle, muscle tension, stomach discomfort related to pH, intestinal tension, and air hunger (Mehling et al., 2012; Paulus & Stein, 2010).
3. *Anxiety*: unconscious defense mechanism to anticipated threats and protect the organism from danger (Grillon, 2008). Two types of anxiety include (1) *state anxiety* which is a temporary psychological and physical response to the existence of an imminent threat, and (2) *trait anxiety* which is excessive apprehension of fear and constant hypervigilance in response to the anticipation of a potentially nonexistent future threat.

Interrelationships between SMD, Anxiety, and AIA

Review of the current literature revealed connections between (1) SMD and AIA, (2) AIA and anxiety, and (3) SMD and anxiety, but no literature was found examining the interrelationship between all three topics in any populations. Research on the interrelationship between the three constructs is further necessary because a significant number of relevant research articles establishing links between pairs of constructs were published over ten years ago (Barsky, Cleary, Sarnie, & Ruskin, 1994; Ehlers, Margraf, Roth, Taylor, & Birbaumer, 1988; Craig, 2003; Kinnealey & Fuiek, 1999; Pollatos, Traut-Mattausch, Schroeder, & Schandry, 2007).

SMD and AIA. Feelings experienced inside of the body such as thirst, hunger, or pain give individuals markers to interpret current state. “Being aware of our internal state is relevant for modulating approach and avoidance behaviors that help us to maintain and regain homeostasis, that is, the regulation of internal body state” (Herbert and Pollatos, 2012, p. 694). Inaccurately interpreting bodily sensations could lead to misperceptions in emotional state or inappropriate responses to bodily and environmental stimuli, similar to SMD. Recently, the taxonomy of SMD has been suggested to include interoception as one of the sensory inputs, based on tenuous connections established between the two, but no established research has provided solid evidence for this inclusion (Miller, 2012).

The connections between SMD and AIA in the current literature are tenuous. Links have been made between the two constructs in adults with ASD. DuBois et. al (2016) suggests that populations with an ASD diagnosis experience heightened interoceptive awareness, as well as interruptions to their sensory modulation processing functions. AIA potentially plays an important role with the presentation of clinical symptoms, though this prospective connection remains poorly understood by the research community. Potential connections have also been shown between specific brain regions, including more somatic and interoceptive processing capabilities than were previously believed to exist (Craig, 2003). Lack of research supporting a link between SMD and AIA in typical adults indicated a need for further research.

AIA and anxiety. Anxiety disorders are the most common mental illness affecting approximately 30% of adults in the United States, however less than half received medical attention (Kessler, Berglund, Demler, Jin, & Walters, 2005; Nepon, Belik, Bolton, & Sareen, 2010). People diagnosed with generalized anxiety disorder (GAD) are predisposed to elevated emotional awareness, AIA, and decreased prefrontal cortex activity (Ainley & Tsakiris, 2013;

Paulus & Stein, 2010). The connection between anxious behaviors to cognitive traits, along with research showing the influence of AIA on emotional (anxiety, depression, social fear) and cognitive states (decision making, judgment, behavior, memory retention), suggests the two constructs may be related (Garfinkle & Critchley, 2013). Studies affirmed the connection between AIA and anxiety, linking high interoceptive awareness with trait anxiety and low interoceptive accuracy with both state and trait anxiety in typical adults and those with ASD (Ainley & Tsakiris, 2013; Dunn et. al., 2010; Garfinkel et al., 2016; Pile et al., 2018; Pollatos et al., 2007). Overall, the lack of general consensus on the relationship between anxiety and AIA in adults warrants future research.

SMD and anxiety. Adults with SMD have been found to endure higher symptoms of social-emotional issues, depression, and anxiety (Kinnealey & Fuiek, 1999). Research examining the relationship between SMD and anxiety found that sensory modulation difficulties may be a risk factor for anxiety (Bar-Shalita & Cermak, 2016; Kinnealey & Fuiek, 1999). Typical adults experiencing sensory modulation difficulties in one or more sensory systems displayed significantly higher symptoms of psychological distress than the comparison group (Bar-Shalita & Cermak, 2016). The fight, flight, or freeze reactions manifested by people with sensory modulation difficulties have also been associated with anxiety (Kinnealey & Fuiek, 1999; Kinnealey, Oliver, & Wilbarger, 1995). Impacts of SMD on occupation can be detrimental. People who are unable to change situations can become anxious and overwhelmed by over-stimulation, leading to low self-efficacy and anxiety, further supporting the link between SMD and anxiety (Evers et al., 2008).

Purpose of Study

Due to the relationships between the pairs of constructs, (1) SMD and AIA, (2) AIA and Anxiety, and (3) SMD and anxiety, a large percentage of the US adult population could be affected by one or more of the conditions. This study examined the correlation between SMD, AIA, and anxiety in the typical adult population. The research questions were as follows: (1) Is there a significant relationship between SMD, anxiety, and AIA in the typical adult population? (2) What are the impacts of SMD, anxiety, and AIA on QOL? Understanding the relationship between the three constructs is the first step in developing improved intervention and treatment measures for occupational therapy and beyond.

