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Using Sensory Interventions to Promote Skill Acquisition for Students with Autism Spectrum Disorders

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ACCEPTANCE

This dissertation, USING SENSORY INTERVENTIONS TO PROMOTE SKILL ACQUISITION FOR STUDENTS WITH AUTISM SPECTRUM DISORDERS, by GINNY L. VAN RIE, was prepared under the direction of the candidate's Dissertation Advisory Committee. It is accepted by the committee members in partial fulfillment of the requirements for the degree Doctor of Philosophy in the College of Education, Georgia State University.

The Dissertation Advisory Committee and the student's Department Chair, as representatives of the faculty, certify that this dissertation has met all standards of the excellence and scholarship as determined by the faculty. The Dean of the College of Education concurs.

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ABSTRACT

USING SENSORY INTERVENTIONS TO PROMOTOE SKILL ACQUISITION FOR STUDENTS WITH AUTISM SPECTRUM DISORDERS

by
Ginny L. Van Rie

Individuals with autism spectrum disorders (ASD) have documented sensory processing difficulties across the lifespan; however there is limited empirical support for the sensory-based interventions that have become ubiquitous with the population. This study was conducted to address this need and examine the effect of sensory-based interventions on skill acquisition for five elementary-age students with ASD. Proponents suggest that sensory-based interventions can be used to facilitate optimal levels of arousal so that children are available for learning. A single-case alternating treatments design was used to evaluate functional relations between the two sensory-based antecedent interventions and correct responding on expressive identification tasks. Upon visual analysis of the graphed data, functional relations were apparent for two participants. A positive relation between one sensory activity and correct responses was evident for a third student, but his rate of skill acquisition was too slow to verify a functional relation during the study. Results were undifferentiated for two students; one reached mastery criteria with both sensory-based interventions, while one made only modest improvement in expressive identification. Hierarchical linear modeling (HLM) was used to identify predictors of growth. Scrutiny of the results of the level-1 analysis revealed that there were significant differences among the participants at the start of the study (τ_{00} = 388.46, $\chi^2(4)$ = 45.97, *p*

$< .001$) and that all of the students made significant gains during the study ($\beta_{10} = 2.35$, $t(4) = 3.43$, $p < .05$). Using treatment as a predictor in Model 2 resulted in the finding of no significance for the sensory-based interventions in predicting growth. The two biggest level-2 predictors of student growth were age ($\beta_{11} = 0.055$, $t(2) = 6.403$, $p < .001$) and IQ ($\beta_{22} = 0.21$, $t(2) = 13.41$, $p < .001$). Although not clinically significant, Childhood Autism Rating Scale scores as a level-2 predictor of growth may have practical significance. Implications for mixed-modality research and applied practice are discussed.

USING SENSORY INTERVENTIONS TO PROMOTE SKILL ACQUISITION FOR STUDENTS WITH AUTISM SPECTRUM DISORDERS

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A Dissertation

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ABBREVIATIONS

AASP	Adult/Adolescent Sensory Profile
ADHD	Attention Deficit Hyperactivity Disorder
AFOs	Ankle-Foot Orthoses
AIT	Auditory Integration Therapy
ASD	Autism Spectrum Disorder
AS	Asperger's Disorder
CA	Chronological Age
CARS	Childhood Autism Rating Scale
DD	Developmental Disability
EBP	Evidence-Based Practice
GAC	General Adaptive Composite
HFA	High Functioning Autism
IOA	Inter-Observer Agreement
IEP	Individual Education Plan
MA	Mental Age
SI	Sensory Integration
SMD	Sensory Modulation Disorder
SP	Sensory Profile
SSP	Short Sensory Profile
VABS	Vineland Adaptive Behavior Scales

CHAPTER 1

SENSORY DIFFERENCES IN AUTISM SPECTRUM DISORDERS

Human beings are continuously inundated with sensory stimulation. Sensory modulation is the ability to regulate responses appropriate to the sensory stimuli (Ben-Sasson et al., 2007). Difficulties with sensory modulation are well documented for individuals on the autism spectrum (e.g., Lane, Young, Baker, & Angley, 2010). Autism spectrum disorders (ASD) include the three major pervasive developmental disabilities identified by the American Psyciatric Association (APA, 2000): autistic disorder (AD), Asperger's disorder (usually called "Aspergers syndrome" or AS), and pervasive developmental disorders-not otherwise specified (PDD-NOS; Lord, Cook, Leventhal, & Amaral, 2000). Individuals with ASD experience sensory processing difficulties across the lifespan, from infancy or early childhood (Rogers, Hepburn, & Wehner, 2003) through adulthood (Crane, Goddard, & Pring, 2009), as well as across the range of severity of ASD from individuals who have an ASD with intellectual disabilities (Kern, Trivedi, et al., 2007) to individuals with high-functioning autism or AS (Minshew & Hobson, 2008). Although sensory processing difficulties are characteristic of ASD, the type and intensity of difficulties varies by age and severity of ASD. According to Kern, Trivedi, et al., (2007) there is a strong correlation between age and severity of ASD in regard to sensory modulation (i.e., younger children with more severe ASD experience more abnormal sensory processing), although this may hold true only during childhood.

For example, Crane et al. (2009) found that sensory processing differences in adults with ASD were not as discrepant from their neurotypical peers as were the sensory processing deficits in children with ASD when compared to their neurotypical peers. Additionally, there was great variation in sensory processing patterns among the adults with ASD. The findings that sensory processing patterns vary by age and severity of ASD provide valuable information in regard to potential interventions that may prove beneficial for individuals with ASD who have sensory processing difficulties.

Sensory Processing Differences by Age

Infants and Toddlers

As the quest for early identification of ASD becomes more urgent, numerous researchers have examined the features that differentiate infants and toddlers with ASD from young children who are typically developing. Ben-Sasson et al. (2007) used the *Infant/Toddler Sensory Profile* (Dunn, 2002) to compare 100 toddlers with ASD to data that had been collected previously from 200 toddlers who were developing typically. The researchers compared the two groups based on chronological age (CA) and mental-age (MA). They found that low registration (under-responsiveness) to sensory stimulation was prevalent among the toddlers with ASD, whereas very few matched controls in either the CA or MA groups showed extreme levels of low registration.

In addition to comparing infants and toddlers who are later identified as having an ASD to those without an ASD, researchers have examined how these behavioral features vary among individuals with other disabilities. For example, Baranek (1999) conducted a retrospective video analysis of infants between the ages of 9-12 months across three groups. She obtained video footage of 11 infants who were diagnosed later as having autism, 10 with a developmental delay, and 11 who were developing typically. She found that the most significant predictors of later autism diagnoses were failure to respond to attention-getting strategies such as his or her name being called, as well as the presence of excessive mouthing of objects. She identified both an under-responsiveness (failure to respond) to sensory stimulation as well as sensory-seeking behaviors (e.g., excessive mouthing) which, when used together, were useful in distinguishing the infants with autism from those who were developing typically and from those with other developmental delays. These differences were observed well before the infants were officially diagnosed with autism.

Dawson et al. (2004) evaluated the responsiveness of toddlers to eight different auditory stimuli through manipulation of the sensory stimuli, four of which they designated as social in nature (i.e., humming, calling the child's name, snapping fingers, and patting hands on legs) and four nonsocial in nature (i.e., phone ringing, whistle blowing, car horn, and timer beeping). Three groups of toddlers participated in the study: a group of toddlers with ASD, a group with developmental disabilities (DD) without ASD, and toddlers who were developing typically. The researchers found that the toddlers with ASD failed to respond more often to all eight of the auditory stimuli than the toddlers with DD or those who were developing typically and that the lack of responding among the toddlers with ASD was even greater for the four social auditory stimuli. Therefore Dawson et al. (2004) were able to distinguish the toddlers with ASD from those without ASD by the frequency with which they failed to respond to the social auditory sensory stimulation.

Rogers et al. (2003) expanded the types of disabilities compared to include a group of toddlers with Fragile X. They studied 102 toddlers divided into four groups: toddlers with ASD, toddlers with Fragile X syndrome, toddlers with DD, and toddlers who were developing typically. The researchers used parents' responses to the *Short Sensory Profile* (SSP; McIntosh, Miller, & Shyu, 1999) to assess the sensory processing abilities of these toddlers. The researchers found that the sensory processing patterns of the toddlers with ASD and those with Fragile X syndrome differed significantly from the toddlers with DD and those who were developing typically. There were similarities between the sensory processing patterns of the toddlers with ASD and those with Fragile X syndrome, but the overall sensory scores correlated with the severity of the ASD symptoms and IQ for the group with Fragile X syndrome. Thus, the toddlers with Fragile X syndrome who had more ASD characteristics and lower IQs tended to have sensory profiles similar to the toddlers with ASD.

Wiggins, Robbins, Bakeman, and Adamson (2009) also used the SSP, which was completed by the primary caregivers, to compare the sensory processing patterns of toddlers with ASD to toddlers with DD. They included 34 toddlers, 17 with ASD and 17 with DD. Wiggins et al. (2009) reported their findings using SSP terminology, which categorizes results as "typical performance," "probable difference," and "definite difference." There were significant sensory modulation differences between the two groups, with 100% of the toddlers with ASD having atypical sensory processing based on SSP criteria (82% of the toddlers with ASD demonstrated a "definite difference" and 18% had a "probable difference") as opposed to 35% of the toddlers with DD demonstrating atypical sensory response patterns (approximately 17.5% scoring in the "definite difference" range and approximately 17.5% in the "probable difference" range). Two of the SSP items that contributed to group differences were "lack of response to voice" and "failure to respond to his/her name being called." Their findings support the findings of other researchers who noted that infants and toddlers with ASD are under or unresponsive to auditory stimulation (e.g., having their name called, orienting to a familiar voice; Baranek, 1999; Ben-Sasson et al., 2007; Dawson et al., 2004; Rogers et al., 2003).

In summary, researchers have noted that infants and toddlers with ASD are under or unresponsive to sensory stimulation. The most notable characteristic of individuals with ASD in this age group was their lack of response to their names being called (Baranek, 1999; Wiggins et al., 2009). Infants and toddlers with ASD also failed to respond to other sensory stimulation that is social in nature such as clapping, humming, and familiar voices (Dawson et al., 2004; Wiggins et al., 2009). Baranek (1999) reported that infants with ASD tended to seek oral sensory stimulation by mouthing objects more frequently and for longer periods of time when compared to typical peers. However, this is the only documented report of sensory-seeking behavior in infants and toddlers with ASD. Thus the main difference between infants and toddlers with ASD and those with other developmental disabilities, as well as those who are developing typically, is their lack of response to sensory stimulation, especially sensory stimulation that is social in nature. These conclusions have led to physicians using failure to respond to parents' or caregivers' voice by age 12 months as a major indicator that further evaluation is necessary in order to confirm or rule out the possibility that the young child has an ASD (Johnson, Myers, & the Council on Children with Disabilities, 2007).

An understanding of the sensory differences in infants and toddlers with ASD is important not only for identification but also for planning of interventions for very young children with ASD. Lane et al. (2009) found an association between sensory processing dysfunction for children with ASD and the presence of maladaptive behaviors. Individuals with ASD may develop maladaptive or inappropriate behaviors because they miss cues or fail to learn appropriate social interactions due to their lack of responding to sensory stimulation as infants or toddlers.

Children and Adolescents

Just as young children who are later identified as having an ASD are unresponsive or underresponsive to sensory stimuli, particularly those stimuli that are social in nature, children and adolescents with ASD exhibit sensory processing patterns that differ from those of their neurotypical peers and their peers with other disabilities. Baker, Lane, Angley, and Young (2008) examined the sensory processing patterns of 22 children with ASD who were 2 – 8 years old. They had parents complete the SSP for each child and analyzed the results to draw conclusions about sensory processing difficulties. Baker et al. (2008) did not include a control group or a comparison group in their study, but stated that 82% of the children with ASD had overall atypical sensory processing as indicated by their total scores on the SSP with 55% of children scoring in the "definite difference" range and 27% scoring in the "probable difference" range. A majority of the children with ASD (68%) scored in the "definite difference" range for both underresponsive/seeks sensation and auditory filtering. Baker et al. (2008) concluded that children with ASD who had atypical sensory processing also had higher levels of inappropriate or aberrant behavior as measured by the Maladaptive Behavior Domain of the *Vineland Adaptive Behavior Scales* (VABS; Sparrow, Balla, & Cicchetti, 1984).

Ashburner, Ziviani, and Rodger (2008) extended the findings of Baker et al. (2008) by comparing the sensory processing patterns of 28 children (ages 6 to 10 years) with ASD and average intelligence to 51 age- and gender-matched peers who were developing typically. Using the SSP completed by the parents, the researchers found significant differences between the children with ASD and children who were developing typically in all areas assessed by the SSP (i.e., tactile sensitivity, taste/smell sensitivity, underresponsive/seeks sensation, auditory filtering, low energy/weak, and visual/auditory sensitivity) except for movement sensitivity. When comparing the overall SSP scores, 79% of the children with ASD scored in the "definite difference" range and 18% in the "probable difference" range, as compared to only 2% of the children who were developing typically who scored in the "definite difference" and 2% in the "probable difference" ranges. Tomcheck and Dunn (2007) restricted their participants to younger ages (3-6 years) and also compared the sensory processing patterns between children with ASD and children who were developing typically. Tomcheck and Dunn (2007) did not state who completed the SSPs for either group of children but used data collected through retrospective chart reviews for the 281 children with ASD, while data for the 281 children who were developing typically were collected by Dunn and Westman (1997) in their standardization work for the SSP. The researchers matched the children by CA for their analyses and found that 83.6% of the children with ASD had total SSP scores in the "definite difference" range, but only 3.2% of the children who were developing typically had total SSP scores that fell in the "definite difference" range. Tomcheck and Dunn

(2007) discovered that they could distinguish children with ASD from children who were developing typically with 95% accuracy based on the results of the SSP. Therefore, Ashburner et al. (2008) and Tomcheck and Dunn (2007) concluded that the children with ASD had significantly different sensory processing profiles as compared to their neurotypical peers.

Consistent with Ashburner et al. (2008) and Tomcheck and Dunn (2007), Watling, Deitz, and White (2001) were able to differentiate children with ASD from children who were developing typically based on their sensory processing patterns; however, they used the Sensory Profile (SP; Dunn, 1999) completed by parents to document differences instead of the SSP. Watling et al. (2001) included 40 children between the ages of 3 – 6 years in each group and matched the children by age and gender. They found that the children with ASD had significantly different scores on seven of the nine SP factors (sensory seeking, emotionally reactive, low endurance/tone, oral sensory sensitivity, inattention/distractibility, poor registration, and fine motor/perceptual). Although, the researchers did not indicate the specific ranges for the SP scores (i.e., "typical performance," "probable difference," or "definite difference"); they did state that the children with ASD had broader ranges in their scores when compared to the children who were developing typically and they interpreted this finding to mean that the children with ASD are more heterogeneous as a group when compared to the group of children who were developing typically. Despite the range of scores for the children with ASD, their overall SP scores were still atypical and, similar to Ashburner et al. (2008) and Tomcheck and Dunn (2007), Watling et al. (2001) were able to distinguish the children with ASD from the children who were developing typically based on their sensory processing patterns.

Brown, Leo, and Austin (2008) also utilized the SP, which was completed by mothers, to distinguish between children with ASD and children who were developing typically. They expanded upon previous studies by conducting their study in Australia. They included 26 students between the ages of 5 – 8 years in each of the ASD and control groups and matched the children by age and gender. The researchers found that the children with ASD had atypical sensory processing patterns for eight of the nine SSP factor scores (i.e., sensory seeking, emotionally reactive, low endurance/tone, oral sensitivity, inattention/distractibility, poor registration, sedentary, and fine motor/perceptual), and all 4 quadrant scores (i.e., sensation seeking, low registration, sensation avoiding, and sensory sensitivity); the only non-significant difference was the sensory-sensitivity factor, which means that the participants with ASD had the same sensitivity to sensory input as the students who were developing typically.

In addition to comparing children and adolescents with ASD to those who were developing typically, Ermer and Dunn (1998) used the SP to differentiate among children with ASD, children with typical development, and a third group of children who had attention deficit hyperactivity disorder (ADHD). They included 38 children with ASD and 61 children with ADHD, between the ages of 3 and 15 years in their study. The comparison group was over 1,000 children (ages 3-10 years) who were developing typically and participated in a national study that developed the norms for the SP (Dunn & Westman, 1997). Ermer and Dunn (1998) were able to discriminate the children with ASD from the children with ADHD and typical development with 90% accuracy using the nine SP factors; however, four of the nine SP factors served as the best indicators. These four factors were sensory seeking, oral sensitivity, inattention/distractibility, and fine motor/perceptual processing difficulties. The children with ADHD had SP results that were similar to typical peers in that both groups engaged in sensory-seeking behaviors; however, the children with ADHD demonstrated greater frequency and intensity than their typical peers and had significantly higher scores in the area of inattention/distractibility. The children with ASD scored significantly lower than both the ADHD and control groups in the area of sensory seeking and significantly higher in the areas of oral sensitivity, inattention/distractibility, and fine motor/perceptual processing difficulties.

Cheung and Siu (2009) expanded the work of Ermer and Dunn (1998) by conducting a similar study in China using the same three classifications of children. Cheung and Siu (2009) evaluated the sensory processing skills of 72 children with ASD, 114 children with ADHD, and 1840 children who were developing typically. All of the children were between the ages of 2.7 – 12 years. The researchers used the *Chinese Sensory Profile* (CSP) completed by parents of each participating child. They found that they could easily distinguish children with ASD and ADHD from children who were developing typically, but they were unable to distinguish children with ASD from children with ADHD based on the CSP results. Cheung and Siu (2009) conducted another analysis with age as a covariate and found that children with ASD and those who were developing typically have improved sensory processing as they get older whereas children with ADHD tend to have more difficulty with sensory processing as they get older. Cheung and Siu (2009), along with Brown et al. (2008), used versions of the SP to differentiate between children with ASD and children who were typically developing in countries outside of the USA. However, unlike Ermer and Dunn (1998), Cheung and Siu (2009) were unable to differentiate between children with ASD and those with ADHD based on the results of the CSP.

Similar to Cheung and Siu (2009), O'Brien et al. (2009) built upon the findings of Ermer and Dunn (1998) by conducting a study that involved three groups of children. The major difference among the three studies is that O'Brien et al. (2009) included a group of children who had a variety of documented learning difficulties. There were 34 children with ASD, 22 with learning difficulties, and 33 children who were developing typically. All of the children were between the ages of 5 and 15 years and were matched by chronological age. The children in the group with learning difficulties had a variety of disabilities including but not limited to Down syndrome, ADHD, selective mutism, Mundes syndrome, and cerebral palsy. The children with ASD and learning disabilities were assessed for their MA using the *British Picture Vocabulary Scale* (Dunn, Whetton, & Burley, 1997) and adaptive functioning using the General Adaptive Composite (GAC) score of the *Adaptive Behaviour Assessment System* (Harrison & Oakland, 2000). The students were not matched on MA across the three groups, but the children with ASD were matched with children with learning difficulties based on their GAC scores. The children who were developing typically were not assessed using the GAC because it was not intended for use with children who were developing typically. O'Brien et al. (2009) adapted the SSP by adding ten items from the SP as well as seven items they developed, to the original 38 items on the SSP, which resulted in a 55-item questionnaire completed by the children's parents. They found significant differences in sensory processing among all three groups. The children with ASD and those with learning difficulties had more sensory processing difficulties than the children who were developing typically, but the children with learning disabilities had more consistency in their sensory processing patterns across all areas whereas the children with ASD had more variability in scoring across the factors. The two main factors that distinguished the children with ASD from the children with learning difficulties were auditory hyper-sensitivity and visual stimulus-seeking; the children with ASD were more sensitive to auditory stimulation and they sought more visual stimulation than the children with learning difficulties. These two factors are not part of the original SSP or SP and were assessed by questionnaire items that were added to the adapted assessment by the researchers. However, the children with ASD had significantly lower scores on the original SSP factor of underresponsive/seeks sensation, indicating that the children with ASD sought less sensory stimulation than the children who were developing typically. The findings of O'Brien et al. (2009) provide additional support of the findings of previous researchers who documented that individuals with ASD can be distinguished from typical peers as well as peers with other disabilities based on their sensory processing. However, O'Brien et al. (2009) identified more specific sensory processing difficulties than previous authors by isolating specific sensory processing characteristics (i.e., auditory hyper-sensitivity and visual stimulus-seeking).

