Abstract

Sensory hyperresponsiveness, anxiety, and restricted, repetitive behaviors are known to be associated with one another, especially in autistic[1] youth, and may be important to the development and presentation of autism over time. Few studies, however, have studied the nature of this three-way relationship prospectively, or in young children at elevated likelihood for autism. The goals of the current study were to gain greater insight into the development of autism from a symptom level before a diagnosis can be made, and specifically, to examine the relationship between sensory hyperresponsiveness, anxiety, and restricted, repetitive behaviors across time during early development in children at elevated likelihood for autism. Extant longitudinal data for a group of children at elevated likelihood for autism (N = 147) were used to conduct path analyses for two mediation model configurations, which included measures of sensory hyperresponsiveness at baseline, and anxiety and restricted and repetitive behaviors at follow-up. Results did not indicate mediating effects for either model; however, higher levels of sensory hyperresponsiveness at baseline were significantly associated with higher levels of anxiety symptoms at follow-up (b = 0.09, SE = 0.04, β = 0.24, p = 0.005, 95% CIs [0.07, 0.40]). Findings suggest that sensory hyperresponsiveness during early development later predicts anxiety symptoms in children at elevated likelihood for autism, which is consistent with prior findings in both autistic (Green et al., 2012) and non-autistic children (Carpenter et al., 2019). Although we are unable to determine whether this is a unidirectional or bidirectional relationship in the current study given the lack of concurrent data on anxiety symptoms at baseline, this result adds to emerging research suggesting that sensory hyperresponsiveness may be a risk factor for later developing anxiety.

[1] Identity-first language is used throughout this document as research indicates that it is more commonly preferred among autistic individuals compared to person-first language (Bury et al., 2020; Kenny et al., 2016; Lei et al., 2021).

DOES ANXIETY MEDIATE THE RELATIONSHIP BETWEEN SENSORY HYPERRESPONSIVENESS AND RESTRICTED, REPETITIVE BEHAVIORS DURING EARLY DEVELOPMENT?

by

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Does Anxiety Mediate the Relationship between Sensory Hyperresponsiveness and Restricted, Repetitive Behaviors during Early Development?

Autism Spectrum Disorder (ASD) is a neurodevelopmental condition characterized by deficits in social communication and social interaction as well as restricted, repetitive patterns of behaviors, interests, or activities including sensory symptoms (American Psychiatric Association, 2013). Restricted and repetitive behaviors commonly include stereotyped or repetitive motor movements, use of objects, or speech; insistence on sameness; inflexible adherence to routines; ritualized patterns of verbal or nonverbal behavior; and preoccupation with restricted patterns of interest (APA, 2013). Sensory symptoms include "hyper- or hyporeactivity to sensory input or unusual interest in sensory aspects of the environment (e.g., adverse response to specific sounds or textures; apparent indifference to pain/temperature; excessive smelling or touching of objects; visual fascination with lights or movement)" (APA, 2013, p. 50). Sensory hyperresponsiveness in particular is used to describe an increased, adverse, or avoidant behavioral response to sensory stimuli (Baranek et al., 2006). Although sensory hyperresponsiveness can occur in other clinical conditions as well as in typically developing populations, it is most highly prevalent in autism (Baranek et al., 2006; Ben-Sasson et al., 2009; Leekam et al., 2007; Marco et al., 2011; Wolff et al., 2019), and will be used as the sensory construct of interest in the current study. According to the Centers for Diseases Control and Prevention (CDC), the current prevalence of autism is estimated to be 1 in 44 children (Maenner et al., 2021), and symptoms often appear during early childhood (APA, 2013), though a reliable diagnosis of autism cannot be made until approximately two to three years of age (Falck-Ytter et al., 2018; Landa et al., 2013).

Data collected during early development have suggested that differences in sensory processing patterns (i.e., sensory symptoms) may play a more important role in the pathogenesis of autism than we may have once thought (Watson et al., 2011). This can be seen at the level of behavior through direct observational assessments (Sensory Processing Assessment; Baranek, 1999) and questionnaires (Sensory Experiences Questionnaire, Baranek; 2006; Sensory Profile; Dunn, 1999), and at the level of the brain through neurophysiological measures (Williams et al., 2021). Behaviorally, longitudinal findings show greater parent-reported sensory symptoms among children at greater genetic likelihoods for developing autism compared to that of children with lower likelihoods of autism (Wolff et al., 2019). Psychophysical and neurophysiological studies demonstrate heightened neural activity in sensory-related brain regions among autistic individuals while completing various sensory-perceptual tasks compared to typically developing peers (Cary et al., 2021; McKernan et al., 2020; Russo et al., 2012; Samson et al., 2012).

Currently, autism cannot be reliably diagnosed before the age of two to three years (Falck-Ytter et al., 2018; Landa et al., 2013). Because of this, and because autism is genetically linked (Szatmari et al., 1998), researchers have started to prospectively follow children who have an older sibling with autism and are therefore considered at elevated likelihood for autism themselves, in order to better understand the development of autism in infancy and toddlerhood, before symptoms begin to emerge. Such longitudinal studies among populations at higher likelihoods for autism allow researchers to make meaningful connections by identifying and understanding possible predictors of autism. Understanding predictors of an autism diagnosis before the age of two or three years is of clinical significance as it can directly impact early identification efforts. Furthermore, early identification is essential for earlier access to intervention, which in turn, can improve long-term outcomes for autistic individuals and their

families (Bölte et al., 2013; Dawson, 2008). Of the children at elevated likelihood for autism, about 16-22% go on to develop an autism diagnosis (Ersoy et al., 2021; Ozonoff et al., 2011; Wolff et al., 2019).

In addition to autism, children at elevated likelihood for autism can instead end up with an anxiety diagnosis and are even more likely to receive diagnoses of both (Ersoy et al., 2021; Miller et al., 2016; Ozonoff et al., 2011; Shephard et al., 2017; Wolff et al., 2019). Thus, in order to understand the developmental trajectories of the majority of youth at elevated likelihood for autism, understanding factors that predict autism and anxiety might be critical. Sensory hyperresponsiveness is one such factor. Findings from prospective studies of children at elevated likelihood for autism suggest that sensory symptoms, such as sensory hyperresponsiveness, often occur prior to an autism diagnosis (Grzadzinski et al., 2020; Wolff et al., 2019). Furthermore, sensory hyperresponsiveness has been found to positively predict anxiety symptoms in both autistic (Green et al., 2012) and typically developing children (Carpenter et al., 2019), with unidirectional effects among both populations. This suggests that sensory hyperresponsiveness may contribute to later development of anxiety, with or without co-occurring autism.

Previous studies have shown positive associations between sensory hyperresponsiveness and restricted, repetitive behaviors, as well as between anxiety and restricted, repetitive behaviors in autistic populations (Rodgers 2012a, Rodgers 2012b, Wigham et al., 2015), while others have demonstrated not only the presence of restricted, repetitive behaviors, but similar associations between sensory hyperresponsiveness and restricted, repetitive behaviors in populations of typically developing children (Schulz & Stevenson, 2018) and of children at elevated likelihood for autism (Wolff et al., 2019). Evidence suggests that restricted, repetitive behaviors are a form of self-regulation, especially in response to increased levels of anxiety or

distress (Jones et al., 2003; Lidstone et al., 2014; Williams et al., 2021), which suggests that anxiety symptoms may precede the onset of restricted, repetitive behaviors. Together, this suggests 1.) that restricted, repetitive behaviors may serve a similar function in both neurotypical and neurodiverse individuals, and 2.) that what is categorically seen as a core symptom of autism (i.e., restricted, repetitive behaviors), may be further indicative of underlying symptoms of anxiety and/or sensory symptoms, regardless of whether or not one also meets diagnostic criteria for an autism spectrum disorder.

In order to better understand the possible connections between each of these behavioral presentations in young children, and whether or how early sensory symptoms may impact the development and presentation of anxiety, and in turn, later autistic symptoms, the goal of the current study was to examine whether anxiety mediates the relationship between sensory hyperresponsiveness and restricted, repetitive behaviors during early development in children at elevated likelihood for autism. By focusing our efforts on the relationship between possible underlying mechanisms and behavioral symptoms of autism, as opposed to measuring diagnostic outcomes of autism, the current study aimed to inform atypical developmental trajectories that may or may not lead to an autism diagnosis, but rather present with atypical features that are largely characteristic of autism.

Sensory Hyperresponsiveness and Restricted, Repetitive Behaviors

Associations between sensory hyperresponsiveness and restricted, repetitive behaviors, have been demonstrated in previous studies amongst typically developing children, autistic children, and children at elevated likelihood for autism while controlling for demographic variables such as age, sex, and IQ (Boyd et al., 2010; Chen et al., 2009; Grzadzinski et al., 2020; Schulz & Stevenson, 2018; Wigham et al., 2015; Wolff et al., 2019). Such findings across

populations consistently indicate that sensory hyperresponsiveness positively predicts restricted, repetitive behaviors. Importantly, this predictive association has been demonstrated in the population of interest to the current study, and within the context of early development.

Sensory Hyperresponsiveness and Restricted, Repetitive Behaviors in Children at Elevated Likelihood for Autism

Researchers have identified a specific association between hyperresponsiveness during early developmental time periods and restricted, repetitive behaviors both concurrently (Wolff et al., 2019) and later in childhood (Grzadzinski et al., 2020) amongst independent samples of children at elevated likelihood for autism. Both studies demonstrated a longitudinal relationship between sensory hyperresponsiveness and restricted, repetitive behaviors in their respective samples of children at elevated likelihood for autism, such that sensory hyperresponsiveness as early as 12-14 months of age predicted increased levels of restricted, repetitive behaviors both concurrently at two separate time points (at 12 months and again at 24 months of age; Wolff et al., 2019) and over time, when children were later 3-5 years of age (Grzadzinski et al., 2020). Together, findings from these studies are not only suggestive of an interplay between restricted, repetitive behaviors and differences in sensory responsiveness beginning as early as 12 months of age, but that sensory hyperresponsiveness by 12-14 months of age may be an indicator of more frequent and more severe restricted, repetitive behaviors later during childhood, especially in those at elevated likelihood for autism.

Sensory Hyperresponsiveness and Anxiety

The majority of literature on sensory hyperresponsiveness is situated within the context of autism due to its high prevalence in autism (Carpenter et al., 2019). For instance, when measured broadly across sensory modalities, sensory hyperresponsiveness, is estimated to occur

in 56% of children with autism ages 1 through 6 years (Baranek et al., 2007). However, some studies indicate that sensory hyperresponsiveness commonly occurs with other psychiatric and medical diagnoses such as Fragile X syndrome, Attention-deficit/hyperactivity disorder (ADHD), and mood disorders, and affects approximately 8% to 28% of typically developing children as well (Baranek et al., 2006; Ben-Sasson et al., 2009; 2010; Carter et al., 2011; Reynolds & Lane, 2008). Given that sensory hyperresponsiveness spans across multiple different presentations including typical development, but remains largely prevalent in autism, more studies are needed to expand upon this area of research and further understand the distinct role of sensory hyperresponsiveness in atypical child development.

Although anxiety can occur in otherwise typically developing children, anxiety also commonly co-occurs with autism with an estimated prevalence rate of 55% in clinical samples, and 11% to 84% in outpatient samples of children and adolescents with autism (de Bruin et al., 2007; Muris et al., 1998; White et al., 2009; Williams et al., 2015). Due to the high prevalence rate of anxiety in autism, in addition to the high prevalence of sensory hyperresponsiveness in autism (Baranek et al., 2007), researchers have explored the possible relationship between sensory hyperresponsiveness and anxiety among autistic individuals (Ben-Sasson et al., 2009; Black et al., 2017; Green & Ben-Sasson, 2010; Green et al., 2012; Pfeiffer et al., 2005). Others have also done so with community samples in order to capture a broader population of children and address similar questions regarding associations between sensory hyperresponsiveness and anxiety in non-clinical groups (Carpenter et al., 2019). However, the relationship between these two have yet to be studied specifically in children at elevated likelihood for autism, despite research focusing on each of these constructs separately (Milosavljevic et al., 2017; Wolff et al., 2019).

Of note, sensory hyperresponsiveness has been linked to certain symptoms of anxiety during childhood in non-clinical groups of children, including gastrointestinal symptoms and difficulty sleeping (Hallet et al., 2013; Mazurek et al., 2013). Sensory hyperresponsiveness is also associated with emotion dysregulation and anxiety in autistic children, typically developing children, those with ADHD, and in those with anorexia nervosa (Ben-Sasson et al., 2009; Bitsika et al., 2016; Carter et al., 2011; Green & Ben-Sasson, 2010; Green et al., 2012; Mangeot et al., 2001; Pfeiffer et al., 2005; Reynolds & Lane, 2009). Therefore, there is substantial evidence to support the relationship between sensory hyperresponsiveness and anxiety in children of both clinical and non-clinical groups; however, demonstrations of longitudinal associations between these variables remain sparse, indicating an important area of research that warrants further exploration and insight into the developmental trajectories of these two intersecting presentations during childhood, regardless of diagnostic outcomes or groupings (Carpenter et al., 2019; Green et al., 2012).

Sensory Hyperresponsiveness and Anxiety in Autism

In order to understand possible directional effects between sensory hyperresponsiveness and anxiety during early childhood, Green and colleagues (2012) conducted a longitudinal study with 149 toddlers diagnosed with autism with low to average nonverbal (M = 78.10, SD = 18.06) and verbal (M = 58.62, SD = 25.15) developmental abilities based on the Mullen Scales of Early Learning (Mullen, 1995). Children were initially assessed at ages 18-33 months (Time 1), and again 12 months later, at ages 30-45 months (Time 2). Sensory hyperresponsiveness and anxiety were measured at Time 1 and Time 2 using parent-rated sensory sensitivity and generalized anxiety scores (Carter & Briggs-Gowan, 2005). General findings revealed that mean anxiety scores significantly increased from Time 1 to Time 2 while mean sensory hyperresponsiveness

scores remained stable over time. At Time 1, only 8.3% of children's anxiety scores fell above the clinical cutoff, while 22.6% of children's sensory hyperresponsiveness scores fell above the clinical cutoff. However, at Time 2, 13.5% of children's anxiety scores fell above the clinical cutoff, and 23.6% of children's sensory hyperresponsiveness scores fell above the cutoff. This indicates that more children from this sample experienced clinically significant levels of sensory hyperresponsiveness than anxiety during early childhood, and that anxiety may continue to develop throughout childhood as anxiety levels increased from Time 1 to Time 2.

Importantly, Green and colleagues (2012) conducted a cross-lag analysis in which sensory hyperresponsiveness and anxiety were simultaneously tested as predictors of change in one another. Findings from the cross-lag analysis showed that sensory hyperresponsiveness positively predicted increases in anxiety over and above age, autism symptom severity, non-verbal developmental quotient, and maternal anxiety, and that conversely, anxiety did not predict changes in sensory hyperresponsiveness (Green et al., 2012). These findings not only suggest that sensory hyperresponsiveness occurs more frequently and is developmentally stable relative to anxiety which appears to increase in prevalence throughout childhood, but that sensory hyperresponsiveness may be a contributing risk factor for later developing anxiety. Furthermore, these findings align with theories that suggest that patterns of hyperresponsiveness to sensory stimuli may be generalized more broadly to entire environments or situations by associating contextual information with certain sensory stimuli, which in turn may increase hypervigilance and symptoms of anxiety (Green & Ben-Sasson, 2010; Green et al., 2012). Though these findings provide support for a unidirectional effect between sensory hyperresponsiveness and anxiety across time, and specifically within the same age range as that of the current study, such

findings are limited in their generalizability to other children who have not yet been identified as having autism.

Sensory Hyperresponsiveness and Anxiety in Community Samples

Heightened responsiveness to sensory input may also be an early emerging risk factor for developing anxiety later in life amongst broader populations, as findings from Carpenter and colleagues (2019) revealed a specific, unidirectional predictive relationship between sensory hyperresponsiveness and anxiety when assessed amongst a community sample of children first at age 2-5 years (N= 917), and again at age 6 years (N = 191). Children were assessed at both time points for symptoms of various psychiatric disorders, sensory hyperresponsiveness, and behavioral difficulties including sleep problems, irritability, gastrointestinal problems, and food selectivity on the basis of caregivers' reports. Of the 191 participants that completed both phases of the study, 127 (61%) met criteria for an anxiety disorder at age 2-5 years. In terms of identifying anxious versus non-anxious groups amongst participants at age 6 (Time 2), children were considered to have anxiety if they met both symptom and impairment criteria for generalized anxiety disorder, separation anxiety disorder, and/or social phobia.

Longitudinal regression analyses and mediation models revealed that sensory hyperresponsiveness in preschool (age 2-5 years) uniquely predicted school-age anxiety (at 6 years of age), over and above preschool anxiety symptoms, co-occurring school-age sensory hyperresponsiveness, or any other psychiatric diagnosis assessed (Carpenter et al., 2019). Furthermore, Carpenter and colleagues (2019) found that school-age anxiety symptoms mediated the relationship between preschool sensory hyperresponsiveness and school-age behavioral challenges, such that children who demonstrated higher levels of sensory hyperresponsiveness at age 2-5 years, also demonstrated increased levels of anxiety symptoms at age 6 years, which in

turn was associated with higher levels of co-occurring behavioral difficulties such as irritability and sleep problems at age 6. Building off of Green and colleagues' (2012) study, this study (Carpenter et al., 2019) was the first to demonstrate that sensory hyperresponsiveness in young children predicts school-age symptoms of anxiety in a community sample of children not referred for any psychiatric condition.

Replicating similar longitudinal studies in broader samples of children may provide important clinical insights regarding the emergence and development of sensory hyperresponsiveness and anxiety more generally, as studies suggest that these two conditions can occur a.) in typically developing children, with evidence to suggest that sensory hyperresponsiveness is causally related to anxiety (Carpenter et al., 2019; Lane et al., 2012), and b.) in children at elevated likelihood for autism, with evidence supporting heightened levels of each in those who later receive a diagnosis of autism compared to those who later do not (Milosavljevic et al., 2017; Wolff et al., 2019). Importantly, such patterns have been demonstrated in the same age range as that of current study (Carpenter et al., 2019; Green et al., 2012). However, exploring this prospectively, and specifically in young children at elevated likelihood for autism, may provide further insight into the possible developmental mechanisms for autism.

Anxiety and Restricted, Repetitive Behaviors

In discussing the distinctive nature or features of restricted, repetitive behaviors, which are part of the core criteria for autism (APA, 2013), researchers and clinicians indicate that restricted, repetitive behaviors are characterized by a variety of behaviors, marked by unchanging repetition and insistence on sameness in the environment (Kanner, 1943; Lidstone et al., 2014). As previously described in early theoretical accounts, as well as several self-reported

accounts, restricted and repetitive behaviors can be understood as a coping mechanism used to self-regulate and sustain homeostatic arousal (Kinsbourne, 1980; Lidstone et al., 2014; Ornitz & Ritvo, 1968; Williams et al., 2021; Zentall & Zentall, 1983). They have been described as an important means of expressing and managing one's need for order and routine, help support daily functioning, and can have self-soothing effects (Jones et al., 2003; Williams et al., 2021).

Restricted, repetitive behaviors are also thought to reflect anxiety (Lidstone et al., 2014) as they can provide a sense of alleviation from anxiety and distress. Consistent with this theoretical basis, restricted, repetitive behaviors can emerge and develop in individuals as a means for minimizing symptoms of anxiety and distress in a similar way that ritualized routines, habits, and restricted and compulsive-like behaviors have been shown to do so in young, typically developing children (Evans et al., 1997), and how compulsive behaviors do so in obsessive-compulsive disorder more generally (Zandt et al. 2007). Despite possible explanations for the formation and development of restricted, repetitive behaviors in response to symptoms of anxiety and varying states of arousal, studies have demonstrated associations between these variables and therefore provide some insight into possible causal mechanisms between anxiety and restricted, repetitive behaviors in children (Rodgers et al., 2012a; Rodgers et al., 2012b; Wigham et al., 2015; Williams et al., 2021). It is important to note, however, that many studies examining associations between anxiety and restricted, repetitive behaviors do so within an older age range than that of the current study despite the availability of valid and reliable measures of anxiety as early as 18 months such as the Child Behavior Checklist for ages 1.5-5 years (Achenbach & Rescorla, 2001; Achenbach et al., 2003), or as early as 2 years for preschool populations such as the Preschool Age Psychiatric Assessment (Egger et al., 2006) and the Revised Preschool Anxiety Scale (Edwards et al., 2010).

Because anxiety often develops and affects autistic children (Ersoy et al., 2021; Vasa & Mazurek, 2015), and because restricted, repetitive behaviors are not only observable behaviors often exhibited by autistic individuals but are also considered a core diagnostic criterion for autism (APA, 2013), many studies have examined the relationship between the two solely within the context of autism (Williams et al., 2021). While this research allows for a level of insight into the nature of anxiety and restricted, repetitive behaviors in autistic populations, it also warrants further exploration of the relationship between anxiety and restricted, repetitive behaviors in other populations such as in children at elevated likelihood for autism, as this may provide a broader foundation prospectively for understanding how these variables can impact each other and/or contribute to the development of autism.

Anxiety and Restricted, Repetitive Behaviors in Autism

Within the context of autism, researchers have demonstrated a positive correlation between restricted, repetitive behaviors and anxiety in autistic children aged 8-16 years (Rodgers et al., 2012a; Rodgers et al., 2012b; Wigham et al., 2015). This association was first demonstrated in a sample of autistic children more generally (Rodgers et al., 2012a), and again in a sample of autistic children categorized as either “anxious” or “non-anxious” (Rodgers et al., 2012b) based on parent-reported anxiety scores either at/above or below the clinical cut-off respectively (Spence, 1998). Findings revealed that autistic children with high anxiety demonstrated significantly higher levels of restricted, repetitive behaviors compared to the non-anxious group. Furthermore, a positive correlation was found between anxiety and a specific type of restricted, repetitive behavior (insistence on sameness/circumscribed interests) in the anxious-autism group but not in the non-anxious-autism group, thus demonstrating a possible mechanistic relationship between the two in autistic children. Although these studies did not

include analyses for directional effects, findings were consistent with other studies in which anxiety was considered to be an intrinsic driver of restricted, repetitive behaviors in autistic individuals (Joosten et al., 2009; Sukhodolsky et al., 2008). Overall, findings suggest that restricted, repetitive behaviors and anxiety are not only associated, but may play a crucial role in the development and maintenance of each other in autistic individuals.

Conceptualization for Hypothesized Model

Wigham and colleagues (2015) examined the relationships between patterns of sensory responsiveness, restricted, repetitive behaviors, and the mediating role of anxiety amongst 53 autistic children aged 8-16 years. In addition to demonstrating a positive correlation between anxiety and restricted, repetitive behaviors, findings revealed that each of these two variables were associated with increased levels of sensory hyperresponsiveness within this sample. Importantly, results demonstrated a sequential path from sensory hyperresponsiveness to restricted, repetitive behaviors through anxiety (Wigham et al., 2015), suggesting that anxiety may play a significant role in the presentation of restricted, repetitive behaviors at least in autistic children. This study is the first to highlight directional effects between all three variables of sensory hyperresponsiveness, anxiety, and restricted, repetitive behaviors with evidence supporting the notion that anxiety mediates the relationship between sensory hyperresponsiveness and restricted, repetitive behaviors, particularly in school-aged children with autism. However, what is still missing from the literature is a.) whether or not this mediating relationship can be replicated in younger children or in young children at elevated likelihood for autism, and b.) whether this relationship remains true when analyzed longitudinally among young children at elevated likelihood for autism.

The current study aimed to address these gaps in the literature by essentially combining and replicating Carpenter and colleagues' (2019) and Wigham and colleagues' (2015) previous mediation models, with main differences centered around the sample characteristics in terms of age-range, clinical presentation/population, and sample size. In examining the potential mediating role of anxiety on the relationship between sensory hyperresponsiveness and restricted, repetitive behaviors among young children genetically predisposed to developing autism, our goal was to gain greater insight into the development of autism, from a symptom level, before a diagnosis can be made, with the hope that such findings could not only strengthen our understanding of these relationships, but potentially be used to inform current assessment, diagnostic, and therapeutic tools.

Conceptualization for an Alternative Model

Despite evidence to suggest that anxiety predicts restricted, repetitive behaviors in autistic individuals (Wigham et al., 2015), other studies conversely suggest that restricted, repetitive behaviors are predictive of anxiety (Baribeau et al., 2020; Kuzminskaite et al., 2020). A review of the literature found that restricted, repetitive behavior severity at the time of an autism diagnosis (2-5 years of age) predicted the level of anxiety symptoms later during adolescence at age 11 years among autistic youth (Baribeau et al., 2020). Findings showed that approximately 58% of children with severe levels of restricted, repetitive behaviors at 2-5 years of age presented with heightened levels of anxiety symptoms by 11 years of age compared to those with moderate (41%) or mild (20%) restricted, repetitive behaviors. Furthermore, both moderate and severe levels of restricted, repetitive behaviors at age 2-5 years were associated with increased odds of clinically significant symptoms of anxiety in adolescence. From a developmental perspective, researchers suggest that children with an inclination toward overly

restricted patterns of behavior, or who tend to engage in repetitive movements to self-sooth beginning at a young age, may lack or avoid exposure to new experiences and consequently natural opportunities to learn to tolerate or develop alternative means of coping to such experiences. In turn, this can lead to increased anxiety when later encountering new or uncertain situations.

Given the empirical support to suggest a predictive relationship between restricted, repetitive behaviors and anxiety in autistic children (Baribeau et al., 2020), in addition to the lack of evidence to suggest a unidirectional effect between these two variables, there is insufficient evidence to favor one mediation model configuration over the other. Therefore, the current study analyzed two separate mediation models in order to examine these associations. Furthermore, the two models were compared to determine which model better represents the relationship between sensory hyperresponsiveness, anxiety, and restricted, repetitive behaviors within the current sample.

Research Questions and Hypotheses

Based on findings gathered from previous studies, it is suggested that sensory features precede the onset of anxiety symptoms or restricted, repetitive behaviors (Carpenter et al., 2019; Green et al., 2012; Lidstone et al., 2014), and that in turn, anxiety and restricted, repetitive behaviors may develop or manifest over time in response to underlying experiences of sensory hyperresponsiveness (Carpenter et al., 2019; Green et al., 2012; Hutt & Hutt, 1965; Hutt et al., 1964; Lidstone et al., 2014; Schulz & Stevenson, 2018). Additionally, anxiety has been found to have mediating effects on the relationship between sensory hyperresponsiveness and restricted, repetitive behaviors in school-aged autistic children (Wigham et al., 2015), though to our knowledge, no study to date has replicated this finding in a sample of children at elevated

likelihood for autism, nor earlier during development in either a sample of autistic children or children at elevated likelihood for autism. For these reasons, the current study examined 1.) whether sensory hyperresponsiveness during infancy or toddlerhood predicts later restricted, repetitive behaviors in young children at elevated likelihood for autism, and 2.) whether anxiety mediates the relationship between sensory hyperresponsiveness and restricted, repetitive behaviors in young children at elevated likelihood for autism. We hypothesized 1.) that sensory hyperresponsiveness at baseline (Time 1) would predict restricted, repetitive behaviors at follow-up (Time 2 or 3), without a mediating influence of anxiety. We also hypothesized 2.) that symptoms of anxiety at follow-up (Time 2 or 3), would mediate the association between sensory hyperresponsiveness at baseline (Time 1) and restricted, repetitive behaviors at follow-up (Time 2 or 3).

Despite empirical support to suggest a predictive relationship between anxiety and restricted, repetitive behaviors (Wigham et al., 2015), some studies have conversely demonstrated that restricted, repetitive behaviors are predictive of anxiety (Baribeau et al., 2020; Kuzminskaite et al., 2020). Given that there is insufficient evidence to suggest a unidirectional effect between these two variables, and because of the cross-sectional nature of these two variables in the current study (i.e., both administered at follow-up), we explicitly tested two mediation model configurations (Mitzel et al., 2021). In addition to our hypothesized model which tested the indirect effect of sensory hyperresponsiveness on restricted, repetitive behaviors via anxiety, we included an alternative model which tested the indirect effect of sensory hyperresponsiveness on anxiety via restricted, repetitive behaviors. Although there is a strong theoretical basis to support our hypothesized model, examining and understanding which of the

two models best fits the data will be useful for guiding future studies, early screeners, and therapeutic approaches (Mitzel et al., 2021).

Method

Participants

Data for the current secondary analyses were drawn from a broader study of early autism risk in a sample of children at elevated likelihood for developing autism. Through the use of deidentified extant data from the Early Autism Risk Longitudinal Investigation network, obtained through the National Institute of Health (NIH) National Database for Autism Research for which secondary analyses may be conducted by other autism researchers with an active National Database for Autism Research account, the current study included 147 participants aged 0-52 months who are at elevated likelihood for autism by virtue of having an older sibling with autism. Inclusion criteria included participants at elevated likelihood for autism, whose parent or caregiver had previously completed the current study's measures temporally such that caregiver-reports of sensory hyperresponsiveness were obtained prior to obtaining caregiver-reports of anxiety, or prior to receiving an autism evaluation. Exclusion criteria included children who did not have a complete version of the current study's measures for which scores of sensory hyperresponsiveness, anxiety, and restricted, repetitive behaviors could be obtained; or who were administered each measure but whose caregiver-reports of sensory hyperresponsiveness were not obtained at baseline prior to caregiver-reports of anxiety; or whose autism evaluation did not occur at one of the two follow-up periods. Participants' sex, race, ethnicity, cognitive ability, and age at corresponding times in which each measure was administered, were collected by original researchers, obtained for the purpose of the current study, and are presented in Table 1 and Table 2.

Measures

Sensory Experiences Questionnaire

The Sensory Experiences Questionnaire Version 2.1 is a brief (10-15 minute) 43-item caregiver questionnaire used to assess children's behavioral responses to sensory stimuli in the context of common daily activities (Baranek et al., 2006; Little et al., 2011). The Sensory Experiences Questionnaire is intended for children aged 5 months to 6 years. It is primarily used by researchers and clinicians to characterize sensory features in young children with autism, and discriminate sensory patterns among autistic children, children with other developmental disorders, and typically developing children. The Sensory Experiences Questionnaire is designed to be used as a supplemental tool in developmental evaluations and measures patterns of sensory seeking behaviors, hyperresponsiveness, and hyporesponsiveness across social and nonsocial contexts, and across five sensory domains (tactile, auditory, visual, vestibular-proprioceptive, and gustatory-olfactory; Little et al., 2011).

Parents were asked to rate the frequency of occurrence of their child's sensory experience based on a 5-point Likert scale (1 = almost never, to 5 = almost always). The Sensory Experiences Questionnaire produces raw subscale scores as well as a raw total score (Baranek et al., 2006; Little et al., 2011). Higher scores indicate greater sensory processing differences. For the purposes of the current study, only scores on the sensory hyperresponsiveness subscale were used. Parents completed the Sensory Experiences Questionnaire when children were between the ages of 0-27 months (mode of age when administered = 12 months; *M*age = 12.37 months) which, for the purposes of the current study, represents baseline (Time 1).

The Sensory Experiences Questionnaire demonstrates high test-retest reliability (Intraclass Correlation Coefficient = 0.92) and good internal consistency overall (Cronbach's α

coefficient = 0.80; Baranek et al., 2006; Little et al., 2011). The internal consistency of subscales ranges from $\alpha = 0.64 – 0.74$, the test-retest reliability of subscale scores ranges from ICC = 0.68 – 0.86, and item reliability ranges from ICC = 0.63 – 0.99. More specifically, the sensory hyperresponsiveness subscale demonstrates high internal consistency with $\alpha = 0.74$, and good test-retest reliability with ICC = 0.71 (Little et al., 2011).

Child Behavior Checklist

The Child Behavior Checklist, which is part of the Achenbach System of Empirically Based Assessment, measures emotional and behavioral problems in children aged 1.5 to 18 years (Achenbach & Rescorla, 2001). The Child Behavior Checklist for ages 1.5-5 years is a 99-item scale and consists of two broadband scales (Internalizing Domain and Externalizing Domain), seven syndrome scales (Emotionally Reactive, Anxious/Depressed, Somatic Complaints, Withdrawn, Sleep Problems, Attention Problems, and Aggressive Behavior), and five *Diagnostic and Statistical Manual of Mental Disorders* (*DSM*)-oriented clinical scales (Depressive Problems, Anxiety Problems, Pervasive Developmental/Autism Spectrum Problems, Attention Deficit/Hyperactivity Problems, and Oppositional Defiant Problems; APA, 2000; APA, 2013).

Parents were asked to complete items describing their child's behaviors over the past 6 months based on a three-point Likert scale (0 = Not true, 1 = Somewhat or sometimes true, and 2 = Very true or often true). The Child Behavior Checklist yields raw scores and *T*-scores, with higher scores on subscales reflecting greater levels of problematic behaviors. Parents completed the Child Behavior Checklist at follow-up when children were between the ages of 24-50 months (mode = 36 months, *M*age = 36.52 months) which, for the purposes of the current study, aligns with either the second or third follow-up time-point (Time 2 or 3). For the purposes of the current study, only the Anxiety problems clinical scale completed by parents were used.

The Child Behavior Checklist is widely used among clinicians and researchers as a screener for various psychiatric symptoms. The clinical scales were developed to reflect the most up to date *DSM* diagnostic criteria (Achenbach & Rescorla, 2001; Llanes et al., 2018). As such, the Anxiety problems scale combines diagnostic criteria for General Anxiety Disorder (GAD), Separation Anxiety Disorder (SAD), and Specific Phobia. Although the Child Behavior Checklist clinical scales may be used as supplemental assessment tools rather than diagnostic tools, heightened scores indicate increased likelihood of these disorders. *T*-scores of 69 or above indicate clinically elevated symptoms of anxiety and *T*-scores of 65-68 indicate borderline clinical elevation. More generally, *T*-scores of 65 or above (i.e., above the borderline range cut-off) on the Anxiety problems clinical scale are considered to reflect "elevated" levels of symptoms. For the Anxiety Problems scale, raw scores of 9 or above are considered clinically elevated, raw scores of 8 indicate borderline clinical elevation, and raw scores of 0–7 are considered within average range. More generally, raw scores of 8 or above on the Anxiety Problems scale are reflective of "elevated" levels of anxiety symptoms. Both raw scores and *T*-scores were normed on the same age range, thus allowing for raw scores to be interpreted within the same age bracket as *T*-scores (aged 1.5 – 5 years of age). Given that all participants in the current study were within this age bracket for all measures examined, and because raw scores in the current dataset provided greater variability than standardized scores, the current study utilized raw scores for this measure.

The Child Behavior Checklist demonstrates strong discriminant, convergent, and predictive validity (Llanes et al., 2018), as well as construct validity with the Behavior Assessment System for Children 2nd Edition (BASC-2) Anxiety problems clinical scale (*r*'s = 0.46 – 0.55; Reynolds & Kamphaus, 2004). The Child Behavior Checklist Anxiety problems

scale demonstrates good test-retest reliability (ICC ranging from 0.57 to 0.86), and adequate internal consistency (α's = 0.63 – 0.73).

Restricted and Repetitive Behavior

The Autism Diagnostic Observation Schedule is a reliable and valid semi-structured, standardized diagnostic instrument designed to measure communication, social interaction, play skills, and restricted, repetitive behaviors, and is informed by current *DSM* diagnostic criteria for autism (APA, 2000; APA, 2013; Lord et al., 2000; Lord et al., 2012). The Autism Diagnostic Observation Schedule, in combination with the Autism Diagnostic Interview-Revised (Rutter et al., 2003) are considered the gold standard for identifying and diagnosing children with autism. In its development, the Autism Diagnostic Observation Schedule – Generic (Lord et al., 2000) demonstrated increased reliability and diagnostic validity compared to the original version of the Autism Diagnostic Observation Schedule (Lord et al., 1989). With further improvements, the most recent version, the Autism Diagnostic Observation Schedule – Second Edition (Lord et al., 2012), allows for even greater accuracy and effectiveness (Dorlack et al., 2018). All items and codes are considered to be functionally identical across the Autism Diagnostic Observation Schedule – Second Edition and its earlier versions. Here, either the Autism Diagnostic Observation Schedule – Generic (Lord et al., 2000) or the Autism Diagnostic Observation Schedule – Second Edition (Lord et al., 2012) was administered by trained clinicians to children at follow-up, including either the second or third time-point (Time 2 or 3) in the current study, when children were between the ages of 24-52 months (mode = 36 months; *M*age = 36.08 months).

The Autism Diagnostic Observation Schedule – Second Edition (Lord et al., 2012) includes five increasingly difficult modules that vary based on the child's language development

and age, whereas the Autism Diagnostic Observation Schedule – Generic (Lord et al., 2000) consists of four modules. Each module across both editions consists of structured tasks and standardized materials that are incorporated in order for the examiner to observe various aspects of the individual's social interactions, communication, and play skills. For the purpose of the current study, total raw scores for the restricted and repetitive behaviors subdomain on only Module 1 or Module 2 of either the Autism Diagnostic Observation Schedule – Generic or Second Edition were used, as these were the appropriate modules administered to children based on their language level and age at the time of the assessment. All restricted, repetitive behavior total scores used in the current study reflect the Autism Diagnostic Observation Schedule – Second Edition scoring algorithm regardless of which version of the Autism Diagnostic Observation Schedule was administered, as other researchers have previously done (Brieger et al., 2021).

Module 1 on the Autism Diagnostic Observation Schedule – Generic (Lord et al., 2000) is given to those whose language consists of single words or short, simple phrases, or those who are preverbal. Module 1 on the Autism Diagnostic Observation Schedule – Second Edition (Lord et al., 2012) is still given to children of the same age range (i.e., 31 months and older) and language level (i.e., those without consistent phrase speech), but can be administered according to two distinct groups for improved validity: to those with no words, and to those with some words (Dorlack et al., 2018; Lord et al., 2012). Similarly, Module 2 on both the Autism Diagnostic Observation Schedule – Generic and Second Edition are administered to those who are not verbally fluent but demonstrate some flexible phrase speech; however, Module 2 on the Autism Diagnostic Observation Schedule – Second Edition is now broken into two separate

groups: for children younger than 5 years of age, and for children older than or equal to 5 years of age.

Although the scoring of the Autism Diagnostic Observation Schedule – Generic (Lord et al., 2000) and the Autism Diagnostic Observation Schedule – Second Edition (Lord et al., 2012) slightly differ, both versions yield raw total scores for the restricted and repetitive behavior domain. The Autism Diagnostic Observation Schedule – Second Edition (Lord et al., 2012) employs a revised diagnostic algorithm for Modules 1 through 3 that includes two subdomains (Social Affect; and Restricted and Repetitive Behavior) which can be summed to produce an overall total score. Assigned item ratings of 3 are converted to algorithm scores of 2, assigned ratings other than 0, 1, 2, or 3 (e.g., 7, 8, or 9) are converted to algorithm scores of 0, and all originally assigned ratings of 0, 1, and 2 are directly transformed to the algorithm form and remain the same. Converted algorithm scores are summed for specific items within each subdomain to allow for total raw scores for each separate subdomain (Social Affect; and Restricted and Repetitive Behavior), and the sum of subdomain raw score totals produces the overall total raw score. For the purpose of the current study, only restricted and repetitive behavior total raw scores on either the Autism Diagnostic Observation Schedule – Generic or Second Edition were used to measure restricted and repetitive behaviors among participants. Here, restricted and repetitive behavior total raw scores on the Autism Diagnostic Observation Schedule – Generic were re-coded by applying the Second Edition scoring algorithm and summing the reassigned item scores that the restricted and repetitive behavior subdomain is comprised of to match that of the Autism Diagnostic Observation Schedule – Second Edition (Brieger et al., 2021).

Restricted and repetitive behavior total raw scores on the Autism Diagnostic Observation Schedule – Second Edition (Lord et al., 2012) are comprised of the examiner's ratings on item codes which assess stereotyped/idiosyncratic use of words or phrases, unusual sensory interest in play material/person, hand and finger and other complex mannerisms, unusually repetitive interests, or stereotyped behaviors, and on module 1, intonation of vocalizations or verbalizations as well. While the restricted and repetitive behavior subdomain on the Autism Diagnostic Observation Schedule – Generic (Lord et al., 2000) is also comprised of several of these codes, it does not include the intonation of vocalizations or verbalizations code on module 1, or the stereotyped/idiosyncratic use of words or phrases code on either module 1 or module 2. As indicated above, for the purpose of the current study, all scores on the restricted, and repetitive behavior domain of the Autism Diagnostic Observation Schedule – Generic were re-coded to include the relevant aforementioned codes and to maintain consistency with the revised scoring system on the Autism Diagnostic Observation Schedule – Second Edition (Lebersfeld et al., 2020). That is, restricted and repetitive behavior total raw scores across both the Autism Diagnostic Observation Schedule – Generic and the Autism Diagnostic Observation Schedule – Second Edition that are used in the current study reflect the same item content and the same algorithm for reassigning item scores within the restricted and repetitive subdomain that is used on the Autism Diagnostic Observation Schedule – Second Edition.

The Autism Diagnostic Observation Schedule – Generic alone demonstrates high sensitivity (.95-.99) and moderate specificity (.64-.75) using the revised scoring algorithm and for children aged 24-47 months (Kim & Lord, 2012; Newschaffer et al., 2012) which aligns with the age range that was used in the current study for this particular measure. Based on a recent meta-analysis, the sensitivity and specificity on the Autism Diagnostic Observation Schedule –

Second Edition range from 0.89-0.92 and 0.81-0.85 respectively, demonstrating adequate diagnostic validity as well (Lebersfeld et al., 2020).

Covariates

Sex assigned at birth (0 = *female*; 1 = *male*) and IQ (as measured by the Mullen Scales of Early Learning, early learning composite score; Mullen, 1995) were included as covariates given their previously published associations with anxiety (Edirisooriya et al., 2021; Hartley & Sikora, 2009; Sukhodolsky et al., 2008) and restricted and repetitive behaviors (Bishop et al., 2006; Uljarević et al., 2022) among autistic youth. Similarly, previous researchers (Ersoy et al., 2021) have included both sex and IQ as covariates when examining anxiety symptoms in children at elevated likelihood for autism. By controlling for the effects of sex and IQ on the mediator and outcome variables of interest in the current study, we aimed to ultimately minimize bias in estimating mediation effects (Kline, 2015).

Procedure

All data in the current study were previously collected, scored, and entered into the NIH National Database for Autism Research data archive by trained clinicians at various research sites within the Early Autism Risk Longitudinal Investigation network. Extant data used for the current study includes three previously administered measures of interest: the Sensory Experiences Questionnaire (Baranek et al., 2006), the Child Behavior Checklist (Achenbach & Rescorla, 2001), and the Autism Diagnostic Observation Schedule – Generic (Lord et al., 2000) or Second Edition (Lord et al., 2012) restricted and repetitive behavior subdomain. Participant data on these measures were obtained for secondary analysis via the National Database for Autism Research, permitted by the National Institute for Mental Health (NIHM) and our currently active and approved Data Use Certification.

Participants were previously or are still currently enrolled in the Early Autism Risk Longitudinal Investigation study which recruits mothers of children who have a diagnosis of autism and are either considering becoming or are already pregnant with a new pregnancy, because children born from the mothers' subsequent pregnancies are considered to be at elevated likelihood for developing autism themselves (Miller et al., 2019). The Early Autism Risk Longitudinal Investigation network is funded by the NIH through their Autism Centers of Excellence program as well as Autism Speaks, and the American Healthcare Council. The ultimate goal of this broader study is to obtain prospective data in order to examine possible factors that impact child development, particularly related to autism.

Mothers of children at elevated likelihood for autism provided consent and children provided assent when applicable. All Early Autism Risk Longitudinal Investigation study protocols, consent, and assent forms were approved by the Drexel University Institutional Review Board and by Institutional Review Boards at all other Early Autism Risk Longitudinal Investigation study sites. The Early Autism Risk Longitudinal Investigation study has also been approved and provided funding for by the NIH. For the purposes of the current study, authorization from the Institutional Review Board at Syracuse University was obtained determining that the current protocol qualifies for exemption from federal regulations under category 4, and that this authorization will remain active for five years from September 13, 2021, until September 12, 2026.

Various sources of direct and indirect data were collected on mothers and children at elevated likelihood for autism, beginning during the gestational period, through the first 4.5 years (52 months) of the children's lives. During this time, researchers from each site within the Early Autism Risk Longitudinal Investigation network (i.e., Drexel University and the Center for

Autism Research; Johns Hopkins University and the Kennedy Krieger Institute; Kaiser Permanente Division of Research; and University of California, Davis, and the MIND Institute) collected biological, environmental, and developmental data at various timepoints through direct and indirect methods via home-visits, clinic-visits, and mail-in surveys. Particularly, developmental data on children at elevated likelihood for autism was collected when children were approximately 0 months, 12 months, 24 months, 36 months, and 42 months of age.

For the purposes of the current study, extant data that was used included parent reports of the Sensory Experiences Questionnaire (Baranek et al., 2006), and the Child Behavior Checklist (Achenbach & Rescorla, 2001), as well as the Autism Diagnostic Observation Schedule (Lord et al., 2000; Lord et al., 2012) which was administered to children in the clinic by trained clinicians. The mean ages, standard deviations (*SD*), and full age range of each measures' administration in the current sample can be found in Table 2. In order to obtain a measure of cognitive intelligence and early learning skills, the Mullen Scales of Early Learning for infancy to 68 months of age (Mullen, 1995) was administered to all children in the clinic by trained clinicians. For the purposes of the current study, Early Learning composite scores on the Mullen Scales of Early Learning were used to covary for IQ amongst participants in our analysis, in addition to covarying for sex. Because cognitive abilities continue to change throughout development and measures of cognitive functioning become more stable over time (Bartels et al., 2002; Blaga et al., 2009), cognitive scores from follow-up were considered to be most representative of participants' cognitive abilities. Thus, Early Learning composite scores obtained at follow-up were used in the current study, with the exception of two participants' scores which were obtained only at baseline.

Consistent across all participants in the current study, the Sensory Experiences Questionnaire was administered at baseline (Time 1), and the Child Behavior Checklist and the Autism Diagnostic Observation Schedule were administered at one of the two follow-ups (Time 2 or Time 3) based on scheduling and family preference. Because the time of administration for the Child Behavior Checklist and the Autism Diagnostic Observation Schedule varied across participants between the two follow-up appointments, but nonetheless were still administered at follow-up (between the ages of 24-52 months), we consider and refer to the timing of these two measures as "Time 2 or Time 3" throughout this paper. Please refer to Table 2 for participants' exact ages at the time of each measure administration.

Data Analytic Strategies

Descriptive analyses and bivariate correlations were conducted using *R*, Version 1.2.5033 (R Studio Team, 2019), and assessment of the study variables' normality was conducted using *Mplus*, Version 8.7 (Muthén & Muthén, 2017). All variables included in the current study were continuous, and there was no missing data. Based on interpretation of preliminary descriptive statistics, all study variables were normally distributed based on univariate skewness and univariate kurtosis values no greater than ± 2 (Kline, 2015; Nevitt & Hancock, 2000). The study variable of restricted, repetitive behaviors had a univariate skew of 1.33 and kurtosis of 1.60 which were within normal range, though visual inspection of the histogram plot indicated some skewness. Thus, the current study included maximum likelihood estimation (ML) with bootstrap methods to further improve the study variables' distributions and account for any skewness (Desalu et al., 2017; Kline, 2015).

To test the hypothesized path model's fit to the data as well the alternative path model's fit to the data, path analyses were conducted using *Mplus*, Version 8.7 (Muthén & Muthén,

2017). Given that the hypothesized mediator and outcome variables were administered at similar time points in the current study, conducting a path analysis with an alternative model in which the hypothesized mediator and outcome variables were switched allowed for more robust interpretations regarding the directionality and temporal relationship between the predictor, mediator, and outcome variables (Mitzel et al., 2021).

For each mediation model, significance testing was performed using estimates of 95% bootstrap confidence intervals of the mediating effect based on 10,000 bootstrap resamples, using *Mplus* Version 8.7 (Muthén & Muthén, 2017). Significant effects are indicated by bootstrap confidence intervals that exclude the value of zero. Because alternative methods such as Sobel's first-order test (Sobel, 1982) can fail to detect significant mediating effects, especially with lower sample sizes or non-normally distributed variables (Fritz & MacKinnon, 2007; Özdil & Kutlu, 2019), conducting analyses with estimates of 95% bootstrap confidence intervals allowed better power for the current mediation analysis and accounted for any non-normality of the mediation effect. An additional measure of effect size, the proportion mediated (based on the proportion of the total effect mediated by the mediating/intervening variable), was included as well (MacKinnon, 2008). To compare non-nested model fits directly, Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC) values were calculated for both the hypothesized and alternative models (Aho et al., 2014; Burnham & Anderson, 2004). The model with the lower AIC and BIC values is suggestive of a better fit to the data (Burnham & Anderson, 2004).

The hypothesized mediation model (Figure 1) included the Sensory Experiences Questionnaire (Baranek et al., 2006) sensory hyperresponsiveness raw score as the predictor variable, the Child Behavior Checklist (Achenbach & Rescorla, 2001) anxiety raw score as the

mediator variable, and the Autism Diagnostic Observation Schedule (Lord et al., 2000; Lord et al., 2012) restricted and repetitive behavior total raw score as the outcome variable. The alternative mediation model (Figure 2) included the Sensory Experiences Questionnaire (Baranek et al., 2006) sensory hyperresponsiveness raw score as the predictor variable, the Autism Diagnostic Observation Schedule (Lord et al., 2000; Lord et al., 2012) restricted and repetitive behavior total raw score as the mediating variable, and the Child Behavior Checklist (Achenbach & Rescorla, 2001) anxiety raw score as the outcome variable. Effects of participants' IQ (as measured by Early Learning composite scores; Mullen, 1995), and sex, were controlled for on the mediation and outcome variables in both models.

Power Analysis

Guidance regarding the necessary sample sizes for common mediation models with 0.8 power can be understood by examining the effect sizes within the literature of both the 'a' path (association between predictor variable and mediator) and 'b' path (association between mediator and outcome variable) in a hypothesized mediation model and then comparing the combination of the two effect sizes to empirical estimates provided by Fritz and MacKinnon (2007). Currently, there are no studies that show an association between sensory hyperresponsiveness and anxiety, nor anxiety and restricted, repetitive behaviors, specifically in populations at elevated likelihood for autism; however, studies show strong associations of each relationship among autistic populations (Black et al., 2017; Green et al., 2012; Rodgers et al., 2012a; Wigham et al., 2015) which are phenotypically similar to our population here, provide the theoretical basis for the current study's research questions and hypotheses, and are representative of the developmental pathways that the current study aims to elucidate. Furthermore, studies have examined some but not all of these relationships among typically developing children

(Carpenter et al., 2019), in which case the effect size of such associations among typically developing populations are also considered to further promote the current study's power. As such, based on the medium to large effect size of the relation between sensory hyperresponsiveness and anxiety in autistic (r = 0.52 – 0.71; Black et al., 2017; Green et al., 2012) and typically developing children (β = 0.55; Carpenter et al., 2019), and the medium to large effect size among anxiety and restricted, repetitive behaviors in autistic children (r = 0.40 – 0.69; Rodgers et al., 2012a; Wigham et al., 2015), the necessary sample size for a mediation with 0.8 power via percentile bootstrap confidence intervals is 78. In other words, comparing combinations of just medium effect sizes across both paths 'a' and 'b' yields a sample size of 78 via percentile bootstrapping with 0.8 power, which is within the range of our current sample size (N = 147). Additionally, regarding the alternative mediation model in the current study, studies demonstrate a medium effect size of the relation between sensory hyperresponsiveness and restricted, repetitive behaviors in populations at elevated likelihood for autism (r = 0.48 – 0.53 for ritualistic/repetitive and restricted behaviors respectively; Wolff et al., 2019). Based on a comparison of medium effect sizes for each path here, the necessary sample size for our alternative mediation model with 0.8 power is 78 via percentile bootstrap confidence intervals. Thus, the obtained sample size in the current study (N = 147) is adequately powered and sufficient to detect statistical significance for a mediation effect using percentile bootstrap confidence intervals in both the hypothesized and the alternative model.

Results

Descriptive Analyses

Descriptive analyses and bivariate correlations were conducted using *R*, Version 1.2.5033 (R Studio Team, 2019), and visual inspection of the study variables' normality was conducted

using *Mplus*, Version 8.7 (Muthén & Muthén, 2017). All study variables were continuous and normally distributed (univariate skewness = 0.87 – 1.33; univariate kurtosis = 1.38 – 1.60). Sample characteristics are presented in Table 1, means and standard deviations of study variables are presented in Table 2, and bivariate correlations are presented in Table 3. Sensory hyperresponsiveness was significantly and positively correlated with anxiety ($r = 0.24$, $p < 0.01$). Covariate variables of sex and IQ were significantly correlated with restricted, repetitive behaviors, such that higher levels of restricted, repetitive behaviors were positively associated with being male ($r = 0.43$, $p < 0.001$), and negatively associated with IQ ($r = -0.35$, $p < 0.001$).

Path Analysis Models

Model 1

In Model 1, the hypothesized model, sensory hyperresponsiveness was entered as the predictor variable, anxiety was entered as the mediating variable, and restricted, repetitive behaviors was entered as the outcome variable. The results of this model, including standardized path coefficients (with 95% bootstrap CIs in parentheses) are shown in Figure 1. The effects of participants' sex and IQ on the mediating and outcome variables were controlled for (paths not shown for simplicity). For the indirect path from the predictor to the mediating variable, sensory hyperresponsiveness had a significant positive effect on anxiety ($b = 0.09$, $SE = 0.04$, $\beta = 0.24$, $p = 0.005$, 95% CIs [0.07, 0.41]), such that that higher levels of sensory hyperresponsiveness at baseline were significantly associated with higher levels of anxiety symptoms at follow-up. In turn, regarding the indirect path from the mediating variable to the outcome variable, the indirect effect of anxiety on restricted, repetitive behaviors was nonsignificant ($b = 0.02$, $SE = 0.05$, $\beta = 0.03$, $p = 0.66$, 95% CIs [-0.10, 0.17]). Regarding the direct path from the predictor to the outcome variable, the direct effect of sensory hyperresponsiveness on restricted, repetitive

behaviors was nonsignificant (b = 0.00, SE = 0.02, β = 0.01, p = 0.91, 95% CIs [-0.16, 0.18]). No significant mediation effect was indicated by the bootstrap confidence interval (95% bootstrap CI [-0.03, 0.05]). However, 20% of the total effect of sensory hyperresponsiveness at baseline on restricted, repetitive behaviors at follow-up at was mediated by anxiety symptoms at follow-up (Table 4). This model explained 8% of the variance in anxiety symptoms (p = 0.12), 19% of the variance in restricted, repetitive behaviors (p < 0.001), and had an AIC value of 1200.476 and BIC value of 1233.371.

Model 2

In Model 2, the alternative model, sensory hyperresponsiveness was entered as the predictor variable, restricted, repetitive behaviors was entered as the mediating variable, and anxiety was entered as the outcome variable. The results of this model, including standardized path coefficients (with 95% bootstrap CIs in parentheses) are shown in Figure 2. The effects of participants' sex and IQ on the mediating and outcome variables were controlled for (paths not shown for simplicity). For the indirect path from the predictor to the mediating variable, the indirect effect of sensory hyperresponsiveness on restricted, repetitive behaviors was nonsignificant (b = 0.01, SE = 0.02, β = 0.02, p = 0.84, 95% CIs [-0.14, 0.18]). In turn, regarding the indirect path from the mediating variable to the outcome variable, the indirect effect of restricted, repetitive behaviors on anxiety was also nonsignificant (b = 0.05, SE = 0.11, β = 0.03, p = 0.66, 95% CIs [-0.11, 0.18]). Regarding the direct path from the predictor to the outcome variable, there was a significant direct effect of sensory hyperresponsiveness on anxiety (b = 0.09, SE = 0.04, β = 0.24, p = 0.005, 95% CIs [0.07, 0.40]), such that that higher levels of sensory hyperresponsiveness at baseline were significantly associated with higher levels of anxiety symptoms at follow-up. No significant mediation effect was indicated by the bootstrap

confidence interval (95% bootstrap CI [-0.02, 0.01]). As such, 0% of the total effect of sensory hyperresponsiveness at baseline on anxiety at follow-up was mediated by restricted, repetitive behaviors at follow-up at (Table 4). This model explained 19% of the variance in restricted, repetitive behaviors ($p < 0.001$), 8% of the variance in anxiety symptoms ($p = 0.13$), and had an AIC value of 1200.476 and BIC value of 1233.371.

Model Comparison

To directly compare model fits, AIC and BIC values were calculated for each model (Aho et al., 2014; Burnham & Anderson, 2004). Model comparisons revealed that Model 1 (AIC = 1200.476; BIC = 1233.371) and Model 2 (AIC = 1200.476; BIC = 1233.371) had the same fit to the data. In other words, neither Model 1 nor Model 2 demonstrated a better fit to the data. Furthermore, such model comparisons are not particularly relevant for interpretation in the current study as neither model demonstrated significant mediating effects.

Discussion

The focus of this study was to examine the relationships between sensory hyperresponsiveness, anxiety, and restricted, repetitive behaviors across time among young children at elevated likelihood for developing autism. Overall, current findings indicate that sensory hyperresponsiveness during early development later predicts anxiety symptoms. This finding is consistent with previous studies in which higher levels of sensory hyperresponsiveness at baseline (Time 1) is shown to predict heightened levels of anxiety later at follow-up (Time 2) in both autistic (Green et al., 2012) and non-autistic children (Carpenter et al., 2019). The current finding was replicated, however, in a sample of children at elevated likelihood for autism, and therefore provides novel insight into this area of literature. These results add to emerging research suggesting that sensory hyperresponsiveness may be a risk factor for later developing

anxiety, though we are not able to determine whether this is a unidirectional or bidirectional relationship given that anxiety symptoms were not measured at baseline (Time 1) in the current study.

Although the path analyses in the current study did not reveal significant mediating effects, the proportion of the total effect that was mediated by the mediating variable of anxiety in the hypothesized model (Model 1) was 20%, whereas the proportion of the total effect that was mediated by restricted, repetitive behaviors in the alternative model (Model 2) was 0%. This suggests that anxiety may potentially play a greater role in the relationship between sensory hyperresponsive and restricted, repetitive behaviors, than restricted, repetitive behaviors may play in the relationship between sensory hyperresponsiveness and anxiety. The current findings, however, did not reveal any change in AIC or BIC values between Model 1 and Model 2. Additionally, although the current model comparisons suggested that neither model was a better fit to the data, there were no significant mediating effects for either Model 1 or Model 2. Therefore, interpretation of the model comparisons is not particularly relevant given the nonsignificant mediation results across each model.

Consistent with previous research (Bishop et al., 2006; Uljarević et al., 2022), the current study found both sex and IQ to be significantly correlated with restricted, repetitive behaviors. Though this was not surprising, the current study showed that higher levels of restricted, repetitive behaviors were found in males compared to females, and that lower IQ scores were associated with higher restricted, repetitive behavior scores. Additionally, IQ was associated with sex such that higher IQ scores were found in females compared to males. Together, these findings are consistent with what we know about autism, as well as the female phenotype in autism (Kirkovski et al., 2013; Ratto et al., 2018). For instance, autistic females with average to

above average cognitive abilities are less likely to be identified or meet full diagnostic criteria for autism compared to autistic males with average to above average cognitive abilities (Loomes et al., 2017; Ratto et al., 2018). Additionally, although autistic males tend to display higher levels of restricted, repetitive behaviors than females, the types of restricted, repetitive behaviors displayed by autistic females often relate to more common content areas such as books, animals, or dolls, compared those of autistic males. These behaviors may therefore be more difficult to readily identify among females using current diagnostic procedures (Halladay et al., 2015; Kirkovski et al., 2013; Ratto et al., 2018). Lastly, negative associations between restricted, repetitive behaviors and IQ have been previously demonstrated in autistic populations, such that higher levels of most restricted, repetitive behaviors have been found to occur in autistic children with lower levels of cognitive functioning (Bishop et al., 2006). The inclusion of sex and IQ as covariates in the current study was determined *a priori*, given their previously known associations with restricted, repetitive behaviors (Bishop et al., 2006; Uljarević et al., 2022), and anxiety (Edirisooriya et al., 2021; Hartley & Sikora, 2009; Sukhodolsky et al., 2008). Overall, the current findings further support such research on restricted, repetitive behaviors with regard to sex and IQ, and add to the existing literature by demonstrating such associations in a sample of children at elevated likelihood for autism.

The Role of Restricted, Repetitive Behaviors

Developmental Considerations

The current study did not find significant predictive associations between either sensory hyperresponsiveness and restricted, repetitive behaviors, or anxiety and restricted, repetitive behaviors. One reason for this may be related to the overall profiles of children in the current sample. For instance, given that autism occurs in approximately 16-22% of children at elevated

likelihood for autism (Ersoy et al., 2021; Ozonoff et al., 2011; Wolff et al., 2019), and that up to 38% of children at elevated likelihood for autism go on to develop other clinical conditions (Ersoy et al., 2021; Miller et al., 2016; Shephard et al., 2017), it is possible that a significant proportion of children in the current sample did not develop autism and therefore perhaps did not demonstrate heightened levels of restricted, repetitive behaviors. Alternatively, it is also possible that perhaps more children who went on to develop autism in the current sample may have presented with greater difficulties related to social communication, rather than restricted, repetitive behaviors at the time of the autism evaluation. Throughout the developmental course of autism, delays in language development and social interaction/social communication tend to emerge as the beginning symptoms, while restricted, repetitive behaviors tend to become more apparent during the second year of life (APA, 2013). Given that typically developing children also tend to demonstrate restricted, repetitive behaviors at this age (e.g., hold strong preferences and enjoy repetition, such as eating the same foods or watching the same video repeatedly), it can be difficult to distinguish restricted, repetitive behaviors that are diagnostic of autism particularly among preschool-aged children (APA, 2013).

In examining the current dataset, 25.5% of the current sample presented with autism, 23.1% presented with other non-neurotypical/developmental presentations (gross motor/fine motor delays [3.4%]; behavioral difficulties such as hyperactivity and inattention [5.4%]; speech and language difficulties and/or delays [11.6%]; clinically significant anxiety [2.7%]), and 51.7% presented as neurotypical. Interestingly, of the 23.1% who presented with other non-neurotypical presentations but not autism, up to 15% of them presented with either a developmental delay or difficulties with speech/language, which are both commonly experienced by young children with autism and as mentioned, are often the first signs or symptoms that begin

to manifest (APA, 2013). These findings provide some insight into a possible phenotype within young children at elevated likelihood for autism, characterized by heightened social communication difficulties, with or without autism.

It is possible that children in the current study did not yet demonstrate restricted, repetitive behaviors due to the time frame in which this measure was collected. Previous studies suggest that in typical development, restricted, repetitive behaviors which form as a normative, adaptive coping mechanism in response to fear and anxiety, begin around 24 months of age, peak at about 72 months of age, and steadily decline thereafter as other forms of self-regulation begin to develop (Arnott et al., 2010; Cevikaslan et al., 2013; Evans et al., 1997; Leekam et al., 2007; Uljarević & Evans 2017). In autism however, such behaviors continue to persist (Rodgers et al., 2012b). Relatedly, although symptoms of autism must be present during early developmental periods in order to be diagnosed with autism, such symptoms, including restricted, repetitive behaviors, may not fully manifest or become as clear until later in life when the social demands of one's environment begin to exceed one's capacity (APA, 2013).

Given that the mean age of the current sample was 36 months when assessed for restricted, repetitive behaviors, it is possible that the children in the current study may have not yet begun to use restricted, repetitive behaviors as a coping mechanism and therefore may have not shown them. Furthermore, the age range of the current sample is much younger compared to the age range (i.e., 8-16 years) of children in previous studies that demonstrated significant associations between restricted, repetitive behaviors and both sensory hyperresponsiveness (Wigham, et al., 2015) and anxiety (Rodgers et al., 2012a; Rodgers et al., 2012b; Wigham et al., 2015) among autistic youth. As such, future studies should include a measure of restricted, repetitive behaviors at a later time-point in development, such as 72 months of age, in order to

potentially capture an increased presence of restricted, repetitive behaviors among children at elevated likelihood for autism.

Sensory Processing Considerations

Lastly, it is possible that other forms of sensory responsiveness may be relevant to restricted, repetitive behaviors in this sample. The current study did not include scores for either sensory hyporesponsiveness or sensory seeking behaviors in our analyses. Instead, our study chose to focus on sensory hyperresponsiveness given that it is most highly prevalent in autism compared to other clinical conditions and neurotypical populations (Baranek et al., 2006; Ben-Sasson et al., 2009; Leekam et al., 2007; Marco et al., 2011; Wolff et al., 2019). Additionally, compared to other sensory symptoms, sensory hyperresponsiveness has been found to show the most robust group differences at 12 months of age in children at elevated likelihood for autism who later developed autism compared to those who did not later develop autism, and compared to neurotypical peers (Wolff et al., 2019) which suggests that it may be more important in the to the etiology of autism than researchers once thought.

However, given that the current study did not find a significant association between sensory hyperresponsiveness and restricted, repetitive behaviors as we had hypothesized, it is possible that other sensory symptoms, including hyporesponsiveness and/or sensory seeking, may play an important role in the presentation of restricted, repetitive behaviors among the current sample. For instance, despite Wolff and colleagues' (2019) previous finding that the most robust group differences at 12 months of age was related to sensory hyperresponsiveness, they also found heightened levels of sensory hyporesponsiveness and sensory seeking behaviors among children at elevated likelihood for autism who were later diagnosed with autism compared to those who were not later diagnosed and compared to neurotypical peers.

Furthermore, positive associations were found between restricted, repetitive behaviors and each form of sensory responsiveness (hyperresponsiveness, hyporesponsiveness, and seeking) in children at elevated likelihood for autism who were later diagnosed with autism, although associations between sensory hyperresponsiveness and restricted, repetitive behaviors were found to have stronger associations overall at both 12 and 24 months of age (Wolff et al., 2019). Prior theories and empirical data (Rogers & Ozonoff, 2005) suggest that under-arousal and under-registration of the external environment (i.e., sensory hyporesponsiveness) in particular may be linked to the pathophysiology of autism, though this literature overall remains sparse and relatively inconsistent (Foss-Feig et al., 2012; Wigham et al., 2015; Wolff et al., 2019). Further research is warranted to explore these possible relations between other sensory symptoms (i.e., sensory hyporesponsiveness, and sensory seeking), and restricted, repetitive behaviors, as well as how each possible association may relate to anxiety.

Clinical Implications

Our findings suggest that sensory hyperresponsiveness in particular may not be as strongly linked to the particular autistic symptom of restricted, repetitive behaviors as we had hypothesized, at least not in our sample of children at elevated likelihood for autism. As discussed earlier, it is possible that this specific sensory symptom of sensory hyperresponsiveness may perhaps be more strongly associated with other symptoms of autism beyond restricted, repetitive behaviors, such as those related to social communication/social affect which were not analyzed here. It is also possible that other sensory symptoms not included in the current study may play a larger role in autism than sensory hyperresponsiveness. Despite not finding a significant association between our variables of interest, our findings neither support nor deny the importance of sensory symptoms in autism, given the caveat that our

sample included children with genetic predispositions of developing autism rather than children all with autism, and that our analyses targeted specific aspects of sensory symptoms and autistic symptoms, but not all.

Early Sensory Hyperresponsiveness Predicts Anxiety

Although we are unable to make any inferences about the importance of sensory hyperresponsiveness in autism, our findings instead provide novel nuances to the literature on children at elevated likelihood for autism. Given the positive association found between sensory hyperresponsiveness and anxiety in our sample, our findings suggest that sensory hyperresponsiveness is important for predicating anxiety in this population. Previous samples of children at elevated likelihood for autism have only demonstrated predictive relationships between sensory hyperresponsiveness and restricted, repetitive behaviors, not anxiety (Grzadzinski et al., 2020; Wolff et al., 2019). Furthermore, a predictive relationship between sensory hyperresponsiveness and anxiety has only been previously demonstrated in groups of autistic children (Green et al., 2012; Wigham et al., 2015), and typically developing children (Carpenter et al., 2019). To our knowledge, our study is the first to demonstrate that sensory hyperresponsiveness positively predicts anxiety in children at elevated likelihood for autism. Consistent with previous studies in which this relationship was demonstrated (Carpenter et al., 2019; Green et al., 2012; Wigham et al., 2015), this finding suggests that sensory hyperresponsiveness is important to anxiety and may play an important role in the development of anxiety symptoms, with or without co-occurring autism symptoms.

Our finding on the relationship between sensory hyperresponsiveness at baseline and anxiety symptoms at follow-up has important implications for both assessment and therapeutic techniques. Sensory hyperresponsiveness, which has now been shown to be associated with later

anxiety symptoms among typically developing children, autistic children, and young children at elevated likelihood for autism, can be seen as early as 0-27 months of age, and on average, as early as 12 months of age (M = 12.37, SD = 4.80), as demonstrated in the current study. Previous studies that have demonstrated this association between sensory hyperresponsiveness and anxiety have done so in samples of children older in age, with the earliest measure of hyperresponsiveness being between 18-33 months in autistic children (Green et al., 2012), and 24-60 months in typically developing children (Carpenter et al., 2019).

Our findings not only provide further support for the predictive relationship between sensory hyperresponsiveness and anxiety but provide novel evidence that this association can be found when including measures of sensory hyperresponsiveness from an even earlier time point. Taken together, findings suggest that sensory hyperresponsiveness during infancy and toddlerhood may serve as an early risk factor for later developing anxiety symptoms. Assessing for sensory hyperresponsiveness among all children during early development can provide possible insight into a child's developmental trajectory, with regards to whether or not they will be more likely to also experience anxiety. Additionally, given that this association has been demonstrated across both clinical and non-clinical populations of children, our findings contribute to the literature by replicating this association among a broader population of children whose later presentations included both neurotypical and non-neurotypical symptoms. Together, such findings may help to further normalize children's experiences of sensory hyperresponsiveness and anxiety, and their potential impact on a child's daily functioning. This can ultimately help reduce the stigma related to either or both of these experiences in children and allow for increased awareness and acceptance of such experiences among all children despite their presentation.

Neurodiversity-Affirmative Education for Youth

Increasing awareness and acceptance of children's sensory needs, and how they may relate to symptoms of anxiety, can allow for increased modifications to children's everyday environments, which can further promote children's learning and overall success. When applied in a school context, such modifications might include dimming or reducing the amount of light in a room, providing children access to noise-reducing headphones throughout the day, or allowing brief breaks in a quiet/calming area when a child becomes over-stimulated and distressed. Although much more work is needed to reframe how educators think about and approach the naturally occurring variability among children's needs, some have begun to further increase opportunities for inclusiveness in education settings by suggesting the adoption of a universal classroom design, based on a neurodiversity-affirmative model for education (Aitken & Fletcher-Watson, 2022).

Consistent with this model, school systems should consider the inclusion of appropriate resources to accommodate children's varying needs in classroom settings as the standard, rather than as an optional or secondary approach (Aitken & Fletcher-Watson, 2022). Furthermore, schools can help create neurodiversity-informed environments and promote inclusive education by using less aversive cues to signal a transition rather than the sound of a bell; by making visual schedules accessible to all students in classrooms rather than only to those with specified needs; and if applicable, by adapting school-wide uniform policies to allow greater flexibility for children with sensory hyperresponsiveness/tactile sensitivities who may be unable to tolerate wearing such uniforms or materials (Aitken & Fletcher-Watson, 2022; Rutherford & Johnston, 2019). In addition to promoting the overall success of children with varying needs, this approach can further support undiagnosed and otherwise-typically developing children as well. For

instance, given findings in previous studies (Carpenter et al., 2019; Green et al., 2012; Wigham et al., 2015), as well as the current study, that suggest a connection between sensory hyperresponsiveness and anxiety in both clinical and non-clinical populations, modifications targeting varying sensory needs from this perspective may have positive impacts on the functioning and well-being of all children in education settings, not just those with identified differences.

Limitations and Future Directions

Measure of Anxiety

There were a number of limitations in the current study. First, anxiety was not measured at baseline (Time 1) in the original sample from which the data was drawn. Therefore, the presentation of anxiety among the current sample cannot be assessed over time. In other words, we are unable to determine whether anxiety increases, decreases, or remains stable over time during early development in children at elevated likelihood for autism. Additionally, because of the lack of data on anxiety at baseline, we are unable to determine whether the relationship between sensory hyperresponsiveness and anxiety is unidirectional or bidirectional. As such, we cannot confirm whether sensory hyperresponsiveness is truly an early predictor/risk-factor for later developing anxiety as others have suggested (Carpenter et al., 2019; Green et al., 2012), though our findings certainly support this notion.

Measure of Restricted, Repetitive Behaviors

Second, restricted, repetitive behaviors were measured as part of the Autism Diagnostic Observation Schedule (Lord et al., 2000; Lord et al., 2012), rather than a specific questionnaire for such behaviors, such as the Restricted Behaviors Questionnaire for instance (Turner, 1996; 1999). Although the Autism Diagnostic Observation Schedule (Lord et al., 2000; Lord et al.,

2012) is a reliable and valid measure for assessing restricted, repetitive behaviors (Kim & Lord, 2012; Lebersfeld et al., 2020; Lord et al., 2000; Lord et al., 2012; Newschaffer et al., 2012), the time of administration is approximately 40-60 minutes (Lord et al., 2012), therefore limiting the amount of time or opportunities in which restricted, repetitive behaviors may have been observed. As such, this may have negatively affected the likelihood of observing restricted, repetitive behaviors and thus clinicians' subsequent ratings of restricted, repetitive behaviors in the current sample.

The restricted, repetitive behaviors measure on the Autism Diagnostic Observation Schedule (Lord et al., 2000; Lord et al., 2012) seeks to assess observations of stereotyped/idiosyncratic use of words or phrases, unusual sensory interest in play material/person, hand and finger and other complex mannerisms, unusually repetitive interests, or stereotyped behaviors, and intonation of vocalizations or verbalizations. Although unusual sensory interests are included in the restricted, repetitive behaviors domain, observations of unusual sensory interests on the Autism Diagnostic Observation Schedule are characterized by sensory seeking behaviors and possible under-arousal/hyporesponsiveness rather than hyperresponsiveness. For instance, the unusual sensory interests item code refers to behaviors such as sniffing, licking, biting, or repetitively feeling certain play material or textures, unusual interest in repeatedly hearing particular sounds/eliciting certain noises, or unusual or prolonged visual inspection of an item/person/aspect of the environment (Lord et al., 2000; Lord et al., 2012).

Conversely, observations of sensory behaviors characterized by sensory hyperresponsiveness seem to be coded under the anxiety item code on the Autism Diagnostic Observation Schedule (Lord et al., 2000; Lord et al., 2012), which is not included in either the

social affect or the restricted, repetitive behavior domain, nor the diagnostic algorithm. For instance, the anxiety item code can include observations of anxiety in response to a particular toy, which can be reflective of sensory hyperresponsiveness given that hyperresponsiveness is characterized by an adverse and/or avoidant response to particular sensory stimuli (Baranek et al., 2006). Given that this item was not included in our measure of restricted, repetitive behaviors, and given that the unusual sensory interests item that was included in the restricted, repetitive behaviors did not capture observations of sensory hyperresponsiveness in particular, we do not suspect there to be any confounding effects on our analyses. However, future studies should consider these implications when choosing which measure of restricted, repetitive behaviors to use, and should perhaps control for unusual sensory interests within the restricted, repetitive behavior domain anyway if using the Autism Diagnostic Observation Schedule.

The current study examined the relationships between sensory hyperresponsiveness, anxiety, and restricted, repetitive behaviors; however, social affect scores were not included in our analyses. Restricted, repetitive behaviors represent one phenotypical aspect/symptom domain of autism, while social affect represents another symptom domain of autism. Future studies should examine the relationships between sensory hyperresponsiveness, anxiety, and social affect as well, as there may be associations between such variables among children at elevated likelihood for autism.

Possible Role of Social Communication/Social Affect

Previous studies have demonstrated links between social communication difficulties and symptoms of various anxiety disorders in clinically anxious children (Halls et al., 2015; Van Steensel et al., 2013). Specific positive associations between social communication difficulties and social anxiety symptoms in particular have also been demonstrated among non-autistic

anxious children (Halls et al., 2015). Furthermore, children with symptoms of social anxiety disorder have been found to demonstrate more social communication difficulties compared to other anxious children without social anxiety symptoms. This is not surprising given the socially impairing nature of symptoms related to social anxiety disorder (APA, 2013). However, children with social anxiety symptoms were also significantly more likely to score above the cut-off criteria for autism compared to anxious children without social anxiety (Halls et al., 2015). Together, these findings not only demonstrate the presence of anxiety and co-occurring social communication difficulties in some children, but further suggest there may be an underlying relationship between the two in relation to autism features as well.

Conversely, others have found varying patterns of social communication difficulties and anxiety among typically developing children, children with prior diagnoses of Pervasive Developmental Disorder-Not Otherwise Specified (a previously recognized phenotype of autism characterized by fewer or less severe autistic symptoms), and children with clinical diagnoses of autism (Davis et al., 2011). Social communication difficulties have been found to predict higher levels of anxiety among typically developing children and those with Pervasive Developmental Disorder-Not Otherwise Specified. However, the opposite has been demonstrated in autistic children. As such, increased social communication difficulties were found to predict lower levels of anxiety in autistic children. Given the variability in the relationship between social communication difficulties and anxiety found across different phenotypes of autism, typical development (Davis et al., 2011), and clinical anxiety (Halls et al., 2015; Van Steensel et al., 2013), it remains unclear what this relationship might look like in children at elevated likelihood for autism. Further research is needed in order to examine such associations within samples of children at elevated likelihood for autism, and in relation to sensory hyperresponsiveness, in

order to better understand whether and how these variables may impact the development and presentation of one another.

Understanding the Manifestation of Anxiety Over Time

Although the current study used a reliable and valid measure designed to assess anxiety as early as 18 months (Achenbach & Rescorla, 2001), the mean age of children in our sample at baseline was 12 months. This may be one reason why anxiety was not also assessed at baseline, and instead, was only assessed at follow-up, when children were older and anxiety scores were perhaps more reliable. Because of this, however, we are unable to make any inferences about the course of anxiety in our sample over time. Future longitudinal studies should collect data on anxiety symptoms at baseline in addition to follow-up periods in order to better understand the development of anxiety over time, and to determine directional effects between sensory hyperresponsiveness and anxiety in this population.

Findings from prior studies (Carpenter et al., 2019; Green et al., 2012) provide some insight into the manifestation of anxiety over time. For instance, anxiety symptoms have been shown to significantly increase over time in autistic toddlers, with increases demonstrated at 30-45 months of age compared to 18-33 months of age (Green et al., 2012). In a community sample, Carpenter and colleagues (2019) found increased levels of anxiety symptoms among children who were sensory hyperresponsive compared to those we were not sensory hyperresponsive. This pattern was found both at baseline when children were preschool-aged (2-5 years), and again at follow-up, when children were school-aged (6 years).

In discussing the changing nature of behavioral presentations of anxiety over time, findings from Carpenter and colleagues' (2019) study further revealed that more children with sensory hyperresponsive experienced separation anxiety (29.8%) than either generalized anxiety

(18.9%) or social phobia (14.4%) when they were 2-5 years of age. This pattern later changed such that more children with sensory hyperresponsiveness later experienced generalized anxiety disorder (36.9%) followed by social phobia (14.13%), followed by separation anxiety (8.12%) when children were 6 years of age. In those who did not demonstrate sensory hyperresponsiveness, levels of anxiety were similar for each category of anxiety at baseline (ranging from 5.6% - 5.9% for generalized anxiety, separation anxiety, and social phobia), but later varied at follow-up, with decreases in separation anxiety (2.0%) and increases in both generalized anxiety (8.4%) and social phobia (5.7%). These findings suggest that not only is anxiety overall more prevalent in children who also experience sensory hyperresponsiveness, but that separation anxiety in particular may be more prevalent during early development and may later manifest into generalized anxiety, as symptoms of separation anxiety dissipate over time.

Consistent with previous theories, separation anxiety during infancy and toddlerhood is considered to be a normative part of development, and a sign of healthy relationships with caregivers (Ainsworth et al., 1978; Milrod et al., 2014). Given that humans are innately dependent on caregivers during infancy, experiencing anxiety when separated from caregivers is adaptive in early childhood (Bowlby, 1973; Bowlby, 1988; Milrod et al., 2014). However, such symptoms can persist and impair children's abilities to appropriately build independence and autonomy and achieve other developmental tasks such as regularly attending school or sleeping independently without a caregiver (Kossowsky et al., 2013). It has been suggested that the persistence of such symptoms into later childhood can lead to experiences of panic disorder and other forms of anxiety over time, as symptoms of separation anxiety left untreated beyond early childhood can lead to increasingly clinically significant self-perceptions, poor self-efficacy, and emotion dysregulation (Bowlby, 1973; Bowlby, 1988; Milrod et al., 2014). This developmental

perspective on anxiety is consistent with previous findings in which levels of separation anxiety were heightened during early childhood, but later decreased while other forms of anxiety increased in later childhood (Carpenter et al., 2019). Given that this pattern was found among children with and without sensory hyperresponsiveness, though appeared to be more prominent among those with sensory hyperresponsiveness (Carpenter et al., 2019), it may be useful for future studies to assess specific forms of anxiety in addition to overall anxiety symptoms when analyzing the relationship between sensory hyperresponsiveness and anxiety. Such studies may provide greater insight into the nature of this relationship, with particular emphasis on whether and how sensory hyperresponsiveness may impact the developmental course of anxiety over time.

Table 1

Sociodemographic Characteristics of Participants

Participant Characteristics	*n*	*%*
Sex		
Female	68	46.3
Male	79	53.7
Race		
Asian	16	10.9
Black or African American	10	6.8
Hawaiian or Pacific Islander	2	1.4
More than one race	9	6.1
Native American or Alaska Native	1	0.7
Unknown or not reported	14	9.5
White	95	64.6
Ethnicity		
Hispanic or Latinx	24	16.3
Not Hispanic or Latinx	111	75.5
Not Reported	7	4.8
Other	5	3.4

Note. $N = 147$

Table 2
Measure Means and Standard Deviations

Measure	*N*(%)	*M*	*SD*	*Age Range*	*M* age (months)	*SD* age (months)
Baseline (Time 1):						
Hyperresponsiveness raw total (out of 65)	147 (100%)	23.14	5.89	0-27	12.37	4.80
Follow-up (Time 2 or 3):						
Anxiety Symptoms raw score (out of 20)	147 (100%)	2.58	2.28	24-50	36.52	1.83
Restricted, Repetitive Behaviors raw total (out of 8)	147 (100%)	1.53	1.63	24-52	36.08	2.92
Early Learning Composite	147 (100%)	100.27	19.69	12-52	36.20	3.50

Note. $N = 147$. *M* = Mean, *SD* = Standard Deviation. *Age Range* = the range of ages (in months) in which that measure was administered to children in the current sample. The Mullen Scales of Early Learning, Early Learning composite yields a standard score ($M = 100$, $SD = 15$). Mean Anxiety Symptoms *T*-scores are not presented for simplicity but were in the average range.

Table 3

Bivariate Correlations among Study Variables

	Correlation Coefficients			
Variable (range)	1	2	3	4
1. Sex (0 = Female; 1 = Male)	–			
2. IQ (49.00 – 141.00)	-0.25**	–		
3. Sensory Hyperresponsiveness (7.00 – 46.00)	-0.02	-0.04	–	
4. Anxiety (0.00 – 11.00)	0.12	-0.10	0.24**	–
5. Restricted, Repetitive Behaviors (0.00 – 7.00)	0.43***	-0.35***	0.02	0.09

Note. $N = 147$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 4

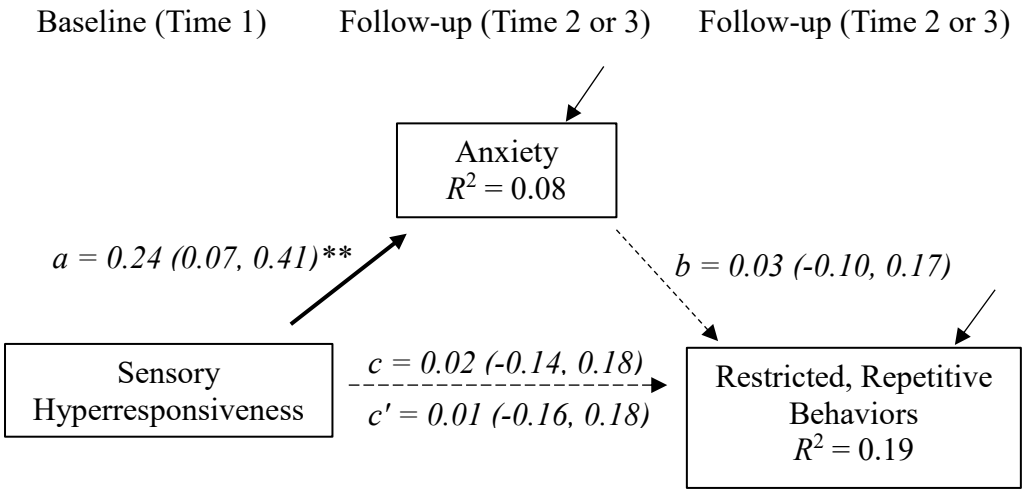
Summary of Results for Mediation Models

Predictor	Mediator	Outcome	Indirect Effect	95% CI of indirect effect	Direct Effect	Total Effect	Proportion Mediated
Sensory Hyperresponsiveness	Anxiety Symptoms	Restricted, Repetitive Behaviors	0.002 (0.01)	-0.01 – 0.01	0.003 (0.01)	0.01 (0.02)	20%
Sensory Hyperresponsiveness	Restricted, Repetitive Behaviors	Anxiety Symptoms	0.00 (0.001)	-0.01 – 0.01	0.09** (0.24)	0.09** (0.24)	0%

Note. $N = 147$. All estimates are unstandardized (standardized coefficients in parentheses). Confidence intervals (CIs) resulted from 10,000 bootstrap draws. *$p < .05$. **$p < .01$. ***$p < .001$.

Figure 1

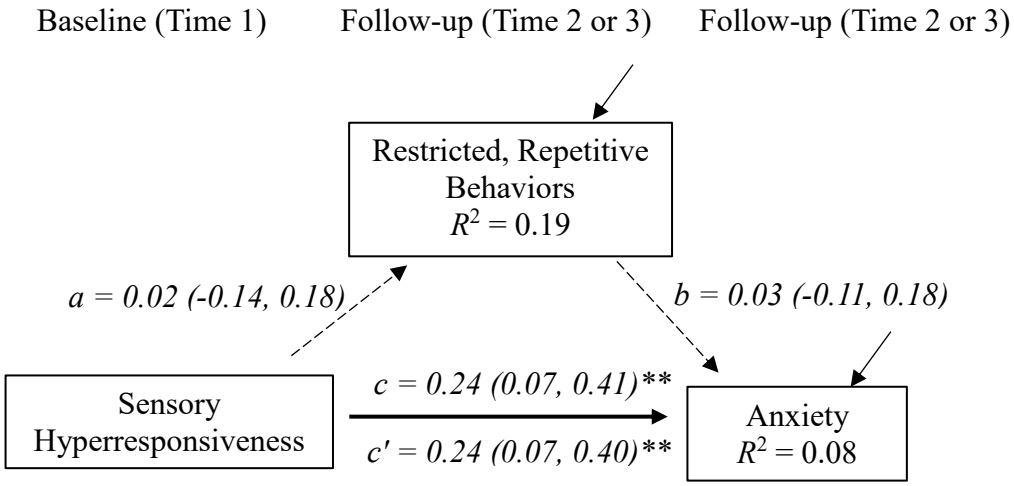
Standardized path coefficients (and 95% bootstrap CIs) of Model 1



Note. N = 147. The effect of sex and IQ on the mediator and outcome variables were controlled for (paths not shown). The indirect pathway was not significant (B = 0.01, SE = 0.02, p = 0.69, 95% bootstrap CI [-0.03, 0.05]). *p < .05, **p < .01, ***p < .001.

Figure 2

Standardized path coefficients (and 95% bootstrap CIs) of Model 2



Note. N = 147. The effect of sex and IQ on the mediator and outcome variables were controlled for (paths not shown). The indirect pathway was not significant (B = 0.001, SE = 0.01, p = 0.94, 95% bootstrap CI [-0.02, 0.01]). *p < .05, **p < .01, ***p < .001.

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Zhang, Z., & Yuan, K.-H. (2018). Practical Statistical Power Analysis Using Webpower and R (Eds). Granger, IN: ISDSA Press

ELLEN C. MASTERS

EDUCATION

Clinical Psychology Internship **2022 – Present**
Rochester Institute of Technology (APA accredited)
Rochester Regional Health Outpatient Child/Adolescent Psychiatry Track

Doctoral Candidate; School Psychology (GPA 3.91) **2018 – Present**
Syracuse University (APA, CAEP accredited, NASP approved)
Advisor: Natalie Russo, Ph.D., Licensed Psychologist
Dissertation: *Does Anxiety Mediate the Relationship between Sensory Hyperresponsiveness and Restricted, Repetitive Behaviors during Early Development?*

M.S. Psychology (GPA 3.90) **2018 – 2021**
Syracuse University (APA, CAEP accredited, NASP approved)
Advisor: Natalie Russo, Ph.D., Licensed Psychologist
Thesis: *The Impact of ADHD Symptoms and Age on Sensory Features in Autism*

B.A. Psychology (GPA 3.82) **2012 – 2016**
Fairfield University
Concentration: Behavioral Neuroscience

HONORS AND AWARDS

Syracuse University Graduate Student Organization Travel Award ($450)	**May 2019**
Syracuse University Psychology Department Travel Award ($250)	**May 2019**
Magna Cum Laude	**May 2016**
Dean's List (8 semesters)	**2012 – 2016**
Magis Scholarship from Fairfield University	**2013 – 2016**
Magis Scholars Program Grant from Fairfield University	**2015 – 2016**
Sigma Xi: The Scientific Research Society	**May 2016**
Alpha Sigma Nu: The National Jesuit Honor Society	**April 2015**
Psi Chi: The International Psychology Honor Society	**April 2015**
John A Weich Memorial Scholarship	**August 2014**
Alpha Mu Gamma: The National Collegiate Foreign Language Society	**January 2014**
National Society of Collegiate Scholars	**February 2013**
Loyola Scholarship from Fairfield University	**2012 – 2013**

RESEARCH EXPERIENCE

Syracuse University, Center for Autism Research & Electrophysiology **Aug. 2018 – Present**
Graduate Student Researcher
PI: Natalie Russo, Ph.D., Licensed Psychologist; (NIH; R01MH101536)

- Administer, score, and report cognitive and neurodevelopmental assessments: Autism Diagnostic Observation Schedule (ADOS-2); Autism Diagnostic Interview (ADI-R); Peabody Picture Vocabulary Test (PPVT-IV); Weschler Abbreviated Scale of Intelligence (WASI-II); Sensory Profile; Behavior Assessment System for Children (BASC-2); Vineland-II; Social Communication Questionnaire (SCQ)
- Schedule and manage clinical evaluations for community members
- Write and distribute integrated clinical reports for families
- Train graduate student researchers to conduct and score the ADOS-2
- Schedule and run participants in behavioral and electrophysiological (EEG and ERP) studies
- Manage and lead Qualtrics and Redcap survey platforms
- Mentor undergraduate research assistants on various projects

SUNY Upstate Medical University, Motion Analysis Lab **Jan. 2021 – June 2022**
Graduate Student Researcher
PI: Christopher Neville, Ph.D., Licensed Physical Therapist
Co-Investigator: Brian Rieger, Ph.D., Licensed Psychologist
- Managed and helped develop survey platform via Redcap
- Implemented data collection on patient-reported outcomes of common health conditions

Syracuse University, Mind Body Laboratory **Aug. 2020 – June 2022**
Graduate Student Researcher
PI: Joshua Felver, Ph.D., Licensed Psychologist
Co-Investigators: Brian Rieger, Ph.D., Licensed Psychologist; Christopher Neville, Ph.D., Licensed PT
- Developed and managed assessment platform via Qualtrics
- Managed SONA research participation pool and implemented data collection
- Managed IRB Protocol and documents
- Trained and supervised undergraduate research assistants to administer self-report and psychophysiological stress measures to concussed adolescents

Syracuse University, RITES Lab **Feb. 2021 – May 2021**
Graduate Student Researcher
PI: Bridget O'Neil-Hier, Ph.D., BCBA
- Conducted intervention research using single-case experimental design
- Assisted in planning, developing, implementing, and examining the effectiveness and feasibility of an evidence-based intervention (the Good Behavior Game) in an online general education classroom
- Assisted in data collection, data analysis, manuscript writing, and preparation for publication

Syracuse University **Feb. 2021 – May 2021**
Graduate Student Researcher
PI: Brian Martens, Ph.D.
- Field tested a novel self-report scale as part of Psychological Measurement graduate course
- Created and developed original self-report scale: Pluralistic Ignorance COVID Scale (PICS)
- Administered PICS to undergraduate Syracuse University psychology students via SONA system
- Conducted item analyses, obtained reliability estimates, and interpreted factor analyses of the PICS scale; made final revisions to the instrument based on analyses

Fairfield University, Behavioral Neuroscience Laboratory **June 2017 – Jan. 2018**
Research Assistant; Undergraduate Student Researcher **Jan. 2015 – May 2016**
PI: Shannon Harding, Ph.D.
- Designed and conducted treatment studies to investigate the effects of acute and chronic intranasal Oxytocin administration on symptoms related to Autism Spectrum Disorder, using a VPA rat model of Autism (Harding et al., 2021)
- Administered intranasal Oxytocin to Long-Evans rats prenatally exposed to Valproic Acid
- Ran various behavioral tests: Elevated Plus Maze; Emergence; Partner Preference; Social Preference; Copulation; Vocalizations/Scent Marking
- Trained undergraduate student researchers

CLINICAL EXPERIENCE

Genesee Mental Health Center, Child & Youth Clinic **July 2022 – Present**
Rochester Regional Health
Clinical Psychology Predoctoral Intern
Supervisors: Cassandra Berbary, Ph.D., Licensed Psychologist; Dennis Drew, LMHC
- Conduct walk-in intake sessions including psychosocial, diagnostic, and trauma interviews
- Implement individual- and family-based services to youth using evidence-based practices including CBT, IPT, Behavioral Activation, MI, ACT, CBTi, and MATCH-ADTC

- Complete feedback sessions, progress notes, plans of care, and comprehensive evaluations
- Consult with team of clinicians and psychiatrists on a weekly basis to coordinate care
- Conduct psychological assessments using semi-structured interviews, personality inventories, and cognitive/neuropsychological assessments
- Write and distribute integrated clinical reports with case-relevant recommendations

SUNY Upstate Medical University Hospital **July 2020 – June 2022**
Golisano Children's Hospital, Center for Children's Cancer and Blood Disorders; and Rehabilitation Psychology Department
Neuropsychology Student-Intern
Supervisors: Brian Rieger, Ph.D., Licensed Psychologist; Stephanie Barry, LCSW-R; Laura Jenkins, M.S.