Method

Participants

A convenience sample of 184 typical adults with a mean age of 34 (age range is 18 to 85 years) participated in the study. Table 2 describes the distribution of participants by gender, ethnicity, highest level of education, existing medical condition, and history of trauma. The majority of our population are female (85%), white (53%), and have at least a bachelor's degree (44%). Approximately 25% sample reports some type of medical condition and 24% report having experienced some type of trauma.

Table 1 Demographic Variables of the Sample (N=184)

Characteristic	N	Percent of Sample
Gender		
Male	28	15.2
Female	156	84.8
Ethnicity		
Asian	51	27.7
Black or African American	1	0.5
Native Hawaiian	1	0.5
Hispanic or Latino	17	9.2
White	97	52.7
Middle Eastern	2	1.1
Other	11	6.0
Education		
GED	1	0.5
Highschool	26	14.1
Associate Degree	11	6.0
Bachelor Degree	81	44.0
Graduate Degree	63	34.2
Other	2	1.1

Medical Condition		
Anxiety	14	7.6
Depression	6	3.3
Arthritis	5	2.7
Lumbago (Low Back Pain)	4	2.2
Fibromyalgia	4	2.2
Other	29	15.8
Total	45	24.5
History of Trauma		
Trauma	43	23.6
No Trauma	139	76.4

Less than 5% responses were missing from the survey. Missing scores were replaced with a scale mean score for participants who were missing fewer than 90% of scores in any one scale. Participants missing more than 10% of their answers were excluded from analysis. Two completed surveys were excluded due to response bias.

Instrumentation and Measures

Four self-report questionnaires were delivered in an online survey: State Trait Anxiety Inventory (STAI), Multidimensional Assessment of Interoceptive Awareness- Version 2 (MAIA-2), the Sensory Responsiveness Questionnaire (SRQ), and the Medical Outcome Survey - Short Form 36 (SF-36).

The STAI (Spielberger, Gorsuch, Lushene, Vagg, & Jacobs, 2015) is an instrument designed to identify a person's feelings of anxiety, delineating between the temporary condition of state anxiety and the long term condition of trait anxiety. The STAI is composed of 40 self-report questions answered via a four point frequency scale response. Higher scores are positively correlated with higher levels of anxiety. Internal consistency is excellent among the general adult population with scores of .95 on the state scale and .91 on the trait scale. The STAI has been

compared to the Beck Anxiety Inventory (BAI) and proved to have positive convergent validity scores ranging from .44 to .68. (Spielberger et al., 2015).

The MAIA-2 (Mehling, Acree, Stewart, Silas, & Jones, 2018) is a 37-item self-report instrument that measures eight scale (1) noticing, (2) not distracting, (3) not worrying, (4) attention regulation, (5) emotional awareness, (6) self-regulation, (7) body listening, and (8) trust. The MAIA-2 has a high internal consistency reliability with Cronbach alpha scores ranged from 0.64 to 0.83 across the eight scales (Mehling et al., 2018).

The SRQ (Wilbarger, 2009) is a self-report measure of sensory sensitivity to typically encountered stimuli. The questionnaire consists of 56 items measuring sensory processing among five categories (taste/smell, movement, auditory, visual, touch). Questions are answered on a seven-point scale ranging from “extremely untrue of you” to “extremely true of you.” Items ask participants if they are bothered by sensory stimuli that do not typically irritate people or if they find themselves avoiding situations because of sensory stimuli. The SRQ scale demonstrates good internal consistency with an excellent Cronbach alpha score of .94.

The SF-36 is a generic self-report health survey that examines health related QOL in eight areas of physical and mental health via self-report questions answered on a Likert scale (Ware, Snow, Kosinski, & Gandek, 1993). Higher scores indicate a more favorable QOL. Physical health scores include general physical functioning, role-physical, bodily pain, and general health scales. The mental health scores include social functioning, role-emotional health, vitality, and mental health scales. Reliability of scores of the SF-36 has been widely researched and all estimates equal or exceed .80.

Procedure

This research was approved by the Institutional Review Board at Dominican University of California. The first page of the online survey included information regarding possible risks and benefits to the study and continuing with the survey indicated consent. Participants completed an online survey via Google Forms consisting of 4 questionnaires: STAI, MAIA-2, SRQ, and SF-36, which took an average of 45 minutes to complete. Only demographic data and codes were placed on the questionnaires and the survey did not ask for any identifying information. A coding scheme was used to identify each participant. Given that online surveys do not guarantee complete anonymity, participants were informed that the data was confidential and any reference to personal URLs was deleted as soon as the survey was downloaded. Only the researchers from Dominican University of California Occupational Therapy department saw the data.

Data Analysis

Descriptive statistics were used to describe the characteristics of participants, the maximum, the minimum, the mean, and the standard deviation. Relationships between all constructs were measured by Pearson's correlation coefficient using SPSS (version 22)

Results

Descriptive Statistics

Table 2 presents the minimum, maximum, and average total scores recorded from the MAIA-2, SRQ, and STAI assessments. Since responses from the MAIA-2 were rated on a 0-6 point scale, a mean rating score of 3.53 indicates that the participants have relatively high interoceptive awareness. Responses on the SRQ were rated on a 7 point scale with a score of 1 meaning “extremely untrue” and 7 meaning “extremely true.” Participants scored an average of 2.92 on the SRQ indicating relatively lower sensory responsiveness. A mean STAI rating score of 3.00 on a 1-4 scale shows that the participants have relatively high anxiety. In addition, the participants score higher in state anxiety (45.25) compared to the norms (32.20 - 36.54) and higher in trait anxiety (43.96) compared to the norms (31.79 - 36.15) (Spielberger et al., 2015).

Table 2 Descriptive statistics for the MAIA-2, SRQ, and STAI (State and Trait)

Assessment	N	Mean Rating Score	Total Mean	Standard Deviation
MAIA-2 Total	185	3.53	107.59	29.05
SRQ Total	184	2.92	187.69	55.30
STAI State Total	182	2.29	45.25	7.82
STAI Trait Total	184	3.00	43.96	7.83

Note. SRQ = Sensory Responsiveness Questionnaire, STAI = State Trait Anxiety Inventory, MAIA = Multidimensional Assessment of Interoceptive Awareness, N = number of participants

Correlations between SMD, Anxiety, and AIA

Table 3 displays moderate positive and significant correlations between (1) AIA and SMD, (2) AIA and state anxiety and trait anxiety, and (3) SMD and state and trait anxiety. Interestingly, increased interoceptive awareness correlates more with state anxiety compared to trait anxiety; whereas higher SMD correlates more with trait anxiety compared to state anxiety.

Overall, the results of the Pearson correlations test supports our hypothesis that there is a relationship between SMD, anxiety, and AIA in the adult population living in CA.

Table 3 Pearson Correlations between the scores on the MAIA-2, SRQ, and STAI

Assessment	SRQ	STAI State	STAI Trait
MAIA-2 Total	.26**	.37**	.26**
SRQ Total	---	.25**	.44**
STAI State Total	---	---	.60**

Note. SRQ = Sensory Responsiveness Questionnaire, STAI = State Trait Anxiety Inventory, MAIA = Multidimensional Assessment of Interoceptive Awareness
* Correlation is significant at the 0.01 level (2-tailed).
** Correlation is significant at the 0.01 level (2-tailed).

Impacts of SMD, Anxiety, and AIA on QOL

SMD, anxiety, and AIA impact QOL in different aspects (table 4). There are moderate significant positive correlations between AIA and (1) physical functioning, (2) role limitations due to physical health, and (3) role limitations due to mental health. Significantly negative correlations were observed between SMD and (1) role limitations due to physical health, (2) energy, (3) emotional well-being, (4) social functioning, (5) pain, and (6) general health. State anxiety significantly, positively correlates with (1) physical functioning, (2) emotional well-being, and (3) pain; and significantly, negatively correlates with (1) energy and (2) general health. Trait anxiety significantly and positively correlates with physical functioning. These results show drastic impacts of SMD, anxiety, and AIA on QOL and confirms the need for our study.

Table 4 Correlations between MAIA-2, SRQ, STAI, AND SF-36

SF-36 Variables	MAIA-2	SRQ	STAI State	STAI Trait
Physical Functioning	.22**	-.06	.21*	.17*
Role Limitations due to Physical Health	.19*	-.16*	.11	-.03
Role Limitations due to Mental Health	-.08	-.11	.14	-0.9
Energy	.02	-.18*	-.25*	.11
Emotional Wellbeing	.09	-.16*	.22**	-.10
Social Functioning	.08	-.23**	.14	0.03
Pain	-.09	-.34*	.20**	-.05
General Health	-.09	-.18*	-.22**	.07

* Correlation is significant at the 0.05 level (2-tailed).

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

Discussion

The findings revealed moderate relationships between three constructs: (1) SMD and AIA; (2) AIA and anxiety; and (3) SMD and anxiety. Interestingly, despite the interrelationship established between all constructs, their effects on QOL are impactful but not consistent.

SMD and AIA

This study found a moderate positive and significant correlation between SMD and AIA. As sensory responsivity increases, interoceptive awareness also increases, and vice versa. These findings support that of Dubios et al. who found that populations with ASD tend to experience heightened interoceptive awareness in addition to their interruptions to sensory modulation (2016). Our findings provide crucial evidence that interoception belongs under atypical sensory processing which is a current criterion for ASD diagnosis.

One explanation for the relationship between SMD and AIA could be that both sensory modulation and interoception describes the process where the brain produces behavioral responses in reaction to sensory input. Sensory integration takes into account external stimuli from the physical environment including vision, audition, touch, taste, smell, vestibular, and proprioception, while interoception considers internal stimuli within the individual's body including bodily states from visceral, somatic, and skeletal systems (Khalsa, Adolphs, Cameron, Critchley, Davenport, Feinstein, … the Interoception Summit 2016 participants, 2018).

AIA and Anxiety

The correlation between increased MAIA-2 scores and increased STAI state anxiety scores as well as the correlation between MAIA-2 scores and STAI trait anxiety scores establish that increased interoceptive awareness is associated with increased state and trait anxiety.

Interestingly, increased interoceptive awareness correlates more with state anxiety compared to trait anxiety. Our findings support research by Paulus and Stein (2010), who found that AIA influences anxiety. Our results agree with research stating increased interoceptive accuracy, awareness, and sensibility are associated with trait anxiety and decreased QOL in typical adults and those with ASD (Dunn, Stefanovitch, Evans, Oliver, Hawkins, & Dalgleish, 2010; Garfinkel et al., 2016; Pile et al., 2018; Pollatos et al., 2007). This research study also aligns with findings that decreased interoceptive accuracy along with AIA correlates with anxiety in individuals with ASD and typical adults (Ainley & Tsakiris, 2013; Garfinkel et al., 2016). Measuring AIA could help to predict relationships to mental health conditions. Though a clear link between AIA and anxiety has been established in this study, further research is required to determine causation.

SMD and Anxiety

The correlation between increased SRQ scores and increased STAI state anxiety scores, as well as the correlation between SRQ scores and STAI trait anxiety scores establish a link between sensory modulation difficulties and anxiety in the study population. Findings indicate that a typical adult with higher scores on the SRQ was more likely to have higher scores on the STAI state. That same adults who scored high on the SRQ were even more likely to have higher scores on the STAI trait. These findings suggest that an adult who initially struggles with correctly interpreting and responding to sensory stimulation may struggle with anxiety. The findings may also suggest that adults who initially struggle with anxiety may have difficulty with sensory modulation. Our results support prior studies examining the relationship between SMD and anxiety, which found that difficulties modulating sensation may be a risk factor for anxiety (Bar-Shalita & Cermak, 2016; Kinnealey & Fuiek, 1999).Outcomes of this study also support previous research by Kinnealy, Koening, and Smith (2011), who discovered a significant

correlation between sensory modulation difficulties and anxiety in a sample of twenty-eight adults. Our larger sample size of typical adults provides support for Kinnealy et al., as well as an increased ability to generalize these findings to the typical adult population.

Interrelationship between SMD, Anxiety, and AIA

This study was not designed to provide definitive causal answers as to which construct may be a risk factor for another, but rather to shine light on the distinct interrelationship between SMD, AIA, and anxiety. Our results indicate a significant interrelationship between SMD, AIA, and anxiety. Findings indicate that there is a relationship between co-occurring constructs: SMD and AIA; AIA and anxiety; SMD and anxiety. However, further research needs to be done to determine directionality.

Impacts of SMD, Anxiety, and AIA on QOL

The data suggests that issues in sensory modulation, anxiety, and interoception play a role in QOL in one aspect or another. Heightened interoceptive awareness correlates with mixed QOL as seen in higher physical ability and lower role performance. Similarly, high sensory responsivity or SMD also have mixed impacts on QOL. Positive effects include improved role performance and decreased pain, while decreased energy levels, emotional wellbeing, social participation, and general health contribute to negative qualities. Different types of anxiety also link with QOL measures differently. Both state and trait anxiety have positive correlations with higher QOL as seen in improved physical functioning. State anxiety also correlates with improved emotional well-being, increased pain, decreased energy and general health.

On one hand, overlapping impacts on QOL facilitate an explanation for the interrelationship between SMD, anxiety, and AIA. Physical functioning has been positively

correlated with AIA, state anxiety, and trait anxiety, while energy and general health have been negatively correlated with SMD and state anxiety. On the other hand, opposite effects on QOL provide interesting insight into diagnosis of these clinical conditions. AIA is linked with lower role performance, while SMD is linked with higher role performance. State anxiety correlates with higher pain and emotional health, while SMD correlates with lower pain and emotional health. In conclusion, the data yielded complicated implications on QOL which proves the importance of this research and warrants the need for further studies in clinical practice.

Study Limitations

The study has several limitations. The participants were recruited by a convenience sample and, thus, represent a non-random sample. The majority of participants were female, white and educated, which is not representative of a typical adult population. Had the sample population been more diverse, generalizability to the general population would have been higher. A history of trauma was reported by 23.6 percent of participants in the study, which is significantly lower than the reported national average of 70% of adults in the US who have experienced at least one traumatic event at least once in their lives (National Council for Behavioral Health, 2013). The assessments utilized to comprise the questionnaire is a potentially limiting factor. The MAIA-2 and the SRQ are not norm-referenced. Though self-report measures have advantages, there are several disadvantages to self-reporting including the potential for response bias, social desirability bias, systematic response distortions, responses that may be exaggerated, omittance of private and/or potentially embarrassing details.