Schoen, Miller, Brett-Green, and Nielsen (2009) extended research in the area of sensory processing for children with ASD by including a physiological measure of the children's responses to various sensory stimuli. The children in their study were between the ages of 4 – 15 years. There were 38 children with high-functioning autism (HFA) or

AS in the ASD group, 31 children with sensory-modulation disorder (SMD) in the second group and 33 children who were developing typically in the third group. Schoen et al. (2009) used the SSP to assess responses to sensory stimuli, and collected data on skin conductance levels to measure physiological responses to various sensory stimuli. In order to measure the participants' physiological responses, the researchers had each child sit in a chair that simulated a captain's chair on a spaceship. The children were strapped into the chair and sensors were placed on them. The children experienced a 3-min baseline with no sensory stimulation, followed by the presentation of six different sensory stimuli, each presented for 3 s with 10-15 s between. Each sensory stimulus was presented 8 times for a total of 48 presentations of sensory stimuli. Then the children were given another 3-min resting period to allow them to recover from the sensory stimulation. The children were not told to attend to the stimuli or asked to complete any tasks. The researchers recorded the stimuli and time of presentation, and compared those times to the children's physiological responses as measured by the sensors. The sensory stimuli included a tone and siren for auditory stimulation, a flash for visual stimulation, scent of wintergreen for olfactory stimulation, brushing with a feather for tactile stimulation, and leaning the chair back (tipping the chair) for vestibular stimulation. Schoen et al. (2009) found that children with ASD and those with SMD had atypical behavioral and physiological responses to the sensory stimuli as compared to the children who were developing typically, and there were significant differences among the responses of the children with ASD and SMD. Physiologically, the group with ASD had lower overall reactivity levels both during the baseline phase and the presentation of all of the sensory stimuli. Behaviorally, the group with ASD was more responsive to taste and smell stimulation. Children and adolescents in the SMD group engaged in more sensory-seeking behaviors than those in the ASD group. Finally the children in the ASD group were less responsive to the vestibular stimulation. Schoen et al. (2009) found that they could distinguish children and adolescents with high-functioning autism and AS from their peers with SMD as well as those who were developing typically by using behavioral and physiological measures.

In summary, although children and adolescents with ASD demonstrate more variability in their responses to sensory stimulation, there are still significant differences in their sensory processing abilities as compared to peers with other disabilities and peers who are developing typically (Watling et al., 2001). Children and adolescents with ASD engage in more sensory-seeking behaviors than infants and toddlers with ASD, but they still do not engage in as many sensory-seeking behaviors as children and adolescents with ADHD and those who are developing typically (Ermer & Dunn, 1998; Schoen et al., 2009). O'Brien et al. (2009) found that the children and adolescents with ASD in their study engaged in more visual sensory-seeking behaviors (which is not assessed by the original SSP and was assessed by the questions they added to their adapted version of the SSP) than did children and adolescents with other disabilities and those who were developing typically. However, for the original SSP factor of underresponsive/seeks sensation, the children with ASD had significantly lower scores than the children who were developing typically which means that in general the children with ASD engaged in fewer sensory-seeking behaviors than peers who were developing typically. Baker et al. (2008) documented a strong relationship between sensory processing difficulties and higher rates of maladaptive behavior for children with ASD. Ashburner et al. (2008)

found a strong association between difficulties processing auditory stimulation and attending/learning, and concluded that this specific sensory processing difficulty negatively affects academic achievement among children with ASD. Thus many children with ASD who have sensory processing difficulties also may engage in other inappropriate behaviors that interrupt their engagement with the environment. There are significant differences in sensory processing patterns for children and adolescents with ASD across the spectrum when compared to peers with other disabilities or those who are developing typically and there is more variability for this age group as compared to infants and toddlers with ASD.

Adults

Very few researchers have concentrated on the sensory processing difficulties of adults with ASD. The few researchers who have investigated sensory processing for adults found that this continues to be a significant problem for individuals with ASD, although adults with ASD have sensory processing patterns closer to their peers who developed typically as compared to infants, children, and adolescents with ASD. Kern et al. (2006) compared the SP results of 104 individuals with ASD, ages 3 – 56 years, to the results of 104 individuals without disabilities in the same age range. The SP was completed by a teacher, job coach, group home manager, or a therapist for the individuals with ASD and by a parent (if the participant was under 21 years), or spouse, or self-report (if the participant was over 21 years) for the control group. Kern et al. (2006) divided all of the participants into seven age groups with a minimum of 12 individuals with ASD and 12 individuals without disabilities in each of the seven age groups. Sensory processing of individuals with ASD was evaluated in regard to four sensory systems:

auditory, visual, tactile, and oral. Kern et al. (2006) found that there were differences in sensory processing between the individuals with ASD and the individuals without disabilities across all seven age groups; however, the differences changed by age with the sensory processing of individuals with ASD becoming more like the sensory processing of the individuals without disabilities in the older age groups. Sensory processing for each of the sensory systems in the control group was relatively stable across all age groups. Although the adults with ASD were closer to the controls in regard to sensory processing as compared to the children and adolescents with ASD, the adults with ASD continued to experience atypical sensory processing.

Kern, Garver, et al. (2007) reanalyzed the data collected by Kern et al. (2006) but excluded the oldest participant (and did not explain the reason for the exclusion). Thus, their study included a total of 103 individuals with ASD ages 3-43 years and age-matched participants without disabilities. This data analysis was conducted to compare sensory quadrant scores on the SP between individuals with ASD and the control group across all of the age groups. The individuals with ASD had atypical responses to sensory stimuli in the four quadrants of the SP (i.e., Low Registration, Sensation Seeking, Sensation Sensitivity, and Sensation Avoidance) as compared to the control group of individuals who were developing typically. Similar to Kern et al. 2006, the researchers found that the adults with ASD had SP results that were closer to the control group, in contrast to the more discrepant scores of younger individuals with ASD and their controls.

Crane et al. (2009) compared the sensory processing abilities of adults with ASD to adults without disabilities, but used the *Adult/Adolescent Sensory Profile* (AASP; Brown & Dunn, 2002), a self-reported measure of sensory processing abilities. The participants in their study were 18- to 65-year-old adults with either HFA or AS who were compared to age-matched peers without disabilities. Crane et al. (2009) found that all 18 members in the ASD group had atypical sensory processing patterns as compared to their age-matched peers without disabilities. They also found that 17 of the 18 members in the ASD group reported extreme sensory processing difficulties in at least one of the quadrants of the AASP. Crane et al. (2009) reported extreme variability between the responses of the individuals with ASD, but noted that there was not a clear pattern for the group as a whole; however, they were able to distinguish the individuals with ASD from those without disabilities based on their atypical responses.

Unlike previous researchers, Minshew and Hobson (2008) developed their own instrument, the *Sensory Sensitivity Questionnaire* (SSQ) and used a neuropsychological test of lower and higher cortical sensory perception instead of a version of the SP. In their study, 60 individuals with HFA were compared to 61 age-matched individuals without disabilities. All of the participants had measurable IQs above 90 and all were between 8 – 54 years of age. On the self-report sensory questionnaire, the individuals with HFA reported more sensory processing difficulties than the individuals without disabilities. Thirty-two percent of participants with HFA endorsed more sensory sensitivity items than any control participants. The individuals with ASD and those without disabilities did equally well on the lower level cortical sensory perception tests (the individuals closed their eyes and had to identify which finger the investigators touched and had to identify a 3-dimensional shape through touch alone); however, 30% of the individuals with ASD had a much harder time than the individuals without disabilities on the higher cortical sensory perception tests (the investigators drew numbers and simple shapes on the insides of the participants wrists with their fingers and the participants had to identify the numbers and shapes through the sensation of touch) and made many more errors. These researchers found that sensory processing difficulties are evident from childhood through adulthood for individuals with HFA, on both the lower and higher cortical sensory perception tests. However, these sensory processing difficulties may not be as universal among individuals with HFA since they found only 32% of the individuals in this category to have sensory processing difficulties.

Similar to Minshew and Hobson (2008), Harrison and Hare (2004) developed their own literature-based assessment, the *Sensory Behavior Schedule* (SBS) instead of using a version of the SP to evaluate the sensory processing abilities of adults with ASD. Harrison and Hare (2004) outlined seven sensory modulation areas that pose difficulties for individuals with ASD and assessed these areas via the SBS. These areas include: (1) hyper/hyposensitivity to sensory input; (2) distortions such as incorrectly judging the height of an object or perceiving an object as moving when it is actually still; (3) sensory tune-outs where an individual may experience sudden deafness or blindness; (4) sensory overload, where an individual cannot process the sensory input; (5) inability to process sensory input from more than one system at a time; (6) cross-channel perception, where an individual may see a visual picture after smelling a certain scent, or hear a song in his/her head when seeing a specific color; and (7) difficulty determining which sensory system is being stimulated. The researchers did not use control or comparison groups. Instead, they included 25 adults (ages 20-50 years) with ASD and asked key workers or caregivers who worked directly with the individuals with ASD to completed the SBS. The researchers found that over 40% of the individuals with ASD were either hypo or hypersensitive to temperature, more than 30% walked in a distinctive manner, and more than 25% engaged in twirling their fingers in front of their eyes and manipulating small objects. Therefore, several of the individuals with ASD who participated in this study engaged in behaviors that are indicative of abnormal sensory processing.

Adding qualitatively to the quantitative research that has been conducted, Grandin (1992) wrote an anecdotal report about her tactile defensiveness as a child and adult, and described how using the squeeze machine she developed helped her habituate to touch and become less tactilely defensive. She reported that although she desired being held as a child she would resist and pull away because the sensation she felt when she was touched was too overwhelming for her and created discomfort. After using her squeeze machine for 5-15 min, Grandin asserted that her anxiety abated and her tolerance for touch increased. Over time, she reported being able to reduce the intensity with which the machine squeezed her to gain the same effects and discovered that she did not need to use the machine as frequently. In an attempt to empirically substantiate her experiences, Grandin (1992) conducted a rudimentary experiment using the squeeze machine with college students without disabilities, but she did not include any formal measures of sensory processing abilities before or after the participants used the squeeze machine and the results were inconclusive.

In summary, the findings of the few researchers who have specifically evaluated the sensory processing abilities of adults with ASD can be interpreted to conclude that there are significant differences between the sensory processing abilities of individuals with ASD and those who were developing typically. The findings of sensory processing difficulties for adults were consistent across researchers who used the SP completed by caregivers of the individuals with ASD (Kern et al. 2006; Kern, Trivedi, et al., 2007) the AASP (Brown & Dunn, 2002), and other instruments that were designed to measure sensory processing abilities (Harrison & Hare, 2004; Minshew & Hobson, 2008), as well as described in an anecdotal self-report (Grandin, 1992). When the findings of all of these researchers are considered, the logical conclusion is that sensory processing difficulties persist into adulthood for individuals with ASD. Kern et al. (2006) and Kern, Trivedi, et al. (2007) hypothesize that although sensory processing difficulties continue to be prevalent in adulthood for individuals with ASD, individuals with ASD may learn to adapt to sensory stimulation with age and respond more appropriately or habituate to the sensory stimulation, rendering their sensory processing profiles closer to controls during adulthood than during childhood and adolescents. Crane et al. (2009) posited that sensory processing difficulties may need to be included in the diagnostic criteria for ASD. All researchers concur that adults with ASD still experience atypical sensory processing and the problems posed for daily functioning among adults with ASD may need to be addressed through targeted interventions including occupational therapy.

Sensory Processing Problems by Severity of ASD

Not only are there relationships between sensory processing abilities and age for individuals with ASD, but there also are correlations between severity of ASD characteristics and sensory processing difficulties. For example, in their third analysis of the large data set collected by Kern et al. (2006), Kern, Trivedi et al. (2007) excluded data from the individuals who were developing typically and evaluated sensory processing abilities across age in relation to severity of ASD characteristics as measured by the *Childhood Autism Rating Scal*e (CARS; Schopler, Reichler, & Renner, 1994).

They found a strong correlation between age, severity of ASD characteristics, and sensory processing patterns. Younger individuals with more severe forms of ASD as measured by the CARS, had more difficulty responding appropriately to sensory stimuli and exhibited more inappropriate behavior in response to sensory stimulation. Interestingly, this relationship did not hold true across the older age groups. The researchers theorized that a maturation or habituation process occurs with age, allowing younger individuals with more severe forms of ASD to learn to regulate sensory input better although not in the same manner as individuals without disabilities.

Myles et al. (2004) also found a relationship between severity of ASD characteristics and sensory processing abilities. These researchers differentiated children and adolescents with AS (milder ASD characteristics) from children and adolescents with autism (more severe ASD characteristics) by their SP results. The researchers matched 86 individuals with AS with 86 individuals with autism ages 6 – 17 years. Caregivers completed the SP for each of the participants in both groups. Both the youth with AS, as well as those with autism, had significant sensory processing impairments when compared to the SP results of the typically developing children in the standardization study (Ermer & Westman, 1997). However, Myles et al. (2004) also found significant differences between the individuals with AS and those with autism. The children and adolescents with AS had significantly more difficulty than those with autism in the areas of social/emotional responsiveness, inattention/distractibility, and auditory processing.

Similar to Kern, Trivedi, et al. (2007) and Myles et al. (2004), Liss, Saulnier, Fein, and Kinsbourne (2006) only evaluated the sensory processing abilities of children with ASD and did not compare the results to individuals with typical development. They conducted a cluster analysis of sensory processing characteristics for 144 children with ASD ranging in age from 4 – 12 years with a mean age of 8.5 years. They created their own 103-item sensory questionnaire which included 60 questions from the SP and 43 sensory-behavior-specific questions they developed based on their experience working with individuals with ASD. The majority of the questions clearly assessed one of the following three responses to sensory information: stimulus seeking, overreactivity, and underreactivity. The parents or caregivers of the 144 children with ASD completed several assessments regarding their children including the sensory questionnaire, the Kinsbourne Overfocusing Scale (Kinsbourne, 1991), a DSM-IV checklist on ASD characteristics, and the VABS. Using a hierarchical agglomerative cluster analysis, the researchers discovered that the children formed four distinct groups based on the following characteristics: overactivity, underreactivity, stimulus seeking, preservative behavior, overfocusing, and high-fidelity memory. Cluster 1 consisted of 17 children who expressed overreactivity to sensory stimuli, engaged in perseveration, and had high overfocusing scores, as well as exceptional memories for selective material. These individuals were relatively high functioning; but, they had the greatest deficits in social skills. The second cluster included 36 children who were considered to have mild ASD characteristics and had the lowest scores across all assessments with the least trouble processing sensory information. The third cluster included 44 children who were lower functioning overall. They had low VABS scores and high underreactivity and sensory seeking scores on the sensory questionnaire. The fourth cluster contained 47 children with mild ASD characteristics with fairly high VABS scores who were overreactive to sensory stimuli. They were similar to the children in cluster one; however, these children were only mildly overfocused as compared to the highly-overfocused characteristic of the children in cluster one. Liss et al. (2006) concluded that children with more severe forms of ASD who were lower functioning had more difficulty with sensory processing; whereas, higher functioning children with ASD had more social impairments.

Chen, Rodgers, and McConachie (2009) examined 29 children ages 8 – 16 years (mean age 11 years 11 months) with IQs above 70 who were diagnosed with either autism or AS. They used the SSP to evaluate the sensory processing patterns of the children and adolescents. They found that 17% of the individuals scored in the "probable difference" range and 76% scored in the "definite difference" range. Chen et al. (2009) reported that their participants had extreme scores in both the hypo and hyper-responsive quadrants of the SSP with underresponsive/seeks sensation and tactile sensitivity being the most common differences distinguishing them from youth who were developing typically. The researchers did not find a relationship between sensory processing difficulties and cognitive task performance for their participants; however, they found a significant relationship between stereotypic behaviors and sensory processing difficulties. The repetitive, ritualistic behaviors, which are associated with more severe forms of ASD (Schopler et al., 1994) had a negative impact on the speed with which the individuals processed and completed cognitive tasks.

Synthesizing the results of these studies leads to the conclusion that there appears to be a relationship between severity of ASD characteristics and sensory processing abilities in children and adolescents; youth with more severe forms of ASD have more difficulty processing sensory stimuli and may engage in more stereotypic behavior (Chen et al., 2009; Myles et al., 2004). However, Kern, Trivedi, et al. (2007) documented that this correlation is viable only for children and adolescents with ASD and, as the adolescents grow into adulthood, they have better sensory processing skills than they did as children and adolescents, although their sensory processing abilities are still atypical as compared to peers without disabilities. This information may be beneficial for teachers, therapists, and parents when working with children and adolescents with more severe ASD characteristics. A concentrated focus on supporting sensory processing may have a positive effect on reducing repetitive/stereotypic behavior and youth with sensory processing deficits may need additional time when asked to complete cognitive tasks.

Sensory Based-Interventions

Evidence-Based Practices in Special Education

During the last decade more emphasis has been placed on the use of evidence-based practices (EBPs) in classrooms because of the No Child Left Behind (NCLB, 2001) federal mandate. Currently there are no set guidelines for identifying EBPs in the field of special education (Cook, Tankersley, & Landrum, 2008). In 2003 the Division for Research of the Council for Exceptional Children (CEC) united a number of renowned researchers in the field of special education to articulate the criteria necessary to determine a practice as evidence-based across methodologies in the field (Odom et al., 2005). Their results were published in a special edition of *Exceptional Children* in 2005 and provide a foundation for the identification of EBPs; however, at this time these criteria have not been universally accepted. Other organizations also have articulated criteria for concluding that a practice is evidence-based such as the American Psychological Association (Lonigan, Elbert, & Johnson, 1998) and the American Speech-

Language-Hearing Association (2004). Regardless of the codified criteria used, there are currently no sensory-based interventions that would qualify as an EBP.

Despite the fact that none of these interventions is considered evidence-based, teachers, occupational therapists, and parents have been using a wide range of sensory-based interventions with the intention of addressing the sensory-processing difficulties experienced by individuals with ASD at all stages of life and across the severity of the spectrum (Dawson & Watling, 2000; Simpson et al., 2005). Hess, Morrier, Heflin, and Ivey (2008) conducted a survey of 185 teachers of children with ASD in Georgia and found that 92.86% of the respondents reported using sensory-based interventions with their students. Over the last twelve years several researchers have conducted meta-analyses of sensory-based intervention studies with the intent to draw meaningful conclusions about the use of sensory-based interventions with individuals with ASD (Baranek, 2002; Case-Smith & Arbesman, 2008; Dawson & Watling, 2000; Parham et al., 2007; Vargas & Camilli, 1998). Although there were some promising findings, not a single sensory-based intervention had sufficient empirical support to qualify as an EBP.

Vargas and Camilli (1998) conducted an early meta-analysis of research in the area of sensory integration (SI) treatment. They operationally defined SI treatment as an intervention designed to improve sensory processing for individuals through stimulation of the vestibular, proprioceptive, or tactile sensory systems. They identified a total of 22 published articles from 1972 – 1994 that met their inclusion criteria. From these 22 articles they identified 32 separate studies in which individuals receiving SI interventions were compared with a group of individuals receiving either an alternative intervention or no treatment. When a group of individuals receiving SI treatments were compared to more than one other group (i.e., compared to a group receiving no treatment and a group receiving an alternative treatment) the results were treated as two separate studies, one comparing the group receiving the SI intervention to the no treatment group and the second using the results comparing the group receiving the SI treatment to the group receiving the alternative treatment. Vargas and Camilli (1998) coded the treatments according to an undefined set of SI quality indicators, which ranged from 3 (low quality) to 11 (high quality). The average SI quality indicator score for the 32 studies was 7.44. Although Vargas and Camilli (1998) concluded that the studies were similar in SI quality, but because they did not report the range of scores for the studies it is impossible to determine if the studies were truly similar in regard to SI quality. Vargas and Camilli observed that the SI treatment had greater effect sizes in earlier studies when the group receiving SI was compared to a group receiving no treatment and the biggest areas of improvement were in the psychoeducational and motor performance areas. However, these findings did not hold true for the more recent studies that were included. The researchers concluded that there were no discernable differences in changes in sensory processing between the individuals who received SI treatments and those who received alternative treatments across all areas measured.

Heflin and Simpson (1998) evaluated a number of practices being implemented with individuals with ASD. They included the following sensory-based interventions in their analysis: SI, auditory integration training (AIT), Irlen lenses, and vision therapy. Based on their assessment of the literature, they made recommendations regarding the use of each of the interventions. They did not give a clear definition of SI treatment, but did state that SI programs were intended to help individuals with sensory processing difficulties learn to appropriately modulate sensory stimulation. Heflin and Simpson (1998) concluded that SI was a promising practice although the therapy lacked empirical support at the time of their analysis.

AIT was first introduced by Guy Berard and involves having the individuals with ASD listen to modified music through headphones for 30 minutes twice a day with a minimum of 4 hours in between the sessions over 10 days. The theory is that individuals with ASD are hypersensitive to sound and that listening to the modified music enables them to learn to tolerate sounds and thus improve their overall behavior. According to Heflin and Simpson (1998) there is no theory to support how this intervention works and no empirical data to justify application to individuals with ASD.

Irlen lenses are color tinted lenses that are hypothesized to aid individuals with scotopic sensitivity syndrome (SSS), which Helen Irlen claims is a severe sensitivity to white light spectrum wavelengths, and can cause vision problems such as blurred vision, double vision, distortion, and other perception difficulties. The colored lenses are anecdotally reported to allow individuals with SSS to correctly perceive and interpret what they see and thus correct the vision problems. Heflin and Simpson (1998) report that there are no empirical studies to support the use of Irlen lenses for individuals with ASD, but there may be some relief for the individuals with ASD who use the lenses, thus they deemed this practice as nonvalidated instead of experimental.

Finally Heflin and Simpson (1998) evaluated the use of vision therapy to improve behavioral, social, and academic functioning for individuals with ASD. The use of vision therapy to address vision problems is a scientifically-validated treatment for individuals with specific medically diagnosed vision problems; however, they did not find any justification for the use of vision therapy to improve the overall functioning of individuals with ASD. Of the four sensory-based interventions for individuals with ASD Heflin and Simpson (1998) evaluated, they found that none of the interventions would be considered evidence-based or scientifically validated, but conceded that more research is needed in the area of SI and Irlen lenses.

Dawson and Watling (2000) reviewed evidence in regard to sensory-based interventions in the areas of auditory, visual, and motor integration for individuals with ASD. They found that there were few empirical studies conducted on interventions that address these sensory systems despite the wealth of documentation on sensory processing difficulties for individuals with ASD. The interventions they reviewed were SI and AIT. Although the title of their article insinuates that they reviewed interventions to facilitate visual integration for individuals with ASD, they did not include any intervention specific to the visual sensory system. Dawson and Watling (2000) used the same over generalized description for SI as Vargas and Camilli (1998). Dawson and Watling (2000) concluded that there were not enough studies to make a valid conclusion about the use of SI treatment for individuals with ASD. Using the same description of AIT as Heflin and Simpson (1998), Dawson and Watling (2000) concurred that there was no evidence to support the use of AIT for individuals with ASD. Dawson and Watling (2000) recommended that additional well-controlled studies be conducted to evaluate the use of sensory-based interventions for individuals with ASD and encouraged researchers to identify ages and characteristics of individuals for whom these sensory-based interventions would be most beneficial.

Baranek (2002) conducted an analysis of sensory and motor interventions that have been used with children with ASD. She found that there were very few studies involving sensory or motor based interventions that met her inclusion criteria despite the amount of research that has been conducted in the field of ASD. Baranek (2002) conducted a search of the literature, gave explanations about each of the interventions she evaluated, and cited the original studies for each intervention. She evaluated SI, AIT, visual therapies, and physical exercise. Baranek (2002) gave the same description of SI as the previous researchers, but she did expand the description to include other required components such as the therapy has to be child-directed and the therapist has to scaffold the challenges for the child and shape the child's responses to the sensory stimulation while maintaining enjoyable and appropriate play activities. Baranek (2002) came to the same conclusion in regard to SI as Vargas and Camili (1998) and Dawson and Watling (2000). Individuals who participated in SI treatment had better psychoeducational and motor skill outcomes when compared to individuals receiving no treatment, but the results were undifferentiated when the individuals receiving SI were compared to individuals receiving an alternative intervention. Barnek (2002) described AIT in the same manner as the previous researchers. After reviewing nine studies involving AIT, she concluded that there were no discernable benefits to the use of AIT for individuals with ASD.

Barnek (2002) grouped several visual therapies such as Irlen lenses, oculomotor exercises, and prism lenses into one general visual therapies category. She found few research studies involving visual therapies. She found no empirical studies involving Irlen lenses or independent oculomotor exercises and only three studies involving prism lenses. Barnek (2002) stated that there were inconsistent findings across the prism lenses studies and that more refined research is needed to draw firm conclusions about the use of prism lenses for individuals with ASD.

Baranek (2002) evaluated the use of physical exercise as a sensory-based intervention for individuals with ASD. She did not give a clear description of physical activity but mentioned that aerobic activity had been hypothesized to decrease self-stimulatory behavior in the past. She found a total of four studies that measured the effect of physical activity on self-stimulatory behavior and play/social skills. Synthesizing the results, Baranek (2002) concluded that there were minimal short term benefits using physical exercise to decrease self-stimulatory behavior, but there were no improvements in the areas of social or play skills unless those skills were specifically taught during the intervention.

Although Baranek (2002) did not find that any of the sensory-based interventions would be considered EBPs, she did make several recommendations for education for children with ASD. A few of these recommendations were that educational environments should incorporate sensory and physical activities that provide developmentally appropriate sensorimotor experiences, environmental adaptations should accommodate children with sensory processing difficulties, and intervention decisions should be based on all available information in conjunction with an occupational therapist. She also recommended that additional research should be conducted to address deficits in the literature including the lack of large scale studies, more control of the characteristics of the participants (age, cognitive level, etc.), and the use of more sound methodological designs.

Simpson et al. (2005) wrote a book in which they provide evaluative information about current interventions, treatments, and practices being used with individuals with ASD. They identified three interventions, Irlen lenses, SI, and AIT, which would be considered sensory-based interventions. They gave very similar descriptions of all three interventions as the previous researchers and concurred that there is no empirical support for the use of Irlen lenses or AIT with individuals with ASD. They agreed with Heflin and Simpson (1998) and Dawson and Watling (2000) that there may be some benefits to the use of SI, but there are not enough well-designed studies with conclusive outcomes to draw a valid conclusion about the effectiveness of SI for individuals with ASD and additional research is needed.

In 2007, Parham et al. conducted a review of empirically-based articles involving pure SI interventions for preschool and elementary age children since 1972. Through their searchers and inclusion / exclusion criteria they identified a total of 34 articles that they used to evaluate the fidelity of SI implementation. Parham et al. (2007), with the assistance of experts in the field of occupational therapy, identified 10 core elements that should be present during the implementation of SI treatment. The elements are: provision of sensory opportunities, providing appropriate challenges, collaboration on activity choice, guiding the child in self-organization, supporting optimal arousal, creating a context for play, maximizing the child's success, ensuring physical safety, arranging the room to engage the child, and fostering a therapeutic alliance with the child. Parham et al. (2007) found that many of the researchers who conducted the empirical research did not describe their methods well enough to identify all 10 core elements, did not implement all of the core elements of an SI program, or actually violated core elements of SI.

Collaboration on activity choice was the main core element that was violated by the researchers. Often the researchers in the identified studies reported that the sensory activities were preselected by the occupational therapist or that the activities were scheduled instead of allowing the child to have a part in deciding what the next sensory activity would entail. Very few of the researchers who conducted the 34 studies reported quantitative fidelity measures or addressed if or how fidelity was measured and if lack of fidelity to SI protocol influenced the outcomes of the studies. Therefore, Parham et al. (2007) recommend that future researchers include stringent measures of fidelity to strengthen the findings and hopefully build a solid evidence base for the use of SI.

Case-Smith and Arbesman (2008) conducted a literature review of interventions and treatments for individuals with ASD in regard to occupational therapy. They only included studies that involved randomized control trials, nonrandomized clinical trials, meta-analyses, and pretest/posttest group designs. Case-Smith and Arbesman (2008) identified three sensory-based practices which included SI, sensory-based interventions, and AIT. Their findings supported the findings of the previous researchers in regard to SI and AIT. They found that SI had some promising preliminary support but that further research is needed before drawing definitive conclusions about the benefits of SI for individuals with ASD. Consistent with previous researchers, Case-Smith and Arbesman (2008) found that the evidence was inconclusive and there was no discernible benefit to using AIT with individuals with ASD. Finally they identified sensory-based interventions as interventions that provide therapeutic touch with the intention of decreasing aberrant behaviors or improving attention. They identified two studies on the effects of massage that met their inclusion criteria. Although there were positive results for participants, these studies contained methodological flaws and the researchers did not provide enough evidence to validate the use of massage. Therefore, Case-Smith and Arbesman (2008) supported the conclusions of previous researchers who described promising results with sensory-based interventions and practices for individuals with ASD, but emphasized that more research is needed in order to draw valid conclusions about the effectiveness of these interventions.

In 2009 the National Autism Center (NAC) published the *National Standard's Report*. The purpose of the report was to help identify EBPs in the field of ASD. They reported their findings on four sensory-based interventions: exercise, massage/touch therapy, AIT, and SI. Their descriptions of each of the interventions were similar to those provided by previous researchers. The NAC classified interventions/practices based on the strength of the empirical support. Their evidence ratings were established, emerging, unestablished, and ineffective/harmful, based on the number, quality, and type of studies supporting each intervention. Exercise and massage/touch therapy were both given an "emerging" evidence designation which means there were a few studies with beneficial results supporting the intervention, but additional research is needed. AIT and SI were both given an "unestablished" rating, which means the beneficial results reported were based on weak or uncontrolled studies. Therefore, the NAC (2009) confirms the recommendations of previous researchers in concluding that additional research in the area of sensory-based interventions is needed before any sensory-based intervention or practice can be endorsed as evidence-based.

Given the clearly documented sensory processing difficulties among individuals with ASD of all ages and levels of functioning, as well as the prolific use of sensory-based interventions with the population, it is surprising that attempts to document benefit are inconclusive. Most advocates for individuals with ASD believe that it is only logical to implement sensory-based interventions (Kaplan, Polatajko, Wilson, & Faris, 1993), but few agree on which interventions are most effective and rarely consider unique characteristics of individuals with ASD when selecting interventions to use. The driving rationale appears to be based on a merging of identified sensory processing differences and purported strategies to address sensory processing differences, without systematic consideration of interaction. Professionals in the fields of occupational therapy and psychology, however, offer theoretical support for implementing sensory-based interventions with individuals with ASD.

Theoretical Support

Although there is limited empirical support, and no vetting of evidence-based practice, there are two theoretical foundations that provide support for the use of sensory-based interventions for individuals with ASD. The two theories are the theory of sensory integration (Ayres, 1972) and the theory of optimal arousal (Leuba, 1955). The theory of sensory integration was proposed by an occupational therapist Jean Ayres (1972) and is based in the field of occupational therapy whereas the theory of optimal arousal was initially proposed by Clarence Leuba (1955), who was a professor of psychology. The two theories emerge from very different fields, but both theories provide possible support for the use of sensory-based interventions with individuals with ASD.

Ayres (1972) initially developed the theory of sensory integration to explain why some individuals have learning disabilities (LD). She theorized that the brain developed sequentially and one of the essential states of development involved the ability of the central nervous system (CNS) to process sensory stimulation. Ayres (1972) posited that students with LD had abnormal brain development and that this abnormal brain development negatively affected their ability to process sensory stimulation, thus resulting in LD. She hypothesized that abnormal brain development could be counteracted with systematic sensory stimulation, resulting in permanent changes in the brain that would allow these individuals to process sensory stimuli appropriately, curing them of their LD and eliminating their need for sensory-based interventions.

Ayres' theory of sensory integration was criticized by professionals because she was unable to explain the neurological changes she proposed (Dunn, 1988). Winnie Dunn (1988), a student of Jean Ayres expanded the theory of sensory integration by explaining neurological functions to support the theory of sensory integration. She used basic and applied neuroscience research to support the theory of sensory integration by explaining that individuals with poor sensory modulation were responding to their CNS thresholds for sensory stimulation. According to Dunn (1988), every receptor in the CNS has a threshold for firing and each threshold can be high, low, or normal. Individuals with high or low sensory thresholds have poor sensory processing skills and would have atypical responses to sensory stimuli as compared to individuals with normal thresholds for sensory stimulation. Individuals with high thresholds need more stimulation in order to trigger that sensory receptor. Individuals with low thresholds need less sensory stimulation to trigger that receptor.

Using this theoretical support, Dunn (1997) developed a conceptual model of sensory processing. She hypothesized that individuals with sensory modulation difficulties either had high or low thresholds for sensory stimuli so that these individuals either acted in accordance with their thresholds or acted to counteract their thresholds. For example, individuals who have very low thresholds for auditory stimulation may cry or scream because the auditory stimulation is uncomfortable. If they were trying to counteract their low thresholds for auditory stimulation they might plug their ears or try to avoid the auditory stimulation all together. Another example would be individuals with high thresholds for auditory stimulation may not respond to someone else calling their names at a normal volume and when they are responding to counteract their high thresholds they may listen to very loud music or enjoy very loud, noisy environments (i.e., sensory seeking).

Although Dunn's (1997) conceptual model of sensory processing was an extension of Ayer's (1972) theory of sensory integration, there were some defining differences between the two. Dunn (1997) stated that an individual's sensory modulation remains fairly stable across the lifespan and that an individual can have high and low thresholds at the same time within different sensory systems. Dunn created the *Sensory Profile* (SP) which is a standardized assessment to measure sensory processing patterns across all of the sensory systems (Dunn, 1997). The SP was normed using approximately 1,050 children, ages 3.0 to 10.11 years, who were developing typically (Dunn, 1999). Based on the SP results of these children, Dunn determined a pattern for sensory processing abilities of children who were developing typically. The original SP has 125 questions and takes approximately 30 min for caregivers to complete (Dunn, 1999). McIntosh et al. (1999) developed the *Short Sensory Profile* (SSP) from the original SP to be used as a measure of sensory processing for research projects. The SSP consists of 38 questions and requires approximately 10 min to complete. According to Dunn (2007), a person's sensory processing difficulties are evident based on the person's behavior and response to sensory stimulation. Although she aligned her model of sensory processing on the constructs of the theory of sensory integration, her hypothesis of identifying an individual's sensory processing patterns based on his/her behavior also supports the tenets of the theory of optimal arousal.

The theory of optimal arousal was first introduced by Clarence Leuba in 1955. Leuba was a professor of psychology who stated that all organisms function best when they are at an optimal level of arousal. He theorized that most organisms were in a state of under-arousal and were striving to increase their stimulation to reach an optimal level of arousal. Although he believed most organisms were in a state of under-arousal, he did concede that some organisms may achieve a state of over-arousal and that those organisms had to decrease their stimulation to reach an optimal level of arousal. Leuba's (1955) theory encompassed all organisms and was not specific to human beings. Zentall and Zentall (1983) extended the theory of optimal arousal by specifically applying the theory to human beings and by comparing populations of individuals with disabilities to those who were developing typically in terms of their optimal arousal.

Zentall and Zentall (1983) stated that individuals could be above or below their optimal level of arousal and that they would engage in behaviors to help them reach their optimal level of arousal. They noted that individuals with ASD behaved in normal environments the way individuals who were developing typically reacted in over or under stimulating settings (Zentall & Zentall, 1983). Thus, they theorized that individuals with ASD were over or under their optimal level of arousal in typical environments when individuals without disabilities would be at their optimal level of arousal. Zentall and

Zentall posited that individuals with ASD engaged in stereotypic behavior increase or decrease their sensory stimulation and achieve their optimal levels of arousal. Although these repetitive behaviors facilitated optimal levels of arousal, they often impede individuals' abilities to appropriately interact with the environment.

According to Repp, Karsh, Deitz, and Singh (1992) one of the best ways to determine if a person is above or below his/her optimal level of arousal is by observing his/her level of activity. Individuals who are over aroused will engage in behaviors to reduce their levels of arousal such as becoming lethargic and unresponsive or engaging in repetitive calming behaviors. Individuals who are under-aroused will engage in behaviors to increase their levels of arousal such as using fast jerky movements or appearing hyperactive (Repp at al., 1992). Therefore, Zentall and Zentall (1983) and Repp et al. (1992) agree with Dunn (2007) that an individual's response to sensory stimulation can be determined based on his or her behavioral response to that stimulation.

Although Dunn (1997) developed her model to align with the theory of sensory integration, her conceptual model is applicable to the theory of optimal arousal. Her model is based on behavioral responses to sensory stimulation and she hypothesized that although there can be variability with an individual's sensory processing abilities over time, based on the environment, amount of sleep, hunger, and so forth, overall sensory processing difficulties are persistent across the lifespan (Dunn, 1997, 2007), which are the basic tenets of the theory of optimal arousal as well. Thus, the SP and SSP can provide information regarding an individual's level of arousal based on his/her behavioral responses to sensory stimulation.

The theory of optimal arousal has more empirical support in the field of ASD than the theory of sensory integration. Several researchers have documented that sensory processing difficulties are persistent across the lifespan of individuals with ASD (Kern et al., 2006; Kern, Garver, et al., 2007; Minshew & Hobson, 2008). Thus, individuals with ASD continue to have difficulty processing sensory stimuli and these difficulties do not go away over time, invalidating the permanent changes in the brain as hypothesized by Ayres (1972). Researchers have documented that younger individuals with more severe ASD characteristics have more difficulty with sensory processing than older individuals with ASD, although older individuals with ASD (regardless of severity) still have atypical sensory processing abilities as compared to typical peers (Kern, Garver, et al., 2007; Kern, Trivedi, et al., 2007). The empirical studies that are available to date regarding the sensory processing abilities of individuals with ASD provide support for the major tenets of the theory of optimal arousal.

Despite the fact that there are no sensory-based EBPs, a couple of research groups have evaluated the use of specific sensory-based interventions to alter arousal levels of children with ASD to improve engagement and student learning. Shilling and Schwartz (2004) evaluated the effectiveness of using exercise balls as alternative seats for young children with ASD to see if they could increase the amount of time the students were engaged in academic tasks. During the course of their study they found that the children with ASD used the exercise ball in ways that were qualitatively different from one another. One child in their study bounced on the ball while another slowly rocked back and forth on the ball, but both children remained seated longer on the ball than in a chair and both showed improvement in task engagement. Therefore, it appears that the students were altering their levels of arousal by using the exercise balls. The student who was bouncing on the ball was providing himself/herself with additional sensory stimulation and the child who was rocking was calming himself/herself and thus decreasing sensory stimulation; both children were able to reach their optimal levels of arousal to improve their learning outcomes.

Van Rie and Heflin (2009) implemented sensory-based interventions with the intent of altering the levels of arousal for children with ASD. They used an alternating treatment design to compare the effects of bouncing on an exercise ball, slowly swinging in a linear motion in a suspended swing, and listing to a story read by the teacher (this was the control activity) to determine if any of these interventions had an effect on student skill acquisition. They found that one student who appeared generally lethargic had improved learning outcomes after bouncing on the exercise ball and two students who appeared hyperactive had improved learning outcomes after swinging. Both Schilling and Schwartz (2004) and Van Rie and Heflin (2009) demonstrated that sensory-based interventions can have a positive effect on learning for children with ASD and that different children with ASD respond to qualitatively different types of sensory-based interventions. In both studies, one student responded to alerting or increasing sensory stimulation activities. One student in the Schilling and Schwartz (2004) study and two students in the Van Rie and Heflin (2009) study benefited from calming activities or sensory-based activities hypothesized to reduce sensory stimulation. However, neither research group included formal measures of sensory processing skills for the children with ASD prior to the start of their studies, and neither group evaluated specific characteristics of the children based on the successful intervention. Given that there were only a total of 5 students with positive results with the sensory-based interventions between the two studies, there is definitely a need for future research.

Although sensory processing difficulties are well documented across every stage of life for individuals with ASD (Ashburner et al., 2008; Ben-Sasson et al., 2007; Kern et al., 2009; Schoen et al., 2009) there are no evidence-based interventions to address these sensory needs for individuals with ASD (Cook et al., 2009). Several researchers have evaluated the effectiveness of a variety of sensory-based interventions such as AIT, Irlen lenses, and SI (Baranek, 2002; Case-Smith & Arbesman, 2008; Dawson & Watling, 2000; Parham et al., 2007; Vargas & Camilli, 1998). These researchers concluded that there is no empirical support for the use of Irlen lenses or AIT with individuals with ASD, however, Heflin and Simpson (1998), Dawson and Watling (2000), and Simpson et al. (2005) all agreed that SI may be a promising practice for use with individuals with ASD, but that more well designed research is needed to draw meaningful conclusions about the use of SI. Several researchers theorize that individuals with ASD engage in repetitive and stereotypic behaviors because of sensory processing difficulties and that these behaviors interfere with learning and appropriate interactions with others and the environment (Ashburner et al., 2008; Crane et al., 2009; O'Brien et al., 2009; Zentall & Zentall, 1983), it is critical to address sensory processing difficulties with EBPs. Because SI constitutes a fairly inclusive intervention package that involves the relationship between the interventionist and the individual with ASD as well as a wide variety of sensory-based activities, future research on the effects of specific sensory-based interventions like the studies conducted by Schilling and Schwartz (2004) and Van Rie and Heflin (2009) may provide more valuable information for identifying sensory-based EBPs for individuals with ASD.

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CHAPTER 2

USING SENSORY INTERVENTIONS TO PROMOTE SKILL ACQUISITION FOR STUDENTS WITH AUTISM SPECTRUM DISORDERS

Researchers have discovered that individuals with autism spectrum disorders (ASD) process sensory stimuli differently when compared to individuals who are developing typically and those with other disabilities (Ben-Sasson et al., 2007; Ermer & Dunn, 1998; Harrison & Hare; 2004; Minshew & Hobson, 2008; Myles et al., 2004; Rogers, Hepburn & Wehner, 2003; Tomcheck & Dunn, 2007). Although they may change slightly over time, these sensory processing differences are persistent across age and severity of ASD (Kern, Garver, et al., 2007). Sensory processing differences for individuals with ASD are evident as early as twelve months of age (Baranek, 1999) and still evident in those who are 65 years old (Crane, Goddard, & Pring, 2009). Even though Kern, Trivedi, et al. (2007) found that older individuals with ASD had improved sensory modulation as compared to younger individuals with ASD, there is still a significant difference in sensory modulation between individuals with ASD and individuals without ASD.

Researchers have identified sensory processing patterns that are fairly consistent for certain age groups of individuals with ASD. Toddlers (ages 1-3 years) with ASD are generally unresponsive to sensory stimuli (Baranek, 1999; Ben-Sasson et al., 2007), and children and adolescents with ASD can be unresponsive to certain sensory stimuli but may seek additional exposure to other sensory stimuli; these responses are not commonly seen in typical peers or peers with other disabilities (Baker, Lane, Angley, & Young, 2007; Tomcheck & Dunn, 2007). This variability in sensory processing patterns also has been identified in adults with ASD (Crane et al., 2009).

Kern, Trivedi, et al. (2007) discovered a strong correlation between age and severity of ASD in regard to sensory modulation (i.e., younger children and those with more severe ASD experienced more abnormal sensory processing). Therefore, sensory processing difficulties are prevalent for individuals with ASD across the lifespan and younger individuals with more severe forms of ASD usually have more difficulty processing sensory stimuli.

Often individuals with sensory processing difficulties engage in inappropriate or stereotypic behavior to regulate sensory modulation and compensate for their sensory processing challenges (Rogers et al., 2003: Schilling & Schwartz, 2004; Zentall & Zentall, 1983). Sensory processing difficulties can result in inattentiveness, distractibility, and lethargy (Baker et al., 2008; Rogers et al., 2003). These behaviors and inappropriate responses to sensory stimulation can impede student engagement and negatively affect student learning (Baker et al., 2008). Interventions that can improve sensory processing for individuals with sensory processing difficulties may prove beneficial for improving student learning outcomes.

There are two theoretical explanations that provide support for the sensory processing difficulties experienced by individuals with ASD. The two theories are (a) the theory of sensory integration, which was postulated by Ayres (1972) and expanded by Dunn (1997), and (b) the theory of optimal arousal which was introduced by Lueba

(1955) and extended by Zentall and Zentall (1983). Ayres theorized that individuals who have poor sensory modulation need to be exposed to systematic and prescribed sensory input to permanently change their neurological functioning. With intervention, affected individuals eventually will process sensory stimuli appropriately. Dunn expanded the theory with an explanation of the neurological basis by describing the function of sensory receptor thresholds and how an individual's threshold, habituation, or sensitization can be affected through exposure to sensory stimuli. In contrast, the theory of optimal arousal is based on the premise that all organisms have an optimal level of arousal that must be obtained to function at full potential. Leuba (1955) argued that most organisms were striving to increase their level of stimulation to reach their optimal level of arousal whereas Zentall and Zentall (1983) theorized that individuals engaged in behaviors to either increase or decrease their stimulation to reach their optimal level of arousal.

Both theories can be used to explain the sensory processing differences experienced by individuals with ASD; however, the theory of optimal arousal is more applicable because Zentall and Zentall (1983) hypothesized that an individual can be either under- or over-aroused at different times and that the individual will engage in behaviors to either increase or decrease sensory input to reach his/her optimal level of arousal. Because previous researchers have documented that individuals with ASD have difficulty modulating sensory stimuli across their life spans (Kern, Garver, et al., 2007; Kern, Trivedi, et al., 2007; Minshew & Hobson, 2008), the theory proposed by Ayres (1972) and Dunn (1997) who stated that neurological functioning can be permanently modified after prescribed interventions, does not hold true.

Even though Dunn (1988) aligns her research with the theory of sensory integration, much of her work also relates to the theory of optimal arousal. Dunn (1997) hypothesized that individuals could be both hypo- and hyper-responsive to sensory stimuli and that an individual's response to the same sensory stimuli can change over time. She developed a conceptual model of sensory processing in which she hypothesized that individuals responded to sensory stimuli based on their sensory receptor thresholds. An individual could have high thresholds and either fail to register sensory input or need to seek additional sensory input to trigger his/her sensory thresholds. In contrast, an individual could have low sensory thresholds and be overly responsive to sensory stimuli or try to avoid sensory stimuli because the stimulation makes him/her uncomfortable (Dunn, 2001). Therefore, her conceptual model of sensory processing is applicable to the theory of optimal arousal because it is an individual's response to sensory stimuli that indicates how the individual is processing sensory input.

Given that sensory processing issues are documented among individuals with ASD (Baranek, 2002; Case-Smith & Abesman, 2008; Dawson & Watling, 2000), it is concerning that there is limited research in regard to the efficacy of using antecedent sensory-based interventions to facilitate optimal levels of arousal necessary for learning for individuals with ASD. Schilling and Schwartz (2004) evaluated the use of therapy balls as alternative seating to increase the amount of time preschool children with ASD were in their seats and engaged in academic instruction. Although, they were not specifically evaluating the use of the therapy balls as an antecedent sensory-based intervention, they found that each of the children in their study utilized the therapy ball in qualitatively different ways. One student slowly rocked back and forth on the ball and another bounced vigorously; both students increased time spent in seats and on task. Van Rie and Heflin (2009) evaluated the effect of bouncing on a therapy ball and swinging in a suspended swing on correct responding for elementary-school-age children with ASD. They found that 5 min of antecedent sensory-based activities resulted in more correct responding for some of the participants; however, it is not known if a shorter time period (e.g., 3 min) might be sufficient. In the few studies that have been conducted, researchers have speculated that the variability in responsiveness to antecedent sensory-based interventions may be predicted by assessing a student's responsiveness to sensory stimuli (i.e., under- or over-aroused) and subsequently using specific sensory input to establish optimal levels of arousal. Given the paucity of empirical support to substantiate sensory-based interventions as an evidence-based practice (Horner et al., 2005), additional research is needed in the area of antecedent sensory-based interventions for students with ASD. The purpose of this study is to answer the following research questions:

1. What effect will antecedent sensory-based interventions, such as slow controlled gliding in a gliding rocking chair or fast jumping on a small trampoline, have on correct responding for elementary-school-age children with severe ASD?

2. What are the associations among person-level predictors and the growth per session for children with ASD who are engaging in the antecedent sensory-based interventions?

3. What is the relationship among a paraprofessional's ratings of child arousal, a naïve observer's ratings of child arousal, and the antecedent sensory-based intervention?

4. How socially valid are the antecedent sensory-based interventions based on the perspective of the implementing teacher?

Method

Participants

Because researchers have documented that younger individuals with severe ASD have more difficulty with sensory modulation than older individuals with milder forms of ASD (Kern, Garver, et al., 2007; Kern, Trivedi, et al., 2007), five elementary-school-age children with severe ASD participated in this study. The participants for this study were recruited from a kindergarten through fifth grade self-contained classroom for students with ASD and/or moderate intellectual disability in a public elementary school outside a major metropolitan area in the southeastern US. The study was approved by Institutional Review Boards at the author's University and the teacher's school district. Written parental permission was obtained prior to inviting the students to participate in the study. There were seven students in the classroom, but only the five students with ASD who met inclusion criteria were invited to participate.

The five students included in the study (a) qualified for special education services with an ASD eligibility; (b) were between 7.4 and 10.75 years old (to control for age variation); (c) had measurable IQs between 30 and 59 (to control for the influence of intellectual functioning); (d) had Childhood Autism Rating Scale (CARS; Schopler, Reichler & Renner, 1994) scores greater than 38 (indicating severe autism); (e) were physically capable of jumping or gliding; and (f) had Short Sensory Profile (SSP; McIntosh, Miller, Shyu, & Dunn, 1999) scores of 141 or less (indicating "definite difference" or highly atypical sensory processing skills). Students who did not have an ASD eligibility, who were younger than 5 years or older than 12 years of age, whose IQs were above 60, who had CARS scores below 38, who had physical/health impairments that prevented them from jumping or gliding, or who had an overall SSP score in the "probable difference" or "typical performance" ranges as indicated by a score of 142 or higher were excluded from the study. Prior to finalizing participant selection, students who met the inclusionary criteria were given the opportunity to jump on the trampoline or glide in the rocking chair. If they were noncompliant with either activity, they would have been excluded from the study; all five students who met inclusion criteria were compliant with the sensory-based intervention activities. Four of the five participants received all of their special education services in the self-contained classroom. One of the participants, Steven, received his special education services in the self-contained classroom, a resource classroom setting, and in the general education classroom with support. He spent approximately two hours of the school day outside the self-contained classroom.

As noted in the inclusion and exclusion criteria, several assessments were used to document participant functioning. These assessments included; the Childhood Autism Rating Scale (CARS; Schopler et al., 1994), the Short Sensory Profile (SSP; McIntosh et al., 1999), and the Vineland Adaptive Behavior Scale (VABS; Sparrow, Balla, & Ciccehetti, 1984). The classroom teacher completed a CARS and SSP for each child prior to implementing the study. The CARS is a 15-item behavioral assessment used to identify autism as well as to quantitatively describe the severity of the disorder (Kern, Garver, et al., 2007). Scores can range from 15 – 60 with a score between 30–37 indicating mild to moderate autism and a score between 38-60 indicating severe autism (Schopler et al, 1994). The CARS is a well-established assessment used by numerous researchers to provide descriptive information related to participants with autism (e.g., Baker et al., 2008; Kern, Trivedi, et al., 2007; O'Reilly et al., 2010; Van Rie & Heflin, 2009).

The SSP is a 38-item questionnaire that can be completed by someone who knows the child well and was developed from the items on the Sensory Profile (SP; Dunn, 1999; Tomcheck & Dunn, 2007) that had the highest discriminative power to determine atypical sensory processing. The norms for the SSP were derived from the SP, which was standardized on 1,037 children ages 3 to 10 years who were developing typically (Dunn, 1999; Tomcheck, & Dunn, 2007). McIntosh et al. (1999) report a discriminate validity of the SSP at >95% for identifying children with and without sensory processing difficulties. Children with typical sensory processing have total scores in the range of 155-190; those with probable difference score in the range of 142-154; and those with definite differences have scores in the range of 38-141 (McIntosh et al., 1999). Given the short administration time of 10 min and high validity for identifying children with sensory modulation difficulties, the SSP is recommended for research (Dunn, 1999; McIntosh et al., 1999).

Although not used for inclusion criteria, VABS scores were used to give an indication of general functioning in the area of adaptive skills for each participant. The VABS is an assessment that is completed through a semi-structured interview with a caregiver involving 297 questions that takes approximately twenty to sixty minutes to complete. The assessment consists of questions to assess the child’s functioning in the domains of communication, daily living skills, socialization, and motor skills. Each domain results in a raw score that is converted to a standard score and when the standard scores are added together the result is an adaptive behavior composite score. The mean standard score for the VABS is 100 with a standard deviation of 15 (Sparrow et al., 1984). VABS scores were culled from student records as each was completed at the time of each student's evaluation for special education services (> 2 years prior to the study). The teacher who implemented the intervention for this study completed the VABS for Steven and Anna. Carlos, Brian, and Carens' VABS were completed by one of their parents. All of the VABS were scored and interpreted by a psychologist employed by the school system. See Table 1 for descriptive information about each participant.

Steven. Steven was an active child who occasionally had "bursts" of energy where he got up from his seat and jumped around before sitting back down, but he generally remained seated. He engaged in frequent verbal stereotypy, repeating lines and sound effects from cartoons and computer games. He used 3-4 word utterances with minimal prompting to communicate his wants and needs. Though usually cooperative, Steven sometimes became noncompliant and dropped to the ground when presented with instructional tasks, particularly when following a preferred activity (e.g., getting off of the computer to do a written assignment) and repeatedly screamed "try again" or "goodbye" when presented with a nonpreferred task. Steven was the youngest participant. His overall SSP score fell in the "definite difference" range. However, he did score in the "typical performance" range for movement sensitivity and in the "probable difference" range for taste/smell sensitivity. Steven scored in the "definite difference" range for the remaining areas of the SSP: tactile sensitivity, underresponsive/seeks sensation, auditory filtering, low energy/weak, and visual/auditory sensitivity. His "probable difference" score for taste/smell sensitivity may be indicative of eating challenges. His "definite difference" scores in the areas of tactile sensitivity, underresponsive/seeks sensation, auditory filtering, low energy/weak, and visual/auditory sensitivity may indicate that he is defensive to and uncomfortable with touch, he has poor sensory modulation, and can have unpredictable responses to sensory stimuli. The SSP results can be interpreted further to infer that Steven may either over- or under-react to auditory stimulation, may have under-developed muscles which results in tiring quickly, and he may be easily distracted by auditory and visual stimulation. During the time of this study, Steven was taking the medications Concerta® for attention deficit/hyperactivity disorder and Paxil® to address anxiety. He was given the medication at home and his mother did not share his daily dosages.

Table 1

Descriptive information about the participants

Name	Age (years)	CARS[a]	Cognitive Assessments	Adaptive Behavior[e]	Sensory Processing[f]
Steven	7.4	42	59[b]	64	127
Anna	8.5	45.5	32[b]	53	139
Carlos	10.75	48	30[b]	59	93
Brian	8.3	43.5	46[c]	52	127
Caren	10	40.5	47[d]	46	101

[a]Childhood Autism Rating Scales; [b]Differential Ability Scales, Second Edition, Early Years Record Form (General Conceptual Ability Standard Score); [c] Battelle Developmental Inventory, Fourth Edition (standard score); [d]Wechsler Preschool and Primary Scale of Intelligence – Third Edition (full scale score); [e]Vineland Adaptive Behavior Scales, Second Edition; [f]Short Sensory Profile total score

Anna. Anna was an active girl who spent much of her day reciting excerpts from cartoons, particularly those related to the character, Elmo, from *Sesame Street*. She frequently engaged in self-stimulatory behaviors such as bouncing, squeezing her hands together, squealing "eeeeeeeee", crashing into things and people, and picking at things (e.g., stickers, labels, sores/scabs - hers or someone else's, wallpaper, anything that she could peel) as well as a self-injurious behavior such as biting her hand when excited or frustrated. Anna communicated vocally with 2-3 word phrases to request items/activities (e.g., "cookies please" or "I want puzzles") but usually required frequent prompting and modeling to make vocal requests (she often pointed to what she wanted and her teacher asked "what do you want?" before Anna would vocally request the item/activity). Anna was difficult to engage in instructional activities because her echolalia (e.g., cartoon repetition) was so persistent. She averted her eyes from instructional materials and watched her hand (which she used as a puppet) while she recited phrases from cartoons. When the teacher continued to present tasks or materials, Anna often bit her hand or squeezed her hands together and stiffened her entire body (contracting all of her muscles). After that, she became more actively noncompliant (e.g., throwing down the materials, attempting to run away) and often aggressive (e.g., kicking or hitting the instructor). Anna's total score on the SSP fell in the "definite difference" range for overall sensory processing. However, there were several areas of the SSP where she scored in the "typical performance" range: tactile sensitivity, movement sensitivity, low energy/weak, and visual/auditory sensitivity. She scored in the "probable difference" range for auditory filtering and in the "definite difference" range for taste/smell sensitivity and underresponsive/seeks sensation. Her score in the "probable difference" range for auditory filtering indicates that she may be either hyper- or hyporesponsive to sensory stimulation. Her scores in the "definite difference" range for taste/smell sensitivity and underresponsive/seeks sensation indicates that she most likely has difficulties with eating certain textures and/or flavors resulting in eating challenges and that her responses to sensory stimulation may be unpredictable. During the time of the study, Anna received a Lupron® shot every 28 days for precocious puberty.

Carlos. Carlos was lethargic in the morning, frequently falling asleep at school. Often he was difficult and/or impossible to awaken to engage in instructional activities. When awake, Carlos regularly engaged in self-stimulatory behaviors (e.g., kicking his legs, shaking his entire body, making loud high-pitched noises, clapping his hands, and laughing inappropriately). Carlos repeated previously-heard phrases (delayed echolalia) at random times throughout the day (e.g., "What you doin' boy?" "Don't touch spider, it bite you."). He enjoyed listening to motor sounds such as the lawnmower, washer/dryers, vacuums, and so forth. He communicated vocally with 2-3 word phrases (e.g., "I want drink" or "it is broom") but had a limited vocabulary that consisted mostly of names of preferred items (e.g., vacuum, lawnmower, toys, and food). Carlos' total score on the SSP placed him in the "definite difference" range for overall sensory processing. He scored in the "typical performance" range for taste/smell sensitivity and visual/auditory sensitivity. He scored in the "definite difference" range for tactile sensitivity, movement sensitivity, underresponsive/seeks sensation, and auditory filtering. These scores in the "definite difference" range indicate that he likely is either defensive or uncomfortable with touch and unpredictable movement, his responses to sensory stimulation is probably unpredictable, and he most likely is either under- or overresponsive to auditory stimuli.

During the time of this study, Carlos took both homeopathic and prescription medication. He took Risperdal® and Clonodine® to address behavior concerns and Zoloft® to treat anxiety, as well as melatonin to aid with sleep. He took these medications at home and his mother did not disclose the dosages.

Brian. Brian was an active boy who frequently bounced in his seat, rocked his chair backward on two legs, slapped his back against the back of his seat, and jumped repeatedly when standing/walking. He also engaged in hand flapping and inappropriate verbalizations (e.g., squealing loudly with a high-pitched voice). He communicated with multiple-word phrases to request items within routine situations (e.g., "I want bathroom," "I want chicken nuggets") and spontaneously requested items throughout the day by stating the item he wanted (e.g., "french fries," "grandma's house") and could label approximately 100 items that were reinforcing for him (e.g., foods, toys), but had a limited vocabulary in relation to social interactions. Brian's total score on the SSP was in the "definite difference" range of overall sensory processing. He scored in the "typical performance" range for tactile sensitivity and movement sensitivity. He scored in the "probable difference" range for taste/smell sensitivity and in the "definite difference" range for underresponsive/seeks sensation, auditory filtering, low energy/weak, and visual/auditory sensitivity. His score in the "probable difference" range for taste/smell sensitivity may be indicative of eating challenges. His scores in the "definite difference" range for underresponsive/seeks sensation, auditory filtering, low energy/weak, and visual/auditory sensitivity indicate that he may be uncertain or uncomfortable with movement, may be hyper- or hyporesponsive to auditory stimulation, have poor muscle development resulting in tiring quickly, and become easily distracted by visual and auditory stimulation. During the time of this study, Brian did not take medication.

Caren. Caren was a calm child who often engaged in delayed echolalia, repeating phrases she heard at other times (e.g., "Stay out of daddy's wallet," "Shut the bathroom door"). She walked on her tip-toes unless she was wearing her ankle-foot orthotics (AFOs). The AFOs were used to hold her feet in a flexed position so that she walked flat-footed, and were not prescribed due to an orthopedic impairment. Caren frequently sucked her thumb and/or hair and wore a chewy tube necklace that she was redirected to chew on instead of sucking her thumb or hair. Caren frequently engaged in self-stimulatory behavior (e.g., hand wringing, finger wiggling, and hand flapping). Caren used 3-4 word utterances to communicate her wants and needs but often required prompts to evoke communication. Caren's total score on the SSP was in the "definite difference" range of overall sensory processing. She scored in the "typical performance" range for taste/smell sensitivity and visual/auditory sensitivity. She scored in the "definite difference" range for tactile sensitivity, movement sensitivity, underresponsive/seeks sensation, auditory filtering, and low energy/weak. These scores in the "definite difference" range may indicate that she is uncomfortable with touch, has unpredictable responses to movement, may be hypo- or hyperresponsive to auditory stimulation, and may have underdeveloped muscles which results in tiring quickly. During the study, Caren did not take medication.

The participating teacher had been teaching students with ASD for over eight years in the same classroom in which the study was conducted. She worked with each of the student participants for approximately two to four years prior to implementing the study. The teacher had been using discrete trial methodology with her students and collected data on student performance since she started teaching. She created a "sensory room" for her students use about five years prior to the study. The investigator trained the teacher to implement both sensory interventions in one training session with follow-up phone calls to ensure understanding of correct implementation (procedural fidelity data will be described in a subsequent section). The teacher also was working on her doctoral degree at the same institution as the investigator.

Setting

All activities for this study took place in a "sensory room" located across the hall from the participants' self-contained classroom. The room was approximately 12.5' by 12'. There were no windows in the room. The room was equipped with a small tent in one corner, a small mini-trampoline in another, a gliding-style rocking chair, a ceiling mount for a suspended swing, and a small table with two chairs for academic instruction. Prior to this study, the room was used by 1-2 students at a time with the teacher or a paraprofessional to engage them in a variety of sensory-based activities as well as 1:1 instruction at the small table. Consequently, the participants associated this room with sensory-based activities and academic instruction prior to the start of the study. The suspended swing was not present during the study and the students were not allowed to engage in other sensory-based activities prior to their instructional sessions for the study. They could, however, engage in any available activities in the sensory room if the opportunity arose during the afternoon.

Independent Variables

The independent variables were the two sensory-based activities: gliding in a gliding-style rocking chair and jumping on a mini-trampoline. The gliding-style rocking chair was used for the calming sensory-based activity because slow linear movement is theorized to be calming (Kashman & Mora, 2005; Kranowitz, 2005; Yack, Aquilla, & Sutton, 2002). A gliding-rocking chair maintains a smooth back-and-forth movement as opposed to a traditional rocking chair. A 36" mini-trampoline (available at most large discount stores) was used for the alerting sensory-based activity (Kashman & Mora, 2005; Kranowitz, 2005; Yack et al., 2002). An 8" audible Time Timer® was used to ensure the sensory-based interventions were implemented for 3 min prior to instruction on the identification tasks. This timer is ideal for use with students with ASD because it provides a visual cue of the length of time for an activity as well as an audible cue indicating when an activity is over. The teacher used a metronome application on her iPhone® to ensure that the students were gliding slowly (30-35 repetitions per min) or jumping at a fast pace (85-95 jumps per min). In the gliding activity, a repetition was counted each time the chair moved forward. The teacher controlled the gliding by sitting in front of the glider while the student sat in the glider and moving the chair by putting her hands on the arms of the glider to ensure that the chair moved in a steady and smooth motion without stopping. The teacher held the students' hands for safety while using the mini-trampoline and a jump was counted each time the student sprung up from the mini-trampoline. The teacher assisted the students to ensure that they jumped at a fast and consistent pace. The gliding-style chair and mini-trampoline were available in the sensory room prior to the start of the study and were not novel to the children when the study was initiated.

Dependent Variable

The dependent variable was the percent of correct responses on two different sets of instructional tasks during academic instruction immediately following each sensory-based activity. The instructional tasks were determined based on each student's Individual Education Plan (IEP). Flashcards were gathered for 2 identification objectives from each student's IEP, and 10 items were selected for each objective for a total of 20 items to identify (i.e., 10 animals and 10 community helpers, or 10 sight words and 10 household items). The flashcards were from the ABBLS™-R kit produced by Autism Concepts Incorporated (www.autism.concepts.com). This set of flashcards includes more than a thousand 4 in x 6 in flashcards printed with high resolution glossy images. Each flashcard was labeled to match the corresponding ABLLS™-R objective; however, the teacher marked through the labels with a black permanent marker to ensure the students did not distinguish the flashcards based on those codes instead of the pictures.

The teacher conducted a preassessment by asking students to identify all 20 items on three different days during the same time block the study would be conducted. Subsequently the flashcards were divided into two sets of 10 cards (five from each objective) by distributing the known flashcards across sets (if the student knew any of the items during the preassessment sessions) and randomly assigning the rest. One set was randomly chosen to be presented to the student after the jumping condition and the other set was presented to the student after the gliding condition to control for practice effect across the sensory-based activities. Table 2 contains the list of flashcards for each condition for each participant. Using event recording (see Appendix A for data collection sheet), correct responses were recorded with a plus sign whereas incorrect responses were indicated using a minus sign. The percentage correct was calculated by taking the total number of correct responses, dividing by the total number of opportunities to respond within each set of academic tasks, and multiplying by 100%.

During the three preassessment sessions, Steven knew the sight word "again" with 100% accuracy (and "because," "air," and "answer" inconsistently), but did not know any of the community helpers. The known sight word (again) and inconsistently identified words (because, air, and answer) were divided as equally as possible between the two sets of flashcards. Anna did not know any of the sight words or community helpers during the three preassessment sessions and thus the flashcards were divided randomly. Carlos gave a few correct responses for community helpers and household items during the three preassessment sessions, but his correct responses were inconsistent. He did not know any one item or person with 100% accuracy so the items he sometimes identified were distributed between the two sets of flashcards as equally as possible and the rest divided randomly. Brian knew one animal (frog) and one household item (plate) with 100% accuracy during the three preassessment sessions. "Plate" was included in the set of flashcards paired with gliding and "frog" was included in the set of flashcards paired with jumping. Caren knew one community helper (bus driver) one time during the three preassessment sessions, which ended up in the flashcards for the gliding intervention.

Table 2

Descriptive information about the identification tasks

	Steven	Anna	Carlos	Brian	Caren
	Sight Words	Sight Words	Animals	Animals	Sight Words
	because	has	Butterfly	bear	has
	air	was	Kangaroo	sheep	up
	answer	his	Worm	worm	was
	kind	there	Ant	ant	his
Paired	point	had	Bee	bee	down
With	Community Helpers	Community Helpers	Household Items	Household Items	Community Helpers
Gliding	librarian	electrician	Plate	plate	electrician
	pilot	lifeguard	Toilet	toilet	lifeguard
	dentist	delivery man	Shampoo	shampoo	delivery man
	barber	soldier	light switch	light switch	soldier
	farmer	chef	Sink	sink	chef
	Sight Words	Sight Words	Animals	Animals	Sight Words
	again	she	Jellyfish	frog	she
	another	her	Shark	shark	her
	found	he	Leopard	leopard	he
	study	but	Bat	bat	but
	why	they	Fly	fly	they
Paired					
With	Community Helpers	Community Helpers	Household Items	Household Items	Community Helpers
Jumping	electrician	bus driver	Shower	shower	bus driver
	lifeguard	librarian	Rug	rug	librarian
	delivery man	pilot	Cabinets	cabinets	pilot
	soldier	dentist	Glasses	glasses	dentist
	chef	firefighter	Napkins	napkins	firefighter

Design

Single-case methodology was used in this study to accommodate the small number of participants and the specificity of the participant qualifications. An alternating treatments design including replication of the more effective sensory-based intervention (Kazdin, 1982) was utilized to demonstrate functional relations between the antecedent sensory-based interventions and percentages of correct responses for each student. As noted, the results of the three preassessment sessions were used to randomly divide the 10 cards from each of two categories into two sets of flashcards that subsequently were randomly assigned to one of the intervention conditions. Once divided, baseline data were stable with 50% or less variability around the baseline mean (Alberto & Troutman, 2009) across instructional tasks.

Each student was assigned to one of the two sensory-based activities each day using counterbalancing schedules. Counterbalancing (Kennedy, 2005) was accomplished by using the following implementation schedules for the students (J represents jumping and G represents gliding): Anna (GJJGJGJGGJGJ…); Brian (JGGJGJGJJGJG...); Caren (GJJGGJJGGJJG…); Carlos (GGJJGJGJJGGJ…) and; Steven (JJGGJGJGGJJ…). The schedules were repeated until the student either reached mastery criteria and began the replication phase or the school year ended.

When a student achieved 80% accuracy over three consecutive sessions for the academic task paired with one of the sensory-based interventions, that intervention was replicated with the instructional materials from the other intervention until the student achieved 80% accuracy across three consecutive sessions (Brian and Caren). This replication demonstrated the functional relation between the intervention and the improvement in correct responses. Steven did have three consecutive sessions at or above 80% correct for the flashcards paired with jumping and should have moved into the replication phase, but due to miscommunication between the investigator and implementing teacher, he continued in the intervention phase and reached mastery under both conditions.

For the students who reached mastery criterion during one or both of the interventions (Steven, Caren, and Brian), maintenance data were collected for two sessions per set of flashcards after the end of the replication phase, presenting all 20 flashcards following the same intervention that was replicated after the intervention phase. Additional maintenance data were collected for two sessions per set of flashcards without sensory-based interventions to determine if maintenance was contingent upon the provision of the intervention. There was a minimum of three school days between the maintenance probes with and without sensory-based intervention.

Implementation Procedures

The sessions for this study were conducted in the mornings between 8:30 a.m. and 10:00 a.m. Toward the end of the study, the teacher started conducting two sessions a day because the school year was concluding. In these cases (i.e., Carlos, Anna, and Brian), the second session of the day was conducted between 12:30 p.m. and 1:30 p.m., a minimum of two hours after completion of the morning session. Child assent procedures (see Appendix B) were followed before and during every session for each student to ensure voluntarily participation.

Once a student agreed to participate, he or she was led to the sensory room to engage in the sensory-based activity assigned to that session. The teacher started the metronome application on her iPhone® and set the audible Time Timer® for 3 min prior to the start of the sensory-based activity; the student was shown the timer so he/she knew how long the sensory activity would last. Then the teacher engaged the student in the assigned sensory-based activity for that session. The teacher controlled the speed of the glider by sitting across from the glider and placing her hands on the arms of the chair and slowly moving the glider to the beat of the metronome while the child sat in the glider with his/her bottom in the chair. The teacher assisted the students while they jumped on the mini-trampoline by holding their hands and helping them keep pace jumping with the metronome. Immediately upon completion of the sensory-based intervention the teacher said "it's time to work" and the student was guided to the table and two chairs in the corner of the room. The instructional tasks for expressive identification were presented in a discrete trial format (DTT). Instruction was implemented through a system of least prompts (Alberto & Troutman, 2009). The system of least prompts was implemented by the teacher presenting a single flashcard while saying "What is it?" "S/he is a…" "Read the word" and so forth. The discriminative stimulus (S^D) varied depending on the category of the flashcards or the student, but was consistent for each set of flashcards for each student. Carlos engaged in severe echolalia and thus the S^D for him was simply the presentation of the flashcard without a vocal stimulus. If the student did not respond after 7-10 s, the teacher gave a partial-model prompt (saying the initial sound of the sight word, community helper, animal, or household item on the flashcard). If the student did not respond after another 7-10 s, the teacher modeled the tact and had the student repeat the word (all students were capable of repeating a word after it was spoken). The flashcards were presented three times each during each instructional session. The flashcards were presented randomly within each task (i.e., the five community helpers were presented randomly and then the five animals were presented randomly, and this procedure was repeated until all ten flashcards were presented three times each). Only independent responses made by the student after the initial S^D were counted as correct.

Data Analysis

Graphed data were analyzed to document effect using visual analysis (Kazdin, 1982; Kennedy, 2005). The alternating treatments design allowed for a direct comparison of the percentage of correct responses following each of the two antecedent sensory-based interventions. For the students whose data fractionated (Brian, Carlos, and Caren), the first intervention to produce three consecutive sessions with 80% or greater correct responses was replicated with the instructional materials from the less successful intervention (Brian and Caren). A functional relation between the sensory intervention and percentage of correct responses was demonstrated if the student reached the mastery criteria during replication phase (Brian and Caren).

The characteristics of all students (those with demonstrated functional relations between the sensory intervention and academic responding, as well as those whose data were undifferentiated) were used to analyze differentiated effectiveness. The effects of the sensory activities were used as the outcome variable in its own two-level hierarchical linear growth model (HLM), with Time at level 1 and with child characteristics (i.e., age, CARS score, IQ, VABS score, and total score on the SSP) as level-2 predictors of the level-1 intercept and of the growth rate. HLM 6.0 (Raudenbush, Bryk, Cheong, Congdon, & du Toit, 2004) was used to conduct the growth modeling analyses, recording the time predictor to have 0 be the final measurement occasion. The results of the analyses that pertain to the intercept were the average ending points for the children in the study, with the variance of the ending points across children before predictors were added (unconditional variance) and after the predictors were added (conditional variance) to the model. The slope coefficients for the level-2 predictors of the intercept were used to explain the variance among children's ending values on the dependent variables. The slope coefficients for the level-2 predictors of the growth rate were used to explain the variance of the growth rates across children. Also included in the output was the average growth rate, the unconditional variance of the growth rate, and the conditional variance of the growth rate after adding predictors to the model.

Interobserver Agreement

A Canon digital video camcorder, model ZR500 (with mini dv cassettes), set on a tripod was used to record at least 48% of the sessions including the sensory-based intervention and the camera was repositioned to capture the instructional activity. The percentage of sessions recorded varied across students because of technical difficulties with recording equipment and were as follows: Steven (48%), Anna (71%), Carlos (72%), Brian (62%) and Caren (63%). The investigator collected response data from a minimum of 33.0% of randomly-selected video-taped sessions for each of the participants across all phases of the study using the same data sheets as the teacher (see Appendix A). Interobserver agreement (IOA) was calculated using point-by-point agreement between the teacher and the investigator, by taking the total number of agreements and dividing them by the number of agreements plus disagreements and multiplying by 100%. IOA ranged from 98.9% to 99.7% across all phases of the study. IOA data for individual participants are reported in Table 3.

Table 3

Interobserver Agreement (IOA) between Investigator and Teacher

Child	Total # of Sessions	Sessions Evaluated	IOA (range) (mean)
Steven	25	36%	97-100% 99.7%
Anna	35	34%	97-100% 99.5%
Carlos	32	34%	97-100% 99.5%
Brian	42	33%	93-100% 99.1%
Caren	35	34%	93-100% 98.9%

Procedural Fidelity

A data sheet with a detailed task analysis was used to collect data on procedural fidelity for the sensory-based interventions and academic instructional sessions (see Appendix C). The investigator reviewed a minimum of 33.0% of the taped sessions for each child and took data on the number of steps in the task analysis that were completed correctly and the number that were not, and then calculated procedural fidelity by dividing the number completed correctly by the total number of steps and multiplying by 100%. A second set of procedural fidelity data were collected by a colleague with her PhD from the investigator's institution who was not on her dissertation advisory committee. The second observer collected data on a random selection of 20% of the sessions the investigator evaluated, using the same task analysis checklist. IOA was calculated using point-by-point agreement between the investigator and second observer for sessions distributed across all phases of the study by taking the total number of agreements and dividing them by the number of agreements plus disagreements and multiplying by 100%. Fidelity data and IOA are presented in Table 4.

Table 4

Procedural Fidelity as Documented by Investigator, Second Observer, and Their Agreement

	Procedural Fidelity (range) (mean)	Procedural Fidelity Check (range) (mean)	IOA
Steven	97-100% 99.7%	-- 100%	99.9%
Anna	93-100% 99%	97-100% 99%	100%
Carlos	97-100% 99.7%	97-100% 99%	99.3%
Brian	97-100% 99.8%	97-100% 99%	99.2%
Caren	-- 100%	-- 100%	100%

Results

Correct Responding

The results of the antecedent sensory-based activities of gliding and jumping and the percentage of correct responses for the participants with ASD are presented in Figures 1-4. Since Steven's data were undifferentiated and he achieved mastery criteria under both the gliding and jumping conditions, he participated in baseline, intervention, and maintenance phases. Anna's data were undifferentiated as well; however, she did not achieve mastery criteria, and participated in only baseline and intervention phases. Carlos' data clearly fractionated; however, he did not achieve mastery criteria and only participated in baseline and intervention phases. Both Brian and Caren achieved mastery criteria for one of the sensory-based interventions and participated in five phases: baseline, intervention, replication of the successful intervention, a maintenance phase with the successful intervention (across all 20 flashcards) and, a minimum of three days later, a maintenance phase without antecedent sensory-based interventions (across all 20 flashcards).

As shown in Figure 1, Stephen's baseline mean calculated from the preassessment data was 10% for the flashcards paired with jumping and 12.2% for the flashcards paired with gliding. During the intervention phase his data were undifferentiated and he reached mastery criteria under both the gliding and jumping conditions. Technically, he achieved mastery following jumping but since the teacher misunderstood the investigator’s directions, three jumping conditions occurred in a row. To provide a contrast to the jumping responses, another gliding session was conducted and Steven also achieved mastery criterion of 80%, so the investigator could not conclude differentiated

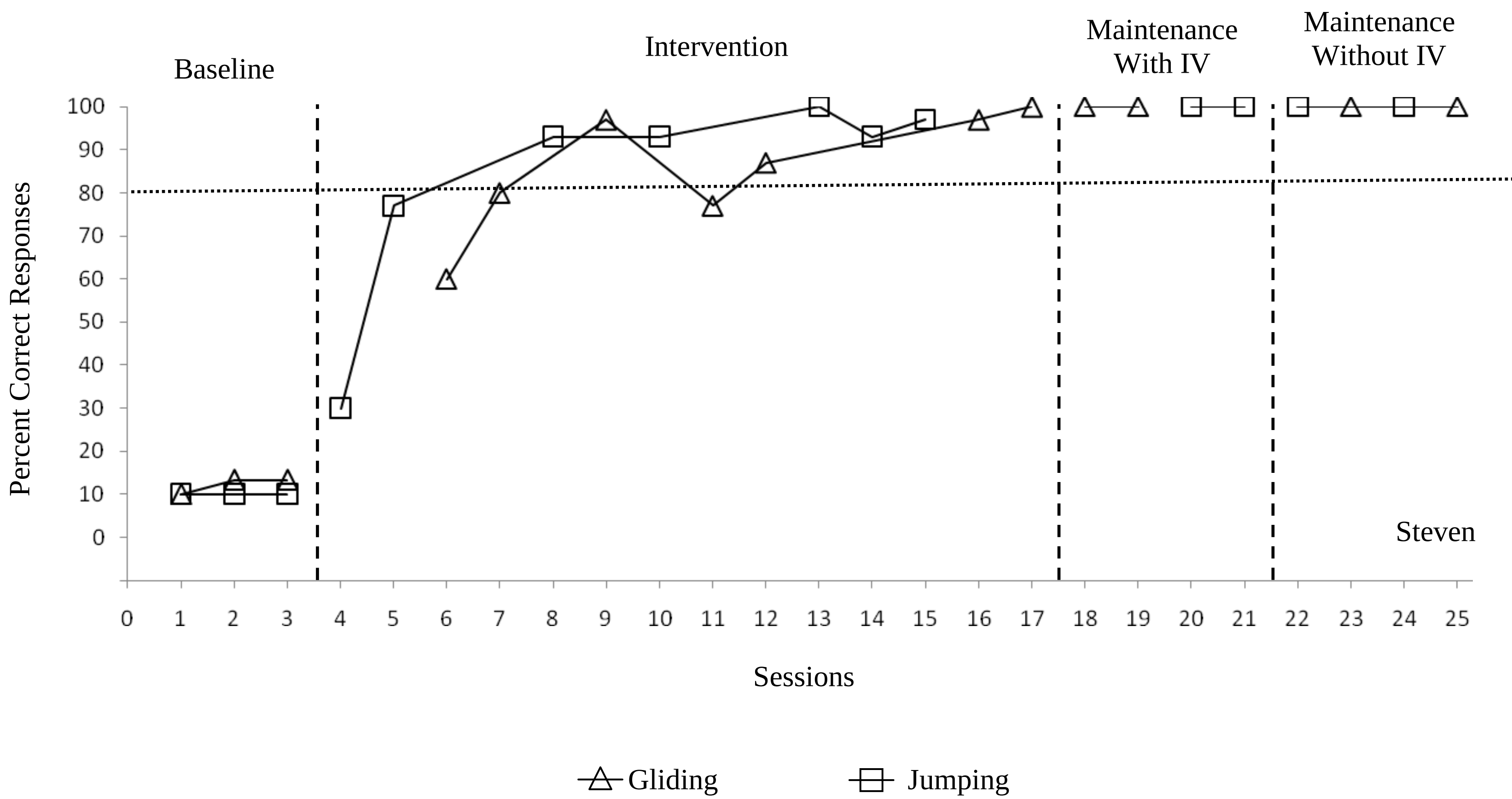

Figure 1. Sight word and community helper data for Steven

effectiveness. Steven participated in seven gliding sessions and seven jumping sessions. His range was 60% - 100% with a mean of 85.4% correct responses for the flashcards paired with gliding and a range of 30% - 100% with a mean of 83.3% correct responses for the flashcards paired with jumping. He participated in the two maintenance phases. During his first maintenance phase he engaged in one orthe other sensory-based interventions prior to the presentation of the all 20 flashcards in his identification tasks. The second maintenance phase did not include sensory-based interventions. Steven scored 100% on all maintenance probes across both maintenance phases. There was no functional relation for Steven because he reached mastery criteria under both conditions and there was no replication phase.

As shown in Figure 2, Anna's baseline means calculated from the preassessment data was 0% for the flashcards paired with both jumping and gliding. Her data were undifferentiated during the intervention phase and she did not reach mastery criteria in the time available for the study. She had 15 gliding sessions and 17 jumping sessions. Her correct responses ranged from 0% - 40% with a mean of 9.5% correct responses for the flashcards paired with gliding and a range of 0% - 37% correct with a mean of 18.9% correct responses for the flashcards paired with jumping. Because Anna's data were undifferentiated and she did not reach the mastery criteria under either condition, there was no functional relation for Anna.

As shown in Figure 3, Carlos' baseline data calculated from the preassessment sessions ranged from 3% - 10% correct responses for the flashcards paired with gliding (M = 6.7%) and a range of 3% - 7% correct responses for the flashcards paired with jumping (M = 4.3%). Although Carlos did not reach mastery criteria under either

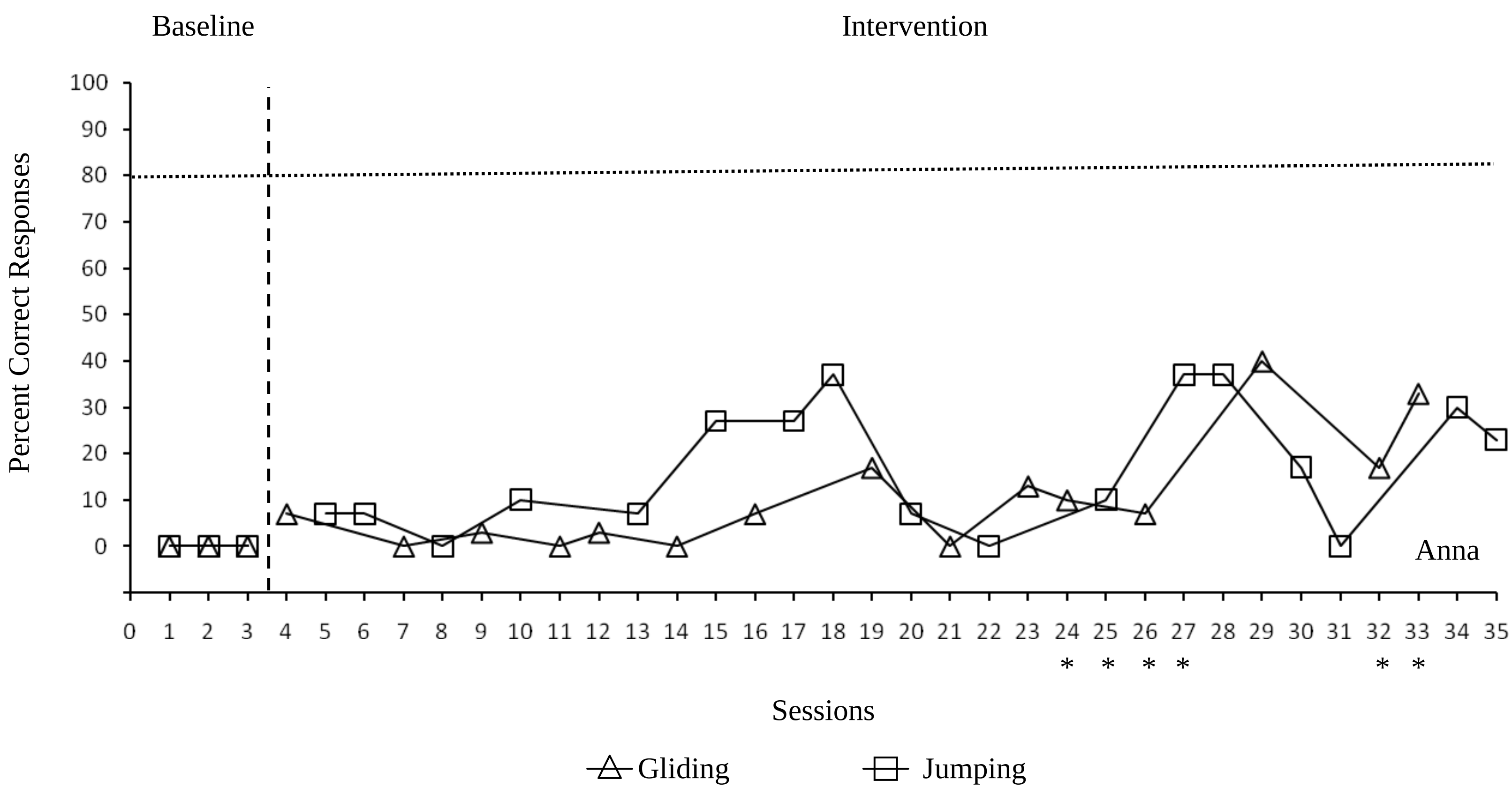

Figure 2. Sight word and community helper data for Anna
*Indicates two sessions on same day

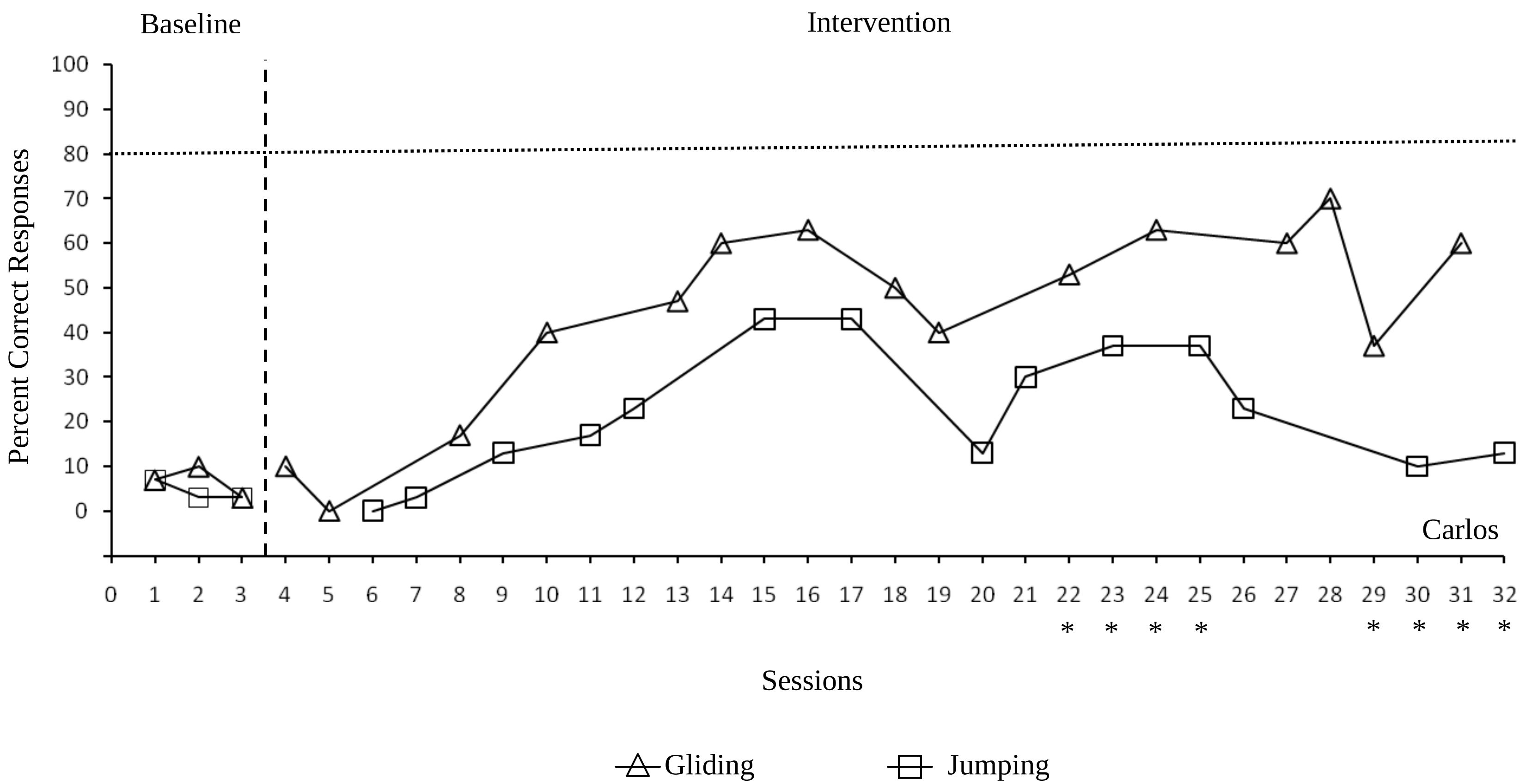

Figure 3. Animal and household items data for Carlos
*Indicates two sessions on same day

condition, his data were clearly fractionated during the intervention phase. He had 15 gliding sessions and 14 jumping sessions. He had a range of 0% - 70% with a mean of 44.7% under the gliding condition and a range of 0% - 43% with a mean of 21.8% under the jumping condition. From the first session of the intervention phase through the last session, the data paths never cross for Carlos. However, because he did not reach the mastery criteria there is no replication phase and thus no functional relation.

As shown in Figure 4, Brian had a mean of 10% during the baseline phase calculated from the preassessment sessions for both sets of flashcards. During the intervention phase he had clear data fractionation with no crossing of the data paths. He had 12 gliding sessions and 13 jumping sessions. He had a range of 20% - 87% with a mean of 63.8% correct responses for gliding and a range of 13% - 67% with a mean of 44.9% correct responses for jumping. Because he achieved mastery criteria under the gliding condition he went into a replication phase where he glided before receiving instruction with the flashcards that were originally paired with jumping. During the replication phase he had six sessions with a range of 70% - 87% and a mean of 80% correct responses. Because Brian reached mastery criteria during the replication phase, a functional relation was demonstrated for him between gliding and correct responding. He participated in two maintenance phases. During the first maintenance phase, all 20 flashcard were presented without either antecedent sensory-based intervention and his range was 87% - 90% with a mean of 88.5% correct responses for the flashcards that were originally paired with gliding and a range of 87% - 93% with a mean of 90% correct responses for the flashcards originally paired with jumping. During the second maintenance phase he participated in gliding prior to the presentation of both sets of

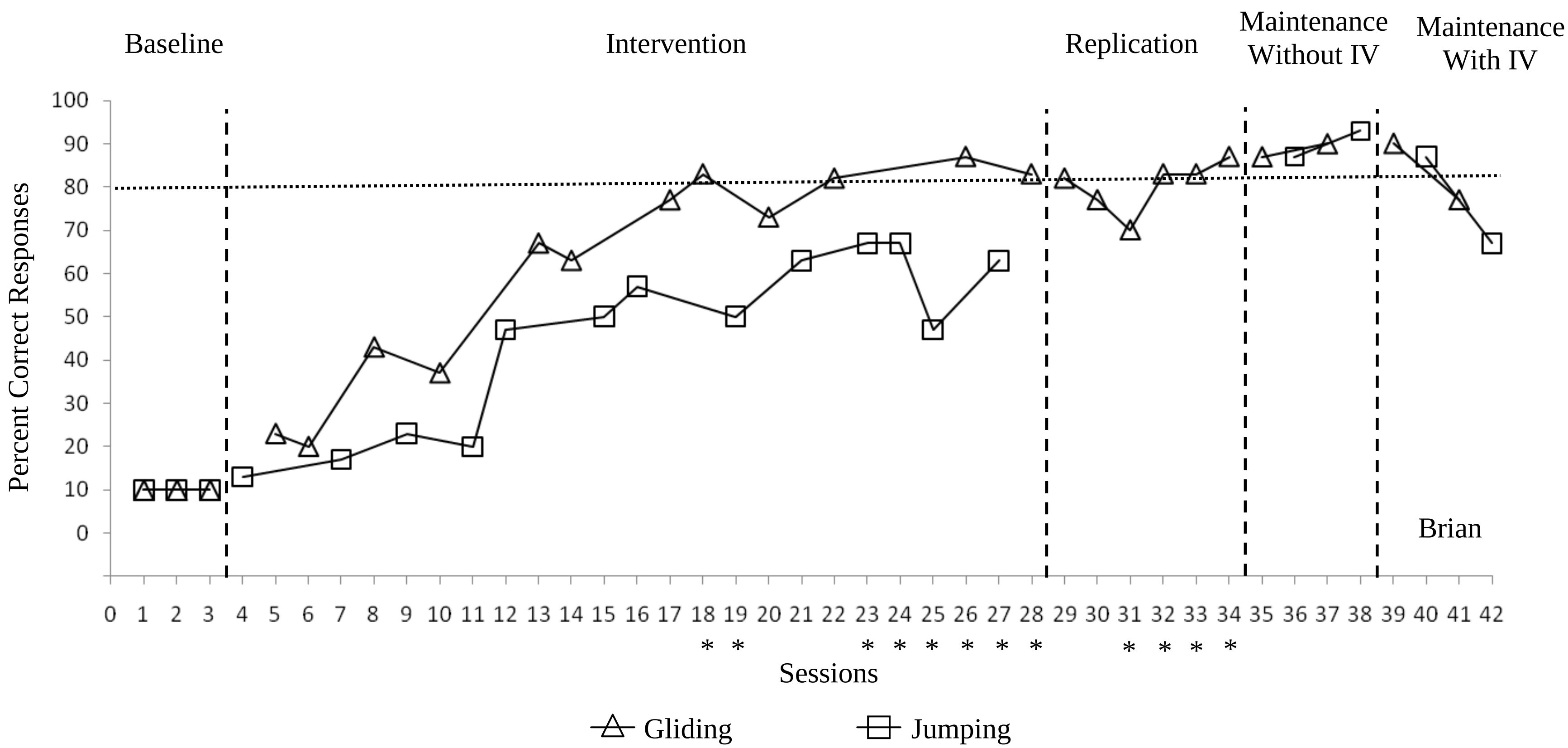

Figure 4. Animal and household item data for Brian
In the last phase Brian participated only in gliding before each set of maintenance probes.
*Indicates two sessions on same day

flashcards. He had a range of 77% - 90% with a mean of 83.5% correct responses for the flashcards originally paired with gliding and a range of 67% - 87% with a mean of 77% correct responses for the flashcards that were originally paired with jumping.

As shown in Figure 5, Caren had a mean of 1.1% correct responses for the flashcards paired with gliding (range = 0 – 3.3%) and a mean of 0% for the flashcards paired with jumping during baseline, as calculated from the three preassessment sessions. Caren did not have clear data fractionation for the first several sessions of the intervention phase; however, her data fractionated over the last seven sessions during the intervention phase and she reached mastery criteria under the jumping condition. She had a total of 9 gliding sessions and 10 jumping sessions. She had a range of 7% - 80% with a mean of 54.4% correct responses for the flashcards paired with gliding and a range of 17% - 87% with a mean of 65% correct responses for the flashcards paired with jumping. Because she achieved the mastery criteria under the jumping condition she went into a replication phase where she jumped before receiving instruction with the flashcards that were originally paired with gliding. There were five sessions in the replication phase with a range of 63% - 87% and a mean of 77.4% correct responses. Because Caren reached the mastery criteria during the replication phase, a functional relation was demonstrated for her between jumping and correct responses. Caren participated in two maintenance phases. During the first she was presented with all 20 flashcards without participating in any sensory-based interventions and her range was 53% - 73% with a mean of 63% correct responses for the flashcards paired with gliding and a range of 73% - 87% with a mean of 80% correct responses for the flashcards paired with jumping. During the second maintenance phase she participated in jumping prior to the presentation of both sets of

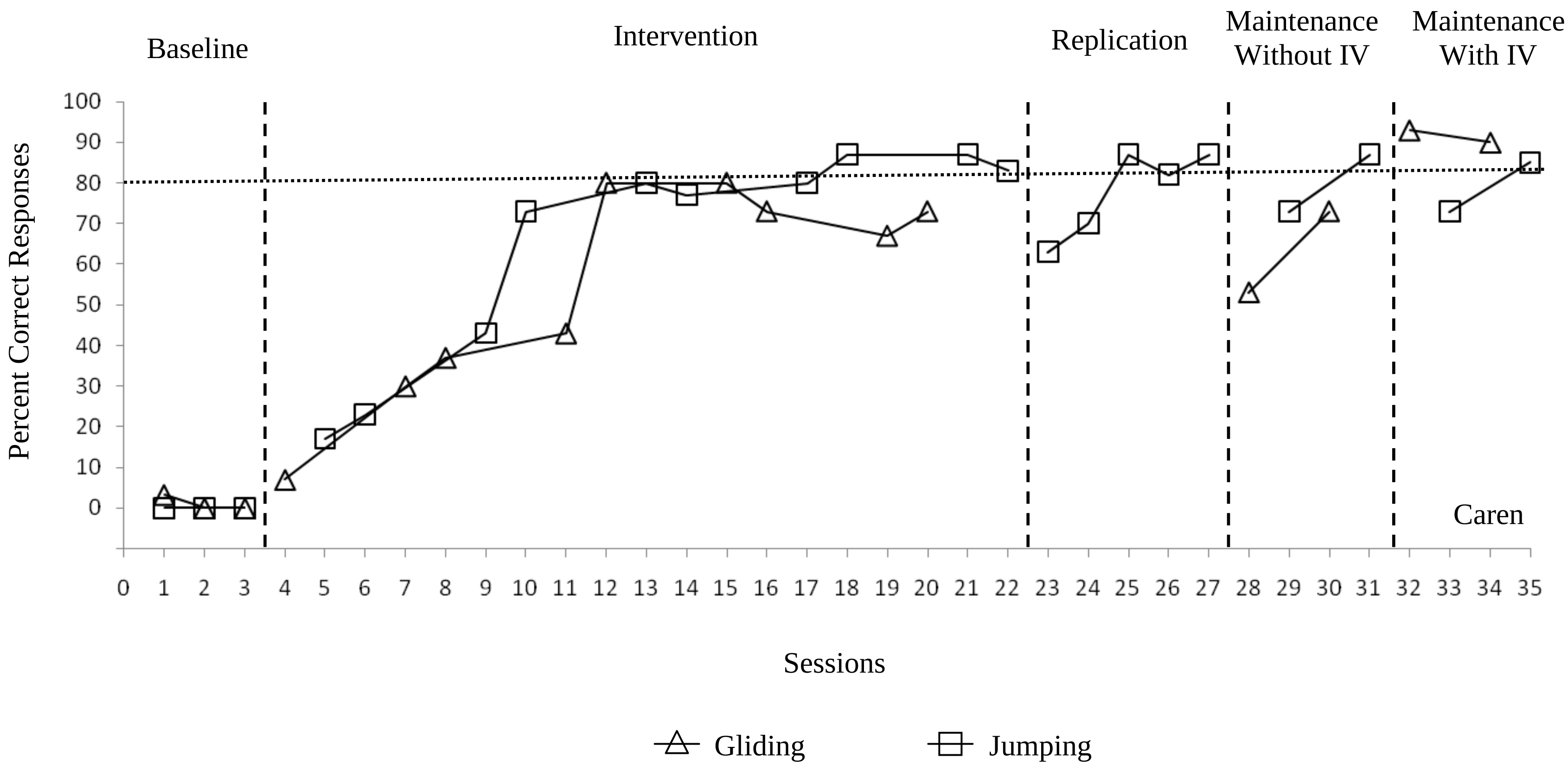

Figure 5. Sight word and community helper data for Caren
In the last phase Caren participated only in jumping before each set of maintenance probes.

flashcards. She had a range of 90% - 93% with a mean of 91.5% correct responses for the flashcards originally paired with gliding and a range of 73% - 85% with a mean of 79% correct responses for the flashcards that were originally paired with jumping.

Growth Modeling Analyses

The average level-1 slope in the HLM growth model (β_{10} = 2.35, $t(4) = 3.43$, $p < .05$) was statistically significant. That is, the participants' correct responding increased significantly across the course of the study by an average of 2.35 percentage points per session. As could be predicted with a group of children with ASD, there was significant variance among the participants (τ_{00} = 388.46, $\chi^2(4) = 45.97$, $p < .001$) prior to implementing the interventions, and significant variance in the participants' growth across the course of the study (τ_{11} = 2.07, $\chi^2(4) = 52.42$, $p < .001$). In other words, the group of participants was not homogenous at the onset of the study but there was a significant amount of growth for the children during the time they participated in the study. Given the small number of participants in the study (n=5), these findings of significance are particularly robust.

Additional level-1 predictors were included in Model 2 to determine whether there was a difference in growth between the interventions. The slope for gliding (i.e., calming activity) was statistically significant and positive (β_{10} = 2.51, SEM = .71, $t(4)$ = 4.23, $p < .05$). The difference between the growth during gliding and the growth during jumping was not statistically significant (β_{30} = -0.20, $t(4)$ = -0.413, $p > .05$). The variance of that difference also was not statistically significant (τ_{33} = 0.60, $\chi^2(4) = 5.11$, $p > .05$). In other words, the growth during jumping was less than the growth during gliding by a nonsignificant 0.20 percentage points per session (or 1% over 5 sessions), and that difference did not vary significantly across the participants. These findings are suggestive but not conclusive, given the small sample size. Because the difference between the interventions in terms of growth was not statistically significant, the level-1 predictors allowing for separate growth coefficients (i.e., treatment and product) were not included in later models.

Age and IQ were used as level-2 predictors of growth per session. Both were statistically significant. Age (controlling for IQ) was statistically significant, such that each month of the child's age was predictive of an increase of 0.055 in the growth per session of the study (β_{11} = 0.06, $t(2) = 6.40$, $p < .001$). IQ (controlling for age) was significant, indicating that participants with higher IQs demonstrated, on average, greater growth during the study (β_{22} = 0.21, $t(2) = 13.41$, $p < .001$). There continued to be significant variance in growth across children (τ_{11} = 0.86, $\chi^2(2) = 16.03$), which may indicate there are other predictors of growth; however, at this point it also is possible that there are no other significant predictors.

In a separate model, VABS and SSP total scores were entered together as predictors of growth per session, so the effect of each was controlled for the other. Neither was statistically significant ($p > .05$) for this particular group of children in predicting growth among participants during the study (VABS: $\beta = -0.16$, $t(2) = -1.99$; SSP: $\beta = -0.0075$ $t(2) = -0.38$). In a fifth model, CARS and VABS were entered as predictors of growth per session. VABS was again not a statistically significant predictor of growth, $\beta_{11} = -0.05$, $t(2) = -0.58$, $p > .05$, and CARS was not a statistically significant predictor of growth, $\beta_{12} = -0.23$, $t(2) = -1.41$, $p > .05$. There may, however, be practical significance for CARS as a predictor of growth to consider in future research, as a 5-point increase in CARS (indicating increasing levels of severity of ASD), holding VABS constant, corresponded to an average decrease of 1.15 percentage points in the average growth per session. The complete printout of the HLM analyses appears in Appendix D.

Social Validity

Social validity was evaluated through two procedures. First, independent raters were asked to evaluate each child before and after the antecedent sensory-based interventions and these ratings were contrasted with the sensory-based intervention implemented that session. Second, upon the completion of the study, the teacher completed a survey about the antecedent sensory-based interventions and her opinion about the effectiveness of the interventions with the students (see Appendix E).

Optimal Arousal. Immediately before the teacher took each student to the sensory room for the antecedent sensory-based intervention and academic instruction, one of the classroom paraprofessionals (who had worked with the students for over a year) rated each student as "1 – ready to learn" or "2 – not ready to learn" based on her impression of the student's activity/arousal level. Although highly subjective, the inference was made that adults who work with children have the ability to determine, and often do on a moment-by-moment basis, whether or not a student is optimally aroused for learning (e.g., not overactive and inattentive or under-reactive and inattentive). When she was asked to rate the student's behavior, the paraprofessional did not know which sensory-based intervention the student was going to engage in during that session. Across 100% of the intervention sessions, a second paraprofessional independently rated the students' readiness to learn. Agreement was calculated on a point-by-point basis by taking the total number of agreements and dividing them by the number of agreements plus disagreements and multiplying by 100%. IOA for the paraprofessionals across the intervention sessions for each student was as follows: 70% for Steven, 78.3% for Anna, 85.7% for Carlos, 100% for Brian, and 100% for Caren for an overall agreement of 86.8%.

The post-sensory-based-intervention data were provided by two naïve observers (dissertation chair and a doctoral student at the investigator's institution who was not the teacher participant) who rated each participant's behavior during academic instruction using the same scale as that used by the paraprofessionals. These observers were considered naïve as they did not know the children and were blind to the sensory-based intervention that preceded instruction; however, both had taught and interacted with students with ASD for a combined total of 40 years. After training the observers to >90% agreement using tapes of the participants during baseline phase, the observers independently rated 100% of the videotapes made during intervention to document the student's readiness to learn. IOA for the naïve observers across all of the recorded intervention phase sessions for each student was as follows: 100% for Steven, 100% for Anna, 100% for Carlos, 94.4% for Brian and 86.7% for Caren, for an overall agreement of 96.2%.

The investigator compared the independently derived scores from the first paraprofessional and naïve observer (i.e., dissertation advisor) across intervention sessions to examine how the antecedent sensory-based interventions affected the participants' readiness to learn. To determine how the sensory-based intervention affected the participants' levels of optimal arousal, the pre- and post-session ratings were compared to identify changes in readiness to learn according to type of antecedent sensory-based intervention used that session (i.e., jumping/alerting or gliding/calming). The results of the optimal arousal analysis are presented in Table 5. IOA for the readiness-to-learn data analysis was determined by having the second observer calculate these associations and the results were compared using a point-by-point agreement method, by taking the total number of agreements and dividing them by the number of agreements plus disagreements and multiplying by 100%. IOA between the investigator and second observer was 98.9% for the readiness-to-learn data because the second observer inadvertently mismarked one of Steven's session ratings.

Table 5

Readiness-to-Learn Data Analysis

	# sessions Rated	Not Ready Then Ready		Ready Then Not		Ready Ready		Not Ready Not Ready	
		Glide	Jump	Glide	Jump	Glide	Jump	Glide	Jump
Steven	10	0%	10%	20%	0%	30%	10%	0%	30%
Anna	23	4.3%	0%	4.3%	8.7%	0%	0%	43.5%	39.1%
Carlos	21	19.0%	14.3%	4.8%	0%	0%	0%	28.6%	33.3%
Brian	18	22.2%	33.3%	0%	0%	0%	5.6%	22.2%	16.7%
Caren	15	26.7%	33.3%	0%	0%	0%	0%	26.7%	13.3%

Teacher Perceptions. Approximately two months after the completion of the study, the teacher completed the social validity survey contained in Appendix E. The investigator developed the survey with assistance from her dissertation advisory committee. The survey consisted of 10 statements that the teacher rated using a four-point Likert scale ("1" = "strongly disagree" to "4" = "strongly agree"). Two of the statements were worded negatively to ensure that the teacher read and ranked each statement based on her opinion instead of just agreeing or disagreeing with all statements without regard to content. Only the teacher completed the survey because no one else at the school was able to observe the students engaged in the sensory-based interventions or during instruction immediately following the sensory-based interventions. The teacher "strongly agreed" with the statements concerning the ease of implementation of the jumping intervention, that the gliding intervention did not take too much time away from instruction, that one or more students benefited from both the gliding and jumping interventions, and that she is likely to use sensory-based interventions with students in the future. The teacher "strongly disagreed" with the statements which suggested that the gliding intervention was difficult to implement and that the jumping intervention took too much time away from instruction. Reversing the scoring for the two negatively-worded statements, the teacher’s mean for the social validity survey was “4,” indicating that she strongly believed in the benefits of using sensory-based interventions.

Discussion

As commonly occurs in research on samples with ASD, the random-intercepts random-slopes HLM Model 1 analysis results were interpreted to conclude that the participants varied significantly at the start of the study despite the investigator's attempt to recruit a homogenous group though stringent inclusion and exclusion criteria. Although relatively homogenous based on visual perusal of characteristics, the students' ages, IQs, SSP total scores, CARS total scores, and VABS total scores synergistically created significantly different composites, and so it is not surprising that there were significant differences in the participants' rates of growth across the duration of the study.

Numerous researchers have noted differentiated effectiveness of interventions among seemingly similar participants with ASD (e.g., Anderson et al., 1987; Harris & Handleman, 2000; Lord, Cook, Leventhal, & Amaral, 2000), and the 2001 National Research Council recommendation that family characteristics be considered when evaluating the effectiveness of interventions has been justified in multiple studies (e.g., Howard, Sparkman, Cohen, Green, & Stanislaw, 2005; Osborne, McHugh, Saunders, & Reed, 2008). Information about family characteristics was not collected in the current study and may have contributed to an understanding of why students made significantly different gains in performance according to the HLM analysis.

In the current study, the best predictors of growth were age and IQ, with the older participants and those with higher IQs making better progress. These findings of statistical significance are quite robust given the highly correlated nature of age and IQ and the small number of participants in the study. IQ has been recognized for decades as a pivotal predictor for gauging the potential effectiveness of an intervention for individuals with ASD (Eikeseth, Smith, Jahr, & Eldevik, 2002; Lovaas, 1987); however, the finding that older children performed better in the current study is in sharp contrast to extant research. Jacobson, Mulick, and Green (1998), Ben-Itzchak and Zachor (2007), and Ozonoff et al. (2010) are just a few of the many proponents insisting that younger children demonstrate the greatest benefit from intervention. Perhaps there is something about the nature of the antecedent sensory-based interventions that facilitated the statistically greater progress among older students in this study.

Despite the vast differences among the students at the inception of the study, there were significant increases in learning for the students as a whole. According to the interpretation of the results of the Model 1 HLM analysis, there was an average of a 2.35 percentage-point increase in learning for every session conducted during the study. Steven, Brian, and Caren all achieved mastery criteria and thus had higher means of correct responses than Anna and Carlos. It may be that Steven, Brian, and Carens' higher percentages of correct responding compared to the relatively lower rates of responding of Carlos and Anna, contributed to the significant variance among the students as well as to the significance in the groups' overall growth rate. Regardless, an interpretation of this finding is that the students learned and benefited from participation in the study, but since Model 2 results of the HLM analysis lead to the conclusion that the antecedent sensory-based interventions did not predict growth, it is not clear what led to this benefit. While DTT has been heralded as the most effective methodology promoting learning in individuals with ASD (Lovaas, 1987), others have determined that type of methodology is irrelevant as long as some intensive, interactive intervention is implemented (Eikeseth, Smith, Jahr, & Eldevik, 2002; Zachor & Ben-Itzchak, 2010). Examination of the Model 2 results lead to the undisputed conclusion that participants' growth was not affected by type of sensory-based intervention. Examination of the results of the optimal level of arousal measures appear to support this conclusion. For example, Steven experienced an improvement in his level of arousal by jumping on one session, while gliding rendered him unready to learn on two sessions, but in general his arousal level was not affected by the antecedent sensory-based interventions. For Anna, gliding was equally as likely to get her ready for learning as not; jumping rendered her unready to learn on two occasions, but most of the time Anna was not ready to learn, regardless of the type of antecedent sensory-based intervention she experienced. Carlos, the most lethargic of the students due to the medications he took, experienced gliding and jumping as almost equally likely to promote his optimal level of arousal (if you subtract the one time his readiness for learning was reversed by the gliding). Similar to Anna, he was not optimally aroused for learning regardless of antecedent sensory-based intervention. Jumping may have promoted or maintained Brian's optimal level of arousal (7/18 sessions), but he was slightly more available for learning as compared to the times he was not ready to learn, regardless of intervention. Finally, the interventions appeared to prime Caren for learning for 60% of her sessions, regardless of the antecedent sensory-based intervention that was provided.

Examination of the Models from the HLM analysis as well as scrutiny of the readiness to learn ratings, leads to the conclusion that the antecedent sensory-based interventions were not instrumental and played no role in the changes in percentage of correct responses among the participants. This conclusion is in sharp contrast to inferences based on the visual analysis of the single-case design graphs representing each individual student's percent of correct responses. Visual analysis reveals that three students performed better on expressive identification tasks relative to a sensory-based intervention. Brian and Carlos achieved higher percentages of correct responding following the gliding intervention whereas Caren had a higher percentage of correct responding following the jumping intervention. Functional relations were established between one of the interventions and correct responding for Brian and Caren, while Carlos had clearly fractionated data paths with a higher mean percentage of correct responses following the gliding intervention. The fact that three of the five students benefited from the sensory-based interventions and their benefit varied by intervention provides additional support for the use of antecedent-sensory-based interventions for some students with ASD, despite the finding that gliding and jumping were not considered predictive of growth in Model 2 of the HLM analysis.

According to Zentall and Zentall (1983) individuals can be above or below their optimal levels of arousal and will engage in behaviors to either increase or decrease their level of arousal to reach their optimal level. Professionals theorize that the gliding intervention is calming and that the jumping intervention is alerting (Kranowitz, 2005; Kashman & Mora, 2005; Yack et al., 2002). Because Brian and Carlos benefited from gliding, one can assume that they required a calming activity to reach their optimal levels of arousal and engage more fully in the academic instruction that followed. Caren benefited from the jumping intervention and therefore needed to experience an alerting activity to reach her optimal level of arousal and engage more fully in the academic instruction. These assumptions garner some credibility because all three students had scores in the "definite difference" range of the underresponsive/seeks sensation section of the SSP.

Further explanation of these three students' beneficial response to the sensory-based interventions may be related to their age, IQ, CARS score, and sensory processing difficulties. First, Caren and Brian both had functional relations and their IQs were 47 and 46, respectively. There was a statistical significance for IQ in the HLM growth model when IQ was used as a level-2 predictor. This meant that students with higher IQs demonstrated more growth during the study than students with lower IQs. Caren and Brian had the second and third highest IQs of all of the participants which probably contributed, along with the effect of the sensory-based intervention that was successful for each of them, to their learning the instructional material faster.

Second, age was found to be a statistically significant predictor as older students had a faster growth rate than younger students. Caren and Carlos were the two oldest students who participated in the study. Therefore, their age may partially account for their growth in learning. Third, although not significant, when the CARS score was used as a predictor of growth in an HLM analysis, there was a finding that higher CARS scores were associated with a decrease in learning per session. Caren and Brian had the first and third lowest CARS scores respectively, whereas Carlos had the highest CARS score. Thus, the lower CARS scores for Brian and Caren may have benefitted them whereas the higher CARS score for Carlos may have hindered his learning. Despite all of the possible person-level variables that may have influenced their learning, all three of these students showed a positive association with only one of the two sensory-based interventions which is an important distinction. Their ages and IQs may have been contributing factors to their growth during the study, but they still demonstrated improvement relative to only one of the sensory-based interventions.

Steven and Anna had undifferentiated data paths and neither sensory-based intervention appeared to affect their skill acquisition as measured by the percent of correct responses. Steven achieved the mastery criteria under both the gliding and the jumping conditions and was able to maintain 100% correct responses during the maintenance phases (with and without the sensory-based interventions). There are a couple of possible explanations for Steven's success with both of the sensory-based interventions. First, he had the highest IQ of all of the participants and since IQ was a statistically significant person-level predictor of growth in the HLM model, his IQ may partially account for learning under both sensory-based conditions. Steven also had one of the lower CARS scores and although there was not a significant finding between CARS scores and rate of growth, there was an inverse association in that the higher the CARS score the slower the rate of learning. Steven had the second lowest CARS score and this may have been a contributing factor to his overall success mastering the material regardless of the sensory-based intervention.

Similar to Steven, Anna's data paths were undifferentiated and she did not reach mastery criteria after approximately 15 instructional sessions with either set of flashcards; Anna had low percentages of correct responses for each identification task. Again, there are a few possibilities to explain her lack of growth. First, Anna had the second lowest IQ of the participating students and thus would be expected to learn at a slower rate than the other students. She also had the fourth highest CARS score which may have negatively affected her skill acquisition. Finally, Anna had the highest overall SSP score (indicating less severe sensory processing issues), which fell in the "definite difference" range, but was only two points shy of falling in the "probable difference" range in comparison to the other participants who all had lower total SSP scores. Therefore her learning may have been hindered more by her cognitive abilities and the severity of her ASD characteristics than by her difficulty processing sensory information.

Although there were only two functional relations and a third student with a positive trend for gliding, these findings support previous research (Van Rie & Heflin, 2009) and the theory that each individual will respond differently to sensory-based interventions to achieve his/her individual optimal level of arousal (Kashman & Mora, 2005; Zentall & Zentall, 1983). Caren was described as a generally lethargic student who was often difficult to engage in academic tasks and instruction. She responded to the jumping intervention which was an alerting sensory-based activity (Kranowitz, 2005; Kashman & Mora, 2005; Yack et al., 2002). This finding provides support for the theory that jumping can help a student who is lethargic become more alert and reach his/her optimal level of arousal thus improving task engagement as measured by the percentage of correct responses. Brian, who was described as overly active, had a functional relation between his percentage of correct responses and the gliding intervention. The gliding intervention was theorized to be calming (Kranowitz, 2005; Kashman & Mora, 2005; Yack et al., 2002) because of the slow linear movement made by the glider. Therefore, Brian's results provide support for the theory that gliding or slow linear movement is calming and can help an overactive student calm down and achieve his/her optimal level of arousal in order to engage in academic tasks or instruction as measured by the percentage of correct responses.

Although there was no functional relation for Carlos, he did have clear data fractionation in favor of the gliding intervention. This finding is contrary to the theories since Carlos was described as being lethargic in the mornings and the gliding should have produced an additional calming effect. Although he would willingly jump on the trampoline during the jumping condition, he did not jump as high off the trampoline as the other students and he required more assistance from the teacher to keep a fast pace. He seemed to enjoy the gliding condition based on his facial expressions (smiling) and interactions with the teacher during the gliding condition. Therefore, the gliding condition may have been preferred by Carlos over the jumping condition, resulting in differentiated effectiveness although contrary to theories of sensory-based effects (i.e., gliding should have been calming). Child preferences for sensory-based activities may have more influence over learning engagement than suggested sensory benefit and should be explored further. Carlos was one of the older students in the study and, based on the HLM growth model analysis, should have been one of the better responders. However, he was taking several medications at the time of the study, which may have interfered with his ability to attend, learn, and retain information. Medication may need to be considered as a predictor of growth in future research of response to antecedent sensory-based interventions.

One interesting finding is that total score on the SSP was irrelevant to predicting growth in the HLM analysis. This, in combination with Carlos' paradoxical response, may suggest that children's sensory profiles are not as critical to responsiveness to sensory-based interventions as has been suggested (Dunn, 2007; Van Rie & Heflin, 2009; Yack et al., 2002). Alternatively, it may be that the total score on the SSP, used in this study, is not sufficiently sensitive for predicting responsiveness to sensory-based interventions. Subscale scores could not be used as units of analysis in this study because of the small number of participants. Future researchers could consider predictive use of subscale scores with a much larger number of participants or new assessments could be created with provide more succinct sensory profiles for this age group (i.e., identify if a child is under or over aroused and via which sensory modalities).

Although the study was conducted to evaluate the effectiveness of antecedent sensory-based interventions on percentages of correct responding in elementary-age children with ASD, the use of a mixed methodology raises interesting considerations.

Specifically, how should researchers reconcile contradictory findings? According to visual analysis of graphed data incorporating a well-established design used in single-case research, three of the participants experienced differentiated responding to one of the antecedent sensory-based interventions, with functional relations established for two of the children. According to random-intercepts random-slopes model, unconditional at level 2, neither of the antecedent sensory-based interventions was predictive of growth. Indeed, the only level 2 predictors that influenced changes in correct responding during the course of the study were age and IQ; however, examination of the characteristics of individual students does not support this linear association (e.g., Carlos was the oldest student but did not experience the greatest growth). One consideration for this contradiction may be that Carlos had the lowest IQ of the participating students and because IQ also was a level 1 predictor of growth, he may have had some conflicting variables that affected his overall growth. A second consideration is that the low number of participants and the variance in the participants at the start of the study confounds the results of the HLM analyses and additional analyses need to be conducted to control for additional variables such as medication and subscale scores of the SSP. Alternatively, it may be that the HLM analysis constructs a model of growth across time, with an indefinite end point. If the intervention sessions had continued (as Steven's inadvertently did), perhaps the differentiated effectiveness of the interventions would have disappeared. Therefore, the results of the HLM growth modeling may provide a more accurate assessment of benefit than a snapshot of behavior presented in a single-case research design.

Limitations

Several limitations must be considered when interpreting the results of this study. First are the time constraints of the school year. The teacher implemented the study during the last quarter of the school year and so there were only about nine weeks available for conducting the study. Although this seems a reasonable amount of time given that nine weeks contain 45 school days, the realities of teaching in the current educational climate result in many days being consumed with the collection of data for mandated alternative assessments, disruptions and displacements due to annual standardized testing for students taking criterion-referenced assessment, teacher's attendance at IEP meetings, and the daily issues that arise in a classroom for children with ASD (e.g., behaviors that disrupt instruction, medical concerns) that interfered with the implementation schedule for the study. Because of time limitations during the study, a second session a day was implemented for Carlos, Anna, and Brian for the last week of the school year. Caren's last set of maintenance probes were conducted during a summer school session, both sets of Brian's maintenance probes were conducted during summer school, and Anna participated in 4 sessions during summer school. The students experienced one session a day during summer school because the school day was only four hours long. Carlos did not attend summer school and Steven had completed the entire study, thus none of the data for these two students was collected during summer school.

There were a couple of instances where the counterbalancing schedules were not implemented with fidelity. There were three consecutive sessions toward the end of the study where Carlos participated in the gliding intervention but should have engaged in gliding for only two consecutive sessions. There also were three sessions in a row toward the end of the intervention phase for Steven when he engaged in the jumping intervention and he was only supposed to jump for two consecutive sessions. There was an implementation schedule error during the maintenance phases for Brian as well. He was supposed to engage in gliding prior to the probes for his first maintenance session and have no sensory-based intervention during his second maintenance phase. However, these errors in the counterbalancing schedule did not appear to have an effect on the results of the study based on a visual analysis of the graphs.

Teacher behavior may be considered a limitation for this study. The teacher was inconsistent with the prompts she provided and time varied between the presentation of the S^D and provision of prompts during the discrete trial format instruction. The investigator created a fidelity checklist prior to the implementation of the study, but failed to include steps specific to the discrete trial instruction format and thus these teacher behaviors were not assessed as part of the fidelity during the implementation of the study.

VABS data were identified via records review and not collected immediately preceding the study similar to what was done for the CARS and SSP data. This seemed more time efficient as VABS composite scores were not used to determine eligibility for inclusion in the study, but the data nature of the scores as well as differences in the informants could have influenced the utility of VABS in the growth modeling analysis. The teacher did not report reservations that the scores were discrepant between current functioning and when the assessment was conducted. However, the fact that the teacher completed the VABS for two of the students while parents completed the VABS for three of the students could have resulted in a response bias that was not controlled in the study.

Finally the paraprofessionals were not trained to rate the students for readiness to learn prior to the start of the study. They were given data sheets with explanations, but were not trained to a specific criterion to ensure they were rating the students with reliability. Another issue with the readiness-to-learn ratings was that not all instructional sessions were recorded because of technical difficulties with the video camera. This limited the number of sessions where readiness to learn prior to the sensory-based intervention and readiness to learn during instruction could be calculated and compared.

Future Research

Replication studies involving sensory-based interventions are needed to identify which sensory-based interventions are effective for which students with ASD, and to either establish or reject sensory-based interventions as evidence-based practices for the population. Future researchers may want to include students with ASD with a wider variety of characteristics such as higher IQs and students who are older. Researchers should continue to explore the utility of blending HLM and single-case methodology with larger participant groups in future studies, not only to identify characteristics of students with ASD who would benefit from sensory-based interventions, but also to reconcile contradictory conclusions. There may be some benefit in evaluating the effect of sensory-based interventions on other areas of functioning such as fine motor skills, following directions, and self-help skills. Additional research involving more participants with ASD as well as HLM analyses of additional person-level and level 2 predictors will enable investigators to identify salient characteristics that influence outcomes for students who engage in sensory-based interventions.

Through this study, the investigator blended single-case and group experimental methodology to evaluate the effectiveness of sensory-based interventions for students with ASD and to identify student characteristics that influenced the outcomes. The use of this blended methodology as well as the establishment of two functional relations and one positive relationship between the sensory-based interventions and student learning add to the literature in regard to research design as well as extend evidence for sensory-based interventions for students with ASD. Although there were a few contradictions in the results between the HLM analyses and the visual analyses of the graphs, there were definitely positive outcomes for three of the students in relation to the sensory-based interventions, and the HLM analyses documented growth for all students. Research findings such as these add to the corpus for determining an evidence base for commonly-used practices and provide guidance for professionals working to support learning in students with ASD.

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APPENDIXES

Appendix A

Sample Data Sheet

Student: **Dates:**

Condition:

Criterion: 80% correct over 3 consecutive sessions

Dates/Trials

Items															
Total # Correct															

(Alberto & Troutman, 2003)

Appendix B

Child Assent Procedure

The teacher will not force the students to participate in this study. Student participation is voluntary. Since the participants in this study will be 5-10 years old with cognitive impairments and they are unable to sign an assent document, verbal assent will be obtained through the following script prior to each session.

1. Teacher: ""**Do you want to glide (or jump)?""**
2. If the student responds 'yes,' the teacher will direct the student to join her at the activity location. If the student responds 'no,' the teacher will not proceed further, but will ask the student again at a later time in the day (a minimum of 1 hour later for a maximum of 3 times a day). If the student does not respond, then the teacher will question the student again and move toward the activity location to demonstrate the activity to ensure the student understands what the teacher is asking.
3. If the teacher prompts the student to participate at a later time and the student continues to refuse to participate the teacher will attempt to engage the student in the activity on the following school day.
4. Any student who refuses to participate 3 days in a row will be dropped from the study.
5. If at any point during the sensory-based intervention the child becomes noncompliant or states that he/she does not want to participate the session will end immediately.

Appendix C

Procedural Fidelity Checklist

Student: ________________________________ Date: ____________

#	Yes / No	Step Description
1.		Did the teacher ask the student, "do you want to ________ (glide, jump)?"
2.		If the student responded yes, did the teacher take the student to the correct area? If the student responded "no" did the teacher move toward the activity to demonstrate and then ask the student again? If the student refused to participate when invited a second time, did the teacher direct the student to an alternate activity?
3.		Did the teacher help the student glide or jump for three minutes?
4.		If gliding, were there 30-35 repetitions per minute? If jumping, were there 85-95 repetitions per minute?
5.		After three minutes, did the teacher direct the student to the work table?
6.		Did the student sit at the work table?
8.		Did the teacher ask the student to expressively identify an item?
9.		Did the teacher repeat the request to expressively identify 4 additional items?
10.		Did the teacher ask the student to expressively identify an item of a different academic task?
11.		Did the teacher ask the student to expressively identify 4 additional items in that category?
12.		Did the teacher ask the student to identify an item from the first set of flashcards?
13.		Did the teacher repeat the request to expressively identify the other 4 items in that set?
14.		Did the teacher ask the student to expressively identify an item from the second set of flash cards?
15.		Did the teacher ask the student to expressively identify 4 additional items in that set?
16.		Did the teacher ask the student to expressively identify an item from the first academic task?
17.		Did the teacher repeat the request to expressively identify 4 additional items from that task?
18.		Did the teacher ask the student to expressively identify an item in the second academic task?
19.		Did the teacher ask the student to expressively identify 4 additional items from that task?
20.		Did the student have a total of 30 opportunities to respond during the academic instruction session?

Appendix D

<u>Model 1: Random-intercepts random-slopes model, unconditional at level 2</u>
Sessions is the lone predictor of Correct
There are no predictors of growth

Final estimation of fixed effects:

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
INTRCPT2, B00	26.372018	9.187505	2.870	4	0.047
For SESSION slope, P1					
INTRCPT2, B10	2.353966	0.673901	3.493	4	0.037

Final estimation of variance components:

Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1,	R0	19.70978	388.47533	4	45.96881	0.000
SESSION slope,	R1	1.43693	2.06476	4	52.42471	0.000
level-1,	E	15.10515	228.16547			

<u>Model 2: Random-intercepts random-slopes model, unconditional at level 2</u>
Sessions, Tx, and Product (Product = Sessions·Tx) are predictors of Correct
There are no predictors of growth

Final estimation of fixed effects:

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
INTRCPT2, B00	26.869679	10.099883	2.660	4	0.055
For SESSION slope, P1					
INTRCPT2, B10	2.510161	0.593065	4.233	4	0.019
For TX slope, P2					
INTRCPT2, B20	-1.618040	5.871839	-0.276	4	0.796
For PRODUCT slope, P3					
INTRCPT2, B30	-0.197561	0.478795	-0.413	4	0.701

Final estimation of variance components:

Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1,	R0	21.50541	462.48261	4	40.83703	0.000
SESSION slope,	R1	1.21777	1.48296	4	24.84111	0.000
TX slope,	R2	8.80895	77.59756	4	5.63634	0.227
PRODUCT slope,	R3	0.77529	0.60108	4	5.10658	0.276
level-1,	E	12.79852	163.80214			

Note: Because neither Tx nor Product were statistically significant in this model, they should be (and now have been) removed from the model for the analyses of the potential predictors of growth (i.e., Models 3-5).

<u>Model 3: Random-intercepts random-slopes model, with two level-2 predictors of the level-1 slope</u>
Sessions is the lone predictor of Correct
Age & IQ are the level-2 predictors of growth

Final estimation of fixed effects:

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
INTRCPT2, B00	26.565590	10.332897	2.571	4	0.059
For SESSION slope, P1					
INTRCPT2, B10	2.270510	0.472105	4.809	2	0.047
AGEMNTHS, B11	0.054720	0.008545	6.403	2	0.000
IQ, B12	0.207585	0.015479	13.411	2	0.000

Final estimation of variance components:

Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1,	R0	22.31824	498.10406	4	47.14982	0.000
SESSION slope,	R1	0.92640	0.85821	2	16.02574	0.001
level-1,	E	14.95647	223.69591			

<u>Model 4: Random-intercepts random-slopes model, with two level-2 predictors of the level-1 slope</u>
Sessions is the lone predictor of Correct
Adaptive Bx & SP_Total are the level-2 predictors of growth

Final estimation of fixed effects:

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
INTRCPT2, B00	26.339179	10.029396	2.626	4	0.056
For SESSION slope, P1					
INTRCPT2, B10	2.324859	0.780410	2.979	2	0.121
ADAPBX, B11	-0.160173	0.080667	-1.986	2	0.157
SP_TOTAL, B12	-0.007484	0.019747	-0.379	2	0.740

Final estimation of variance components:

Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1,	R0	21.68049	470.04386	4	47.05623	0.000
SESSION slope,	R1	1.68459	2.83786	2	47.95308	0.000
level-1,	E	14.92267	222.68612			

<u>Model 5: Random-intercepts random-slopes model, with two level-2 predictors of the level-1 slope</u>
Sessions is the lone predictor of Correct
Adaptive Bx & CARS are the level-2 predictors of growth

Final estimation of fixed effects:

Fixed Effect	Coefficient	Standard Error	T-ratio	Approx. d.f.	P-value
For INTRCPT1, P0					
INTRCPT2, B00	26.085179	9.648622	2.704	4	0.053
For SESSION slope, P1					
INTRCPT2, B10	2.381104	0.544953	4.369	2	0.108
ADAPBX, B11	-0.049767	0.085750	-0.580	2	0.619
CARS, B12	-0.229232	0.162582	-1.410	2	0.292

Final estimation of variance components:

Random Effect		Standard Deviation	Variance Component	df	Chi-square	P-value
INTRCPT1,	R0	20.68424	427.83782	4	46.36251	0.000
SESSION slope,	R1	1.07308	1.15149	2	24.45917	0.000
level-1,	E	14.98149	224.44512			

Appendix E

Social Validity Survey: Please use this scale to indicate the extent to which you agree with the following statements.

1= Strongly Disagree *2 = Slightly Disagree* *3 = Slightly Agree* *4 = Strongly Agree*

1. Prior to this research study, I used sensory activities with students.

   1 2 3 4

2. The gliding sensory-based intervention was difficult to implement.

   1 2 3 4

3. The gliding sensory-based intervention did not take too much time away from instruction.

   1 2 3 4

4. One or more students seemed to benefit from the gliding sensory-based intervention.

   1 2 3 4

5. I will implement the gliding sensory-based intervention in the future.

   1 2 3 4

6. The jumping sensory-based intervention was easy to implement.

   1 2 3 4

7. The jumping sensory-based intervention took too much time away from instruction.

   1 2 3 4

8. One or more students seemed to benefit from the jumping sensory-based intervention.

   1 2 3 4

9. I will implement the jumping sensory-based intervention in the future.

   1 2 3 4

10. I am likely to use sensory-based interventions with students in the future.

    1 2 3 4