- Conducted neuropsychological and psychoeducational assessments with children who have a history of cancer and cancer treatment, and are at-risk for cognitive late-effects and/or learning challenges (WISC-V; WPPSI-IV; WAIS-IV; WIAT-III; CVLT-C/-II; CMS; WMS-IV; NEPSY-II; RCFT; Trail Making Test; ABAS-II; CPT-3; Beery VMI; BASC-3; BYI-II; Grooved Pegboard; MSVT; BRIEF)
- Managed patient intakes including chart review, insurance authorization, and scheduling
- Conducted initial background interviews with parents and teachers, and provided parent/patient feedback sessions, including IEP meetings
- Wrote and distributed integrated clinical reports with case-relevant recommendations
- Attended Child Rounds

Syracuse City School District – Syracuse Latin School **August 2021 – June 2022**
School Psychology Practicum
Supervisors: Joshua Felver Ph.D., Licensed Psychologist; Kristina Goodman, M.S., Licensed School Psychologist

- Conducted school-based evaluations for elementary and middle school students
- Assessed students using classroom observations, academic probes, achievement, and cognitive testing
- Conducted weekly individual psychotherapy sessions with students
- Presented assessment data at Committee for Special Education (CSE) meetings to inform Individualized Education Plans (IEP) and school accommodations
- Provided intervention and assessment supervision to other graduate students

Oswego City School District **February 2021 – May 2021**
Behavior Therapy Practicum
Supervisor: Bridget O'Neil-Hier, Ph.D., BCBA

- Conducted Problem Identification Interviews (PII) with caregivers, teachers, and direct care staff
- Measured behavior using indirect and direct assessment techniques
- Developed and implemented empirically supported behavioral treatments based on the function of children and adolescents' behaviors

Elmcrest Children's Center **Aug. 2019 – May 2020**
Special Preschool Integration for Children's Education (SPICE)
Behavioral Consultant
Supervisors: Sarah Feocco, Psy.D., Licensed Psychologist; Jamie Burridge, M.S., BCBA, Licensed Behavior Analyst; Laura Assisi, M.S., BCBA, Licensed Behavior Analyst

- Developed and implemented applied behavioral analysis (ABA) therapy protocols for children with behavior concerns, and/or IEPs or Section 504 Plans
- Consulted with multidisciplinary teams including teachers, administrators, therapists, and parents
- Conducted, scored, and reported various assessments (i.e., Functional Behavioral Assessments [FBA]; Verbal Behavior Milestones Assessment and Placement Programs [VB-MAPP]; Vineland Adaptive Behavior Scales)
- Developed, implemented, and monitored Behavior Intervention Plans (BIP)

Elmcrest Children's Center **Jan. 2020 – April 2020**
Special Preschool Integration for Children's Education (SPICE)
Consultation Practicum
Supervisors: Bridget O'Neil Hier, Ph.D., BCBA; Sarah Feocco, Psy.D., Licensed Psychologist; Jamie Burridge, M.S., BCBA, Licensed Behavior Analyst

- Administered PII, Functional Analysis (FA) and/or FBA to determine functions of behavior, and designed and implemented function-matched treatments for challenging behavior
- Directed caregivers on site to implement the treatment protocols
- Participated in support activities, professional development, and outreach

The Center for Growth and Development **Aug. 2016 – Aug. 2017**
Applied Behavioral Analysis Therapist
Supervisors: Jillian Cano, M.Ed., BCBA; Nicole Nemchek, M.Ed., BCBA; Lynn Hartigan, M.Ed., BCBA; Michelle Brennan, M. Ed., BCBA

- Implemented social, behavioral, and academic programs for children and young adults ages 2-21 years with Autism Spectrum Disorder and other developmental disorders in clinical, home, community, and school settings
- Assisted in speech therapy, occupational therapy, and physical therapy
- Attended bi-weekly meetings and helped develop individualized behavior plans with Board Certified Behavior Analysts
- Collected and graphed data on all behaviors and taught skills to evaluate efficacy of treatment plans

The Summit Center **June 2016 – Aug. 2016**
Community Connections Clinical Counselor
Supervisors: David Meichenbaum, Ph.D., Licensed Psychologist; Joseph Forgione, M.Ed., BCBA

- Community Replica of the Institute for Autism Research (IAR) summer treatment program for children with Autism Spectrum Disorder and other developmental disorders (40-hour training required)
- Led social skills groups and therapeutic cooperative/recreational activities with fidelity for children with Autism Spectrum Disorder, and developed and implemented individual behavioral targets
- Managed team activities/treatment, collected and entered daily behavioral data, and provided daily parent feedback on their child's progress

Institute for Autism Research at Canisius College **June 2015 – Aug. 2015**
Research-Clinician
Supervisors: Marcus Thomeer, Ph.D.; Christopher Lopata, Psy.D.; Christin McDonald-Fix, Ph.D., BCBA
MAX Treatment and Research Programs, Institute for Autism Research, Canisius College, Buffalo, NY

- *summerMAX*^{yc} Treatment Program for Young Children with High-Functioning Autism Spectrum Disorder
- Served as a research-clinician for a grant-funded Phase 2 Feasibility Trial evaluating the feasibility and initial effectiveness of an intensive summer psychosocial treatment program for high-functioning young children, ages 4 – 6 years with Autism Spectrum Disorder (HFASD)
- Facilitated social skills groups, instituted an intensive response-cost structured behavioral program, and led cooperative and therapeutic groups
- Implemented active treatment components including instruction in social skills, face-emotion recognition, interest expansion, and an individual daily note
- Completed pre- and post-test protocols for child participants including SRS-2, ABAS-3, Vineland-II, and the ASCyc (a researcher-designed measure)
- Collected and entered data (i.e., daily behavioral data, pre- and post-test data)

TEACHING EXPERIENCES

Syracuse University **Aug. 2018 – May 2019**

PSY 205 Teaching Assistant

Supervisors: Shannon Houck, Ph.D.; Abigail Caselli M.S.

- Taught four recitation sections Fall 2018, and three recitation sections Spring 2019
- Created weekly power-point presentations to teach new material and review previously taught material
- Facilitated small group discussions and activities
- Created, administered, and graded weekly quizzes and essay tests, and provided final course grades

Garden Nursery School, Buffalo NY **Sept. 2017 – April 2018**

Private substitute teacher

- Assisted in typical school activities in private pre-school setting for children aged 2-5 years

Fairfield University **Sept. 2014 – Dec. 2014**

Academic Tutor

Professor: Linda Henkel, Ph.D.

Course: Statistics for Life Sciences

- Z-tests, T-tests, One-Way ANOVAS, Two-Way ANOVAS, SPSS

PUBLICATIONS

Manuscripts published and under review

Masters, E. C., Antshel, K. M., Kates, W. R., & Russo, N. (submitted). Brief report: Sensory features associated with autism after controlling for ADHD symptoms.

Hier, B. O., Mackenzie, C. K., Ash, T. L., Maguire, S. C., Nelson, K. A., Helminen, E. C., Watts, E. A., Matsuba, E. S. M., **Masters, E. C.**, Finelli, C. C., Circe, J. J., Hitchings, T. J., Goldstein, A. R., & Sullivan, W. E. (revised and resubmitted). Effects of the good behavior game on students' academic engagement in remote classrooms. *Journal of Positive Behavior Interventions*.

Harding, S. M., **Masters, E. C**., D'Agata, C. M., Rivera, A. C. A., & Smith, E. C. (2021). Prenatal exposure to valproic acid and treatment with intranasal oxytocin have sex-specific effects on behavior in Long Evans rats. *Behavioural Pharmacology, 32* (7), 561-570. doi:10.1097/FBP.0000000000000650

Manuscripts in preparation

Cary, E. L., Rodrigues A., **Masters, E. C.**, Matsuba, E., & Russo, N. (in prep). Trauma mediates the relation between autistic traits and sensory sensitivity and avoiding in adults.

Matsuba, E., **Masters, E. C.**, Russo, N. (in prep). Mediation effects of the P1 on the relationship between the MMN and sensory features in typically developing adults.

Osborne, J., Cascio, C., Laine, C., **Masters, E. C.**, Baranek G., Russo, N. (in prep). The relationship between alpha asymmetry and sensory features of autism.

Albert, A., **Masters, E. C.**, Rodrigues A., & Simmons, J. (in prep). College student perceptions of peer norms for COVID risk-behavior.

POSTER PRESENTATIONS

Cary, E., Rodrigues A., **Masters, E. C.**, Matsuba, E., MacKenzie, C., Osborne, J., Russo, N. (2022, May). *Trauma Mediates the Relation between Autistic Traits and Sensory Sensitivity and Avoiding in Adults*. Poster presented at the International Society for Autism Research 2022 Annual Meeting, Austin, TX.

Cary, E., Rao, A., Matsuba, E., **Masters, E. C.**, MacKenzie, C., Osborne, J., Russo, N. (2022, May). *Barriers to an Autistic Identity: How RRBs may Contribute to the Underdiagnosis of Females*. Poster presented at the International Society for Autism Research 2022 Annual Meeting, Austin, TX.

Masters, E. C., McKernan, E., Kopec, J., Kaplan-Kahn, E., Cary, E., Matsuba, E., Rodrigues, A., MacKenzie, C., & Russo, N. (2021, May). *The Impact of ADHD Symptoms and Age on Sensory*

Features in Autism. Poster presented at the International Society for Autism Research 2021 Annual Meeting, Boston, MA.

Cary, E. L., Kaplan-Kahn, E., **Masters, E.**, Matsuba, E., MacKenzie, C., Rodrigues, A., Prieve, B., Pacheco, D., Madrid, A., & Russo, N. (2021, May). *Relating ASD Traits and Sensory Overresponsivity to Early Electrophysiological Indices of Auditory Processing in Children with and without ASD*. Poster presented at the International Society for Autism Research 2021 Annual Meeting, Boston, MA.

Kaplan, E. A., Cary, E., **Masters, E.**, Matsuba, E., & Russo, N. (2020, May). *Pathways of Perceptual Primacy: ERP Evidence for Relationships between Autism Traits and Enhanced Perceptual Functioning.* Poster accepted for the International Society for Autism Research 2020 Annual Meeting, Seattle, WA.

Kaplan, E. A., Cary, E., **Masters, E.**, Matsuba, E., Rodrigues, A., & Russo, N. (2020, May). *Early Neural Difference in Auditory Processing of Speech in Children with ASD: Is It Habituation or Discrimination?* Poster accepted for the International Society for Autism Research 2020 Annual Meeting, Seattle, WA.

McKernan, E. P., Kopec, J., Kaplan, E. P., Koelmel, E. L., **Masters, E. C.**, and Russo, N. (2019, May). *Individuals with higher levels of autistic traits are less susceptible to social conformity on a perceptual decision-making task*. Poster presented at the International Society for Autism Research 2019 Annual Meeting 2019, Montreal, Canada.

Harding, S. M., & **Masters, E. C.** (2016, November). *The effects of intranasal oxytocin on anxiety, social, and sexual behaviors in male rats prenatally exposed to valproic acid.* Poster presented at the Society for Neuroscience's 46th annual meeting, Neuroscience, San Diego, CA.

Masters, E. C., & Harding, S. M. (2016, April). *The effects of intranasal oxytocin on anxiety and social behaviors in an animal model for autism.* Poster presented at the 14th annual Sigma Xi Student Research Poster Session, Fairfield, CT.

Harding, S. M., Caputo, J. A., Barrett, S. R., **Masters, E. C.**, McDonough, M. M. (2016, February). *The effects of acute prenatal exposure to valproic acid on sociosexual behaviors and anxiety in female rats.* Poster presented at the 27th annual Northeast Under/graduate Research Organization for Neuroscience (NEURON) Conference, Hamden, CT.

Harding, S. M., Caputo, J. A., Barrett, S. R., **Masters, E. C.**, McDonough, M. M. (2015, October). *The effects of acute prenatal exposure to valproic acid on sociosexual behaviors and anxiety in female rats.* Poster presented at the Society for Neuroscience's 45th annual meeting, Neuroscience, Chicago, IL.

PROFESSIONAL DEVELOPMENT

Brief Observation of Symptoms of Autism (BOSA) Training **2021**
- University of California, Los Angeles; UCLA Center for Autism Research and Treatment
- Online Training

Women in Science and Engineering Future Professionals Program **2020 – 2022**
- Syracuse University

Trauma-Focused Cognitive Behavioral Therapy 2.0 Online Training **2018**
- The Medical University of South Carolina
- 11 continuing education contact hours

Autism Diagnostic Observation Schedule (ADOS-2) Clinical Training **2019**
- Emory University, Marcus Autism Center
- 18 contact hours

Collaborate Institutional Training Initiative (CITI) Program **2018 – Present**
- Syracuse University
- SUNY Upstate Medical University
- Rochester Institute of Technology

PROFESSIONAL SERVICE

Communications Committee	**2021 – 2022**
Psychology Action Committee Peer Mentor	**2020 – 2022**
Student Affiliates to National Groups	**2020 – 2021**
School Psychology Professional Development Committee	**2019 – 2022**

MEMBERSHIPS

American Psychological Association, Division 53	**2020 – Present**
Society of Clinical Child and Adolescent Psychology (SCCAP)	
International Society for Autism Research (INSAR)	**2018 – Present**
Society for Neuroscience	**2014 – 2017**
National Society of Collegiate Scholars	**2013 – 2014**

SKILLS

Clinically certified in the Autism Diagnostic Observation Schedule-2 (ADOS-2) Modules 1-4 and Toddler
Trained in Applied Behavior Analysis (ABA)
Certified in CPR and First-Aid
Use of R for Data Science, Mplus, SPSS, Redcap, Microsoft Access, Qualtrics, Zotero

VOLUNTEER EXPERIENCE

Fairfield University **Jan. 2015 – May 2015**
Head Start Program; Bridgeport, CT
- Served as a community mentor for children aged three to five years at the Jamie A. Hulley Center
- Incorporated knowledge and skills pertaining to developmental psychology

Fairfield University **Sept. 2012 – May 2015**
Best Buddies Program
- Established and maintained one to one friendships with intellectually and developmentally disabled adolescents and adults