Implications for Occupational Therapy Practice

To best support clinical reasoning in treatment planning, it is essential for occupational therapy practitioners to consider the bodies response to both internal and external sensory input. The findings of this study have several implications for occupational therapy practice:

1. Establishing the link between SMD, interoception, anxiety, and their impact on QOL is an important first step for future research which could provide crucial insight into the practice area of mental health.
2. Understanding the link between SMD, interoception, anxiety and their impact on QOL could be appleied to developing interventions for populations with deficits in those areas.

Conclusion

This correlational study is the first of its kind to link SMD, AIA, and anxiety. This research found fair to moderate correlations between SMD, AIA, and anxiety in the typical adult population in the US. Further research is suggested to provide increased insight into the causality between the relationships between constructs and to examine implications for intervention and prevention. These findings have important clinical implications for effective treatment of people experiencing difficulties with sensory processing and anxiety.

References

Abernethy H. (2010). The assessment and treatment of sensory defensiveness in adult mental health: a literature review. *British Journal of Occupational Therapy, 73*(5), 210–218. doi: 10.4276/030802210X1273499166418.

Ahn, R., Miller, L., Milberger, S., & McIntosh, D. (2004). Prevalence of parents' perceptions of sensory processing disorders among kindergarten children. *American Journal of Occupational Therapy, 58*(3), 287-293. doi:10.5014/ajot.58.3.287.

Ainley, V., & Tsakiris, M. (2013). Body conscious? Interoceptive awareness, measured by heartbeat perception, is negatively correlated with self-objectification. *PLoS ONE, 8*(2), 1-9. doi:10.1371/journal.pone.0055568.

Alonso, J., Petukhova, M., Vilagut, G., Chatterji, S., Heeringa, S., Üstün, T., & Bromet, E., et al. (2011). Days out of role due to common physical and mental conditions: Results from the WHO world mental health surveys. *Molecular Psychiatry, 16*(12), 1234-1246. doi:1359-4184/11.

American Psychiatric Association. (2013). *Diagnostic and statistical manual of mental disorders* (5th ed.). Arlington, VA: American Psychiatric Publishing.

Antony, M., Brown, T., Craske, M., Barlow, D., Mitchell, W., & Meadows, E. (1995). Accuracy of heartbeat perception in panic disorder, social phobia, and nonanxious subjects. *Journal of Anxiety Disorders, 8*(5), 355-371. doi:10.1016/0887-6185(95)00017-I.

Ayres, A. J. (1972). *Sensory integration and learning disorders*. Los Angeles: Western Psychological Services.

Ayres, A. J. (1979). *Sensory integration and the child.* Los Angeles: Western Psychological Services.

Ayres, A. J. (1989). *Sensory integration and praxis test (SIPT).* Los Angeles, CA: Western Psychological Services.

Ayres, A. J. (2005). *Sensory integration and the child*. Los Angeles: Western Psychological Services.

Bar-Shalita, T., & Cermak, S. A. (2016). Atypical sensory modulation and psychological distress in the general population. *American Journal of Occupational Therapy*, *70*(4), 1-9. doi:10.5014/ajot.2016.018648.

Barsky, A., Cleary, P., Sarnie, M., & Ruskin, J. (1994). Panic disorder, palpitations, and the awareness of cardiac activity. *Journal of nervous and mental disorder, 183*(2), 63-71. doi:10.1097/00005053-199402000-00001}.

Ben-Sasson, A., Carter, A. S., & Briggs-Gowen, M. J. (2009). *Sensory over-responsivity in elementary school: Prevalence and social-emotional correlates. Journal of Abnormal Child Psychology, 37*(5), 705-716. doi:10.1007/s10802-008-9295-8.

Bourland, S., Stanley, M., Snyder, A., Novy, D., Beck, J., Averill, P., & Swann, A. (2000). Quality of life in older adults with generalized anxiety disorder. *Aging and Mental Health, 4*(4), 315–323. doi:10.1080/13607860020010466.

Bundy, A., Murray, E., & Lane, S. (2002). *Sensory Integration: Theory and Practice.* Philadelphia, PA: F. A. Davis.

Carrière, I., Ryan, J., Norton, J., Scali, J., Stewart, R., Ritchie, K., & Ancelin, M. L. (2013). Anxiety and mortality risk in community-dwelling elderly people. *The British Journal of Psychiatry, 203*(4), 303–309. doi:10.1192/bjp.bp.112.124685.

Champagne, T., & Koomar, J. (2011). Expanding the focus: addressing sensory discrimination concerns in mental health. *Mental Health Special Interest Section Quarterly*, *34*(1), 1–4.

Cohn, E., Miller, L. J., & Tickle-Degnen, L. (2000). Parental hopes for therapy outcomes: Children with sensory modulation disorders. *American Journal of Occupational Therapy*, *54*(1), 36-43. doi:10.5014/ajot.54.1.36.

Craig, A. D. (2003). Interoception: the sense of the physiological condition of the body. *Current Opinion in Neurobiology, 13*(4), 500-505. doi:10.1016/S0959-4388(03)00090-4.

Cullen, L. & Barlow, J. (2002). “Kiss, cuddle, squeeze”: The experiences and meaning of touch among parents of children with autism attending a Touch Therapy Programme. *Journal of Child Health Care*, *6*(3), 171-181. doi:10.1177/136749350200600303.

Demopoulos, M. (2009). *A pilot study of the effect of a sensory diet on the in-seat behaviour of grade one learners in the classroom* (Unpublished doctoral dissertation or master’s thesis). University of Witwatersrand, Johannesburg.

DuBois, D., Ameis, S. H., Lai, M. C., Casanova, M. F., & Desarkar, P. (2016). Interoception in autism spectrum disorder: A review. *International Journal of Developmental Neuroscience*, *52*, 104-111. doi:10.1016/j.ijdevneu.2016.05.001.

Dunn, B., Stefanovitch, I., Evans, D., Oliver, C., Hawkins, A., & Dalgleish, T. (2010). Can you feel the beat? Interoceptive awareness is an interactive function of anxiety- and depression-specific symptom dimensions. *Behavior Research and Therapy, 48*(11), 1133-1138. doi:10.1016/j.brat.2010.07.006.

Ehlers, A., Margraf, J., Roth, W., Taylor, C., & Birbaumer, N. (1988). Anxiety induced by false heart rate feedback in patients with panic disorder. *Behavior Research and Therapies., 26*(1), 1-11. doi:10.1016/0005-7967(88)90028-9.

Elksnin, L. K., & Elksnin, N. (2001). *Assessment and Instruction of Social Skills: A Special Double Issue of Exceptionality*. London, England: Routledge.

Elwin, M., Ek, L., Schroder, A., & Kjellin, L. (2012). Autobiographical accounts of sensing in Asperger syndrome and high-functioning autism. *Archives of Psychiatric Nursing, 26*(5), 420-429. doi:10.1016/j.apnu.2011.10.003.

Evers, A., Rasche, J., & Schabracq, M. J. (2008). High sensory-processing sensitivity at work. *International Journal of Stress Management, 15*(2), 189-198. doi:10.1037/1072-5245.15.2.189.

Eysenck, M. W., & Calvo, M. G. (1992). Anxiety and performance: The processing efficiency theory. *Cognition & Emotion, 6*(6), 409-434. doi:10.1080/02699939208409696}.

Gallacher, J., Bayer, A., Fish, M., Pickering, J., Pedro, S., Dunstan, F., Ebrahim, S., & Ben-Shlomo Y. (2009). Does anxiety affect risk of dementia? Findings from the Caerphilly prospective study. *The American Journal of Psychosomatic Medicine, 71*(6), 659-666. doi: 10.1097/PSY.0b013e3181a6177c.

Garfinkel, S., & Critchley, H. (2013). Interoception, emotion and brain: new insights link internal physiology to social behaviour. Commentary on: "Anterior insular cortex mediates bodily sensibility and social anxiety" by Terasawa et al. (2012). *Social Cognitive and Affective Neuroscience, 8*(3), 231-234. doi:10.1093/scan/nss140.

Garfinkel, S., Seth, A., Barrett, A., Suzuki, K., & Critchley, H. (2015). Knowing your own heart: distinguishing interoceptive accuracy from interoceptive awareness. *Biological Psychology, 104*, 65-74. doi:10.1016/j.biopsycho.2014.11.004.

Garfinkel, S., Tiley, C., O'Keeffe, S., Harrison, N., Seth, A., & Critchley, H. (2016). Discrepancies between dimensions of interoception in autism: implications for emotion and anxiety. *Biological Psychology, 114*, 117-126. doi:10.1016/j.biopsycho.2015.12.003.

Grillon, C. (2008). Models and mechanisms of anxiety: evidence from startle studies. *Psychopharmacology, 199*(3), 421-437. doi:10.1007/s00213-007-1019-1.

Henning, E. R., Turk, C. L., Mennin, D. S., Fresco, D. M., & Heimberg, R. G. (2007). Impairment and quality of life in individuals with generalized anxiety disorder. *Depression and Anxiety, 24*(5), 342-349. doi:10.1002/da.20249.

Herbert, B. M., & Pollatos, O. (2012). The body in the mind: on the relationship between interoception and embodiment. *Topics in Cognitive Science, 4*(4), 692-704. doi:10.1111/j.1756-8765.2012.01189.x.

Hoffman, D. L., Dukes, E. M., & Wittchen, H. U. (2008). Human and economic burden of generalized anxiety disorder. *Depression and Anxiety, 25*(1), 72-90. doi:10.1002/da.20257.

Horikawa, M., & Yagi, A. (2012). The relationships among trait anxiety, state anxiety and the goal performance of penalty shoot-out by university soccer players. *PLoS ONE, 7*(4), 1-5. doi:10.1371/journal.pone.0035727.

Kessler, R., Berglund, P., Demler, O., Jin, R., & Walters, E. (2005). Lifetime prevalence and age-of-onset distributions of DSM-IV Disorders in the national comorbidity survey replication. *Archives of General Psychiatry, 62*(6), 593-602. doi:10.1001/archpsyc.62.6.593.

Kessler, R., Greenberg, P., Kikelson, K., Meneades, L., & Wang, P. (2001). The effects of chronic medical conditions on work loss and work cutback. *Journal of Occupational and Environmental Medicine, 43*(3), 218-225. doi:10.1097/00043764-200103000-00009.

Khalsa, S., Adolphs, R., Cameron, O., Critchley, H., Davenport, P., Feinstein, J, … the Interoception Summit 2016 participants (2018). Interoception and Mental Health: A Roadmap. *Biological Psychiatry, 3*, 501-513. doi:10.1016/j.bpsc.2017.12.004.

Kinnealey, M., & Fuiek, M. (1999). The relationship between sensory defensiveness, anxiety, depression, and perception of pain in adults. *Occupational Therapy International, 6*(3), 195-206. doi:10.1002/oti.97.

Kinnealey, M., Koenig, K. P., & Smith, S. (2011). Relationships between sensory modulation and social supports and health-related quality of life. *American Journal of Occupational Therapy, 65*(3), 320-327. doi:10.5014/ajot.2011.001370.

Knickerbocker, B. M. (1980). A holistic approach to the treatment of learning disorders. Thorofare, NJ: Slack.

Kobasa, S. (1979). Stressful life events, personality and health: An inquiry into hardiness. *Journal of Personality and Social Psychology, 37*(1), 1–11. doi:10.1037//0022-3514.37.1.1.

Lane, R.D., Reiman, E.M., Axelrod, B., Yun, L.S., Holmes, A., Schwartz, G.E. (1998). Neural correlates of levels of emotional awareness: evidence of an interaction between emotion and attention in the anterior cingulate cortex. *Journal of Cognitive Neuroscience, 10*(4), 525-35. doi:10.1162/089892998562924.

Leal, P.C., Goes, T. C., da Silva, L. C. F., & Teixeira-Silva, F. (2017). Trait vs. state anxiety in different threatening situations. *Trends in Psychiatry and Psychotherapy, 39*(3), 147-157. doi:10.1590/2237-6089-2016-0044.

Mantella, R., Butters, M., Dew, M., Mulsant, B., Begley, A., Tracey, B., Shear, M., Reynolds, C., & Lenze, E. (2007). Cognitive impairment in late-life generalized anxiety disorder. *American Journal of Geriatric Psychiatry, 15*(8), 673-679. doi:10.1097/JGP.0b013e31803111f2.

Martens, E., Jonge, P., Na, B., Cohen, B., Lett, H., & Whooley, M. (2010). Scared to death? Generalized anxiety disorder and cardiovascular events in patients with stable coronary heart disease. *Archives of General Psychiatry, 67*(7), 750-758. doi:10.1001/archgenpsychiatry.2010.74.

Mehling, W., Price, C., Daubenmier, J., Acree, M., Bartmess, E., & Stewart, A. (2012). The multidimensional assessment of interoceptive awareness (MAIA). *PLoS ONE, 7*(11), 1-22. doi:10.1371/journal.pone.0048230.

Miller, L. , Anzalone, M., Lane, S., Cermak, S., & Osten, E. (2007). Concept evolution in sensory integration: a proposed nosology for diagnosis. *The American Journal of Occupational Therapy*, *61*(2), 135-140. doi:10.5014/ajot.61.2.135.

National Comorbidity Survey (NCS). (2017). Retrieved from https://www.hcp.med.harvard.edu/ncs/index.php.

National Council for Behavioral Health (2013). *How to Manage Trauma*. Retrieved from https://www.thenationalcouncil.org/wp-content/uploads/2013/05/Trauma-infographic.pdf

Nepon, J., Belik, S., Bolton, J., & Sareen, J. (2010). The relationship between anxiety disorders and suicide attempts: findings from the national epidemiologic survey on alcohol and related conditions. *Depression and Anxiety*, *27*(9), 791-798. doi:10.1002/da.20674.

Paulus, M., & Stein, M. (2010). Interoception in anxiety and depression. *Brain Structure and Function, 214* (5-6), 451-463. doi:10.1007/s00429-010-0258-9.

Panacek, L. J., & Dunlap, G. (2003). The social lives of children with emotional and behavioral disorders in self-contained classrooms: A descriptive analysis. *Exceptional Children*, *69*(3), 333-348. doi:10.1177/001440290306900305.

Parush, S., Sohmer, H., Steinberg, A., & Kaitz, M. (1997). Somatosensory functioning in children with attention deficit hyperactivity disorder. *Developmental Medicine & Child Neurology*, *39*(7), 464-468. doi:10.1111/j.1469-8749.1997.tb07466.x.

Paulus, M., & Stein, M. (2010). Interoception in anxiety and depression. *Brain Structure and Function, 214* (5-6), 451-463. doi:10.1007/s00429-010-0258-9.

Petzschner, F., Weber, L., Gard, T., & Stephan, K. (2017). Computational Psychosomatics and Computational Psychiatry: Toward a Joint Framework for Differential Diagnosis. *Biological Psychiatry*, *82*, 421-430. doi:10.1016/j.biopsych.2017.05.012.

Pfeiffer, B., Kinnealey, M., Reed, C., & Herzberg, G. (2005). Sensory modulation and affective disorders in children and adolescents with Asperger's syndrome. *American Journal of Occupational Therapy*, *59(3),* 335-345. doi:10.5014/ajot.59.3.335}.

Pile, V., Lau, J., Topor, M., Hedderly, T., & Robinson, S. (2018). Interoceptive accuracy in youth with tic disorders: exploring links with premonitory urge, anxiety, and quality of life. Journal of Autism and Developmental Disorders, 1-9. doi:10.1007/s10803-018-3608-8.

Pollatos, O., Traut-Mattausch, E., Schroeder, H., & Schandry, R. (2007). Interoceptive awareness mediates the relationship between anxiety and the intensity of unpleasant feelings. *Journal of Anxiety Disorders, 21*(7), 931-943. doi:10.1016/j.janxdis.2006.12.004.

Ruscio, A. M., Chiu, W. T., Roy-Byrne, P., Stang, P. E., Stein, D. J., Wittchen, H. U., & Kessler, R. C. (2007). Broadening the definition of generalized anxiety disorder: Effects on prevalence and associations with other disorders in the National Comorbidity Survey Replication. *Journal of Anxiety Disorders, 21*(5), 662-676. doi:10.1016/j .janxdis.2006.10.004.

Schauder, K. B., Mash, L. E., Bryant, L. K., & Cascio, C. J. (2015). Interoceptive ability and body awareness in autism spectrum disorder. *Journal of experimental child psychology, 131*, 193-200. doi:10.1016/j.jecp.2014.11.002.

Schoen, S. A., Miller, L. J., & Green, K. E. (2008). Pilot study of the sensory over-responsivity scales: assessment and inventory. *American Journal of Occupational Therapy, 62*(4), 393-406. doi:10.5014/ajot.62.4.393.

Seth, A. K. (2013). Interoceptive inference, emotion, and the embodied self. *Trends in cognitive sciences*, *17*(11), 565-573. doi:10.1016/j.tics.2013.09.007.

Sherrington, C. S. (1948). *The integrative action of the nervous system*. Cambridge, UK: Cambridge University Press.

Spielberger., C., Gorsuch, R., & Lushene, R.. (1970). *Manual for the state-trait anxiety inventory ("self-evaluation questionnaire")*. Palo Alto, CA: California Consulting Psychologists Press.

Wang, P. S., Lane, M., Olfson, M., Pincus, H. A., Wells, K. B., & Kessler, R. C. (2005). Twelve-month use of mental health services in the United States: Results from the National Comorbidity Survey Replication. *Journal of the American Medical Association Psychiatry, 62*(6), 629–640. doi:10.1001/archpsyc.62.6.629.

Warner, E., Koomar, J., Lary, B., & Cook, A. (2013). Can the body change the score? Application of sensory modulation principles in the treatment of traumatized adolescents in residential settings. *Journal of Family Violence*, *28*(7), 729–738. doi:10.1007/s10896-013-9535-8.

Wetherell, J., Thorp, S., Patterson, T., Golshan, S., Jeste, D., & Gatz, M. (2004). Quality of life in geriatric generalized anxiety disorder: a preliminary investigation. *Journal of Psychiatric Research, 38*(3), 305–312. doi:10.1016/j.jpsychires.2003.09.003.

Wilbarger, J. L., & Cook, D. B. (2011). Multisensory hypersensitivity in women with fibromyalgia: Implications for well being and intervention. *Archives of Physical Medicine and Rehabilitation*, *92*(4), 653–656. doi:10.1016/j.apmr.2010.10.029.

Wilbarger, J., & Stackhouse, T. (1998, September 12). Sensory Modulation: A Review of the Literature [Blog]. Retrieved from https://www.ot-innovations.com/clinical-practice/sensory-modulation/sensory-modulation-a-review-of-the-literature/.

Wilbarger, P., & Wilbarger, J. L. (1991a). *Sensory defensiveness in children aged 2-12*. Santa Barbara, CA: Avanti Educational Programs.

Wilbarger, P., & Wilbarger, J. L. (1991b). *Sensory defensiveness in children aged 2–12: An intervention guide for parents and other caretakers*. Denver, CO: Avanti Educational Programs.

Wilbarger, P., & Wilbarger, J. L. (1991c). *Sensory integration theory and practice* (2nd ed.). Philadelphia, PA: F. A. Davis.

Wilbarger, J.L. & Wilbarger, P.L. (2019) The Wilbarger Approach to Treating Sensory Defensiveness. In A. Bundy & S. Lane (Eds.) Sensory Integration Theory and Practice 3rd Edition. FA Davis: Philadelphia.