CHAPTER

4 An Ecological Model of Sensory Modulation:

Performance of Children With Fragile X Syndrome, Autistic Disorder, Attention-Deficit/Hyperactivity Disorder, and Sensory Modulation Dysfunction

LUCY JANE MILLER, PH.D., OTR

JUDITH E. REISMAN, PH.D., OTR, FAOTA

DANIEL N. MCINTOSH, PH.D.

JODIE SIMON, PH.D.

Defining Sensory Modulation

The term *sensory modulation* references both physiological reactions and behavioral responses. Behaviorally, the term refers to the ability of an individual to regulate and organize responses to sensations in a graded and adaptive manner, congruent with situational demands (Ayres, 1972; Parham & Mailloux, 1996; Royeen & Lane, 1991). Physiologically, the term refers to cellular mechanisms of habituation and sensitization that alter the structure and/or function of nerve cells, affecting synaptic transmission (Kandel, 1991). Occupational therapists should be aware of the difference between the two uses of the term and carefully indicate the process to which they are referring. Most critical is the distinction between neurophysiological and neuropsychological views on sensory integration processes and use of the terms in occupational therapy to discuss behaviors related to sensory integration function and dysfunction (Miller & Lane, 2000). In particular, differentiating the terminology that describes *processes* that are not observable (i.e. occurring at the cellular and/or nervous system level) from the terminology that describes *behavioral manifestations* of these processes that are observable in sensory integrative functions and dysfunctional patterns is essential. Occupational therapists must begin to differentiate clearly between what they observe and what they infer occurs in the central nervous system (Miller & Lane). Clinicians can infer that dysfunctional behavior patterns in sensory modulation dysfunction relate to underlying *neurophysiologic processes,* but empirical research proving this hypothesis does not exist at the current time (Hanft, Miller, & Lane, 2000). (See Appendix 4-A for a glossary of definitions.)

Recently, a group of occupational therapists with extensive knowledge of sensory integration theory and practice collaborated to define sensory modulation processes, sensory modulation abilities, and sensory modulation dysfunction (SMD). Sensory modulation ability was defined as the "capacity to regulate and organize the degree, intensity, and nature of responses to sensory input in a graded and adaptive manner. This allows the individual to achieve and maintain an optimal range of performance and to adapt to challenges in daily life" (Miller & Lane, 2000). Dysfunction in sensory modulation (SMD) was defined as a problem in regulating and organizing the degree, intensity, and nature of responses to sensory input in a graded manner. SMD disrupts an individual's ability to achieve and maintain an optimal range of performance, and to adapt to challenges in daily life. SMD includes hyperresponsivity, hyporesponsivity and fluctuating responsivity (Lane, Miller, & Hanft, 2000). The behavioral and physiological processes that occur in SMD might be related, but empirical evidence demonstrating that common mechanisms underlie both is lacking. Those using the term SMD should specify "physiological modulation" or "behavioral modulation."

Is Sensory Modulation Dysfunction a Valid Syndrome?

Several occupational therapy researchers (Ayres, 1972; Fisher, Murray, & Bundy, 1991) have hypothesized that sensory modulation dysfunction (SMD) is a syndrome. To be a syndrome, SMD must have documented convergent and divergent validity, demonstrating that characteristics within a group found to have SMD occur reliably, and that this exact pattern of symptoms is not replicated in any other diagnostic group (e.g., AD/HD, Mood Disorders) (Pennington, 1991). The underlying hypothesis of this chapter is that SMD is a syndrome that can occur either with other disorders such as Fragile X syndrome, Autistic Disorders, Obsessive Compulsive Disorders, Mood Disorders, and Attention Deficit Disorders, or as a separate condition. Researchers need to conduct additional research to clarify the comorbidities between SMD and other disorders before stating with certainty that SMD is a valid, separate syndrome from other recognized disorders (e.g., AD/HD and Anxiety Disorders), research must confirm the comorbidity vs. differentiation of SMD and other disorders.

Though anecdotal and theoretical discussions suggest the validity of SMD as a separate diagnostic condition (Fisher & Murray, 1991; Kimball, 1993), little empirical research exists validating this theory. Miller and colleagues have implemented a program of research (1995 to 2000) to evaluate this and other related questions about SMD. This chapter summarizes the ongoing research and presents

1. a new model of SMD, including definitions of four *external dimensions* and three *internal dimensions* in SMD
2. physiological and behavioral data on five cohorts of children with Fragile X syndrome (FXS), Autistic Disorder (Aut), Attention Deficit Hyperactivity Disorders (AD/HD), sensory modulation dysfunction (SMD), and typical development (Typ)
3. the physiological methods and behavioral scales used to research the group differences
4. preliminary empirical data for each group

This chapter relates the observed data to the theoretical model and suggests directions for additional research.

Behavioral Symptoms of Dysfunction in Sensory Modulation

Individuals with SMD demonstrate hyperresponsivity, hyporesponsivity, or lability in response to sensory stimuli (Dunn, 1997; Parham & Mailloux, 1996; Royeen & Lane, 1991) and exhibit unusual patterns of sensation seeking or avoiding (e.g., "fight or flight" reactions to non-noxious sensations) (Ayres, 1979). Accompanying emotional states include anxiety, depression, anger, hostility, and lability. Attentional concomitants include distractibility, disorganization, impulsivity, and hyperactivity. Children with SMD frequently have problems with functional performance in such activities as dressing, play, mealtime, bath time, and social interactions (McIntosh, Miller, Shyu, & Hagerman, 1999). Parents of children with SMD report concerns related to poor social participation, insufficient self-regulation, and inadequate perceived competence and self-esteem (Cohn & Miller, 2000). Some symptoms overlap with behaviors observed in Attention Deficit and Anxiety Disorders.

Physiological Symptoms of Sensory Modulation Dysfunction

Empirical research on the physiological manifestations of SMD is limited. Individuals with FXS almost always evidence symptoms of sensory hyperreactivity as measured by electrodermal reactivity (EDR) (Hagerman, 1996) and have atypical EDR after sensation (Belser & Sudhalter, 1995; Miller et al., 1999). Like children with FXS, children with SMD and no identified comorbid disorder also demonstrate increased magnitude, higher frequency, and less habituation in response to sensory stimuli as measured by EDR (McIntosh, Miller, Shyu, et al., 1999). Children with AD/HD have widely disparate sensory modulation capacities as measured by EDR (Mangeot, 1999).

The New Theoretical Model

The literature suggests that SMD is associated with both physiological abnormalities and behavioral deficits. It is a widely held belief that contextual factors play a vital role in mediating responsivity in SMD (Parham & Mailloux, 1996). The complexity of considering all these factors led to the development of a new conceptual model to help focus research questions and interpret results.

The new theoretical model, the *Ecological Model of Sensory Modulation* (EMSM), elaborates both contextual factors and individual symptoms. The four contextual *external dimensions* (culture, environment, relationships, and tasks) influence the three personal *internal dimensions* (sensation, emotion, and attention). This model builds on two earlier working models of SMD:

- Royeen and Lane (1991) suggested a linear continuum of SMD from hyperreactive to hyporeactive.
- Dunn (1997) later proposed a categorical model with two dimensions: one axis represented *behavioral response* varying from "Responds in Accordance with Threshold" to "Responds to Counteract the Threshold"; the other axis depicted neurological threshold varying from high to low.

The EMSM highlights the external contextual factors interacting with internal characteristics to create SMD. In addressing the importance of ecological factors in understanding human performance, numerous theoreticians have considered the effect of context and task on behavior (Banaji & Prentice, 1994; Cohn & Cermak, 1998; Dunn, Brown, & McGuigan, 1994; Moen, Elder, & Luscher, 1995; Rogoff, 1982; Vygotsky, 1962). However, the occupational therapy literature has not previously emphasized the importance of ecological factors in SMD. Previous discussions of SMD tended to focus on performance components, such as sensory and motor responses, instead of more contextual factors, such as the effect of sensory responsivity at home, in school, and in community life. The EMSM embodies the belief that the responses of individuals with SMD can be understood only within the context of their external life. Accordingly, it is the ***interaction between the internal and external factors*** that produces SMD.

Elements of the Ecological Model of SMD

The Four External Dimensions

The occupational therapy literature, particularly literature related to sensory integration dysfunction, frequently overlooks the four *external dimensions*—culture, environment, relationships, and task (see Figure 4.1)—particularly in relation to sensory integration theory and practice. In SMD, however, referrals for occupational therapy come from a person's inability to interact appropriately with the environment.

Figure 4.1. External dimensions of the Ecological Model of Sensory Modulation

Culture: The societal mores and expectations that surround the person.

Environment: The physical and sensory milieu in which the individual finds him- or herself.

Relationships: The interactions and connections that one has with other people.

Task: The occupations (roles and "jobs") of the individual. For children, this includes activities of daily living, play, school, sleep, and social relating.

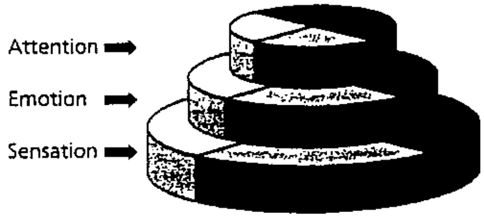


Figure 4.2. Internal dimensions of the Ecological Model of Sensory Modulation

Attention: The ability to sustain performance for tasks and relationships, including controlling impulses and activity level.

Emotion: The ability to perceive emotional stimuli and regulate affective and behavioral responses.

Sensation: The ability to receive and manage the sensory information that comes into the nervous system from the outside world.

In the EMSM, *each* external dimension interacts with *each* internal dimension, either to support or to challenge responses in a specific situation. A "just-right match" between internal and external dimensions occurs when there is a good fit between (a) the supports or demands of task, relationships, environment, and culture and (b) the individual's capacity for processing sensation, emotion, and attention. A good fit results in adaptive performance (e.g., completed tasks or processes). When the external dimensions do not provide the appropriate "scaffolding" or impede performance, problems occur.

When there is good fit between external dimensions and occupational roles and tasks, the situation provides a "just-right challenge" and adaptive responses are maximized. Adaptive responses occur when the child is engaged and challenged and has the structures and supports needed for activity or action completion. For example, a *culture* with good fit has the right mix of permissiveness and structure to match the child's needs. An *environment* with good fit provides interesting but not overwhelming stimulation. A *relationship* with good fit can help mitigate the fear that certain sensations can induce. Finally, a *task* with a good fit provides a balance between structure and freedom that "fits" the needs of the individual.

Sometimes the demands of task, relationships, environment, and/or culture can cause dysregulation in the individual. For example, the demands for quiet in a certain *culture* might pressure a child who is active to fit into that *cultural* milieu. Similarly, the presence of too complex or too simple an *environment* can produce severe disorganization. The demand for direct eye contact and maintenance of personal space in *relationships* can exacerbate anxiety. The *task* of coloring inside the lines can be either too easy or too hard for a child, resulting in poor performance.

The Three Internal Dimensions

The *internal dimensions*—sensation, emotion, and attention—constitute aspects of enduring differences among individuals, varying with learned or constitutional individual difference. The *internal dimensions* are affected by input from the four *external dimensions*. For example, one's perception of the sound of footsteps differs according to whether one is walking on a dark night on an unfamiliar, deserted street or walking on a sunny day in a familiar, crowded market. The perception also likely varies depending on whether one is typically anxious or carefree.

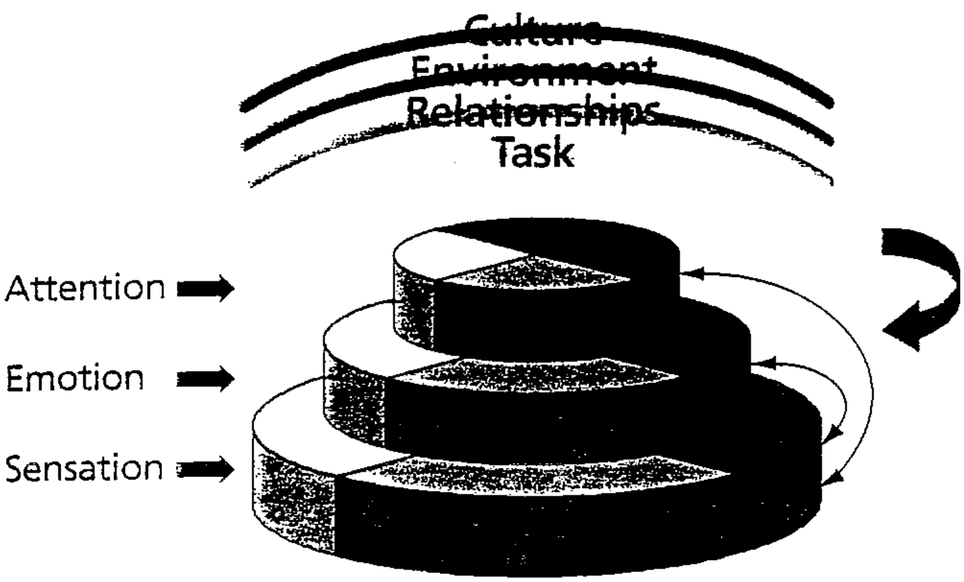


Figure 4.3. The Ecological Model of Sensory Modulation

light shading = underresponsivity
medium shading = normal responsivity
(a match between the external and internal dimensions)
dark shading = overresponsivity
black = lability, severe overresponsivity alternating with severe underresponsivity

Figure 4.2 depicts the three *internal dimensions* with stacked rings. Each ring rotates independently but can affect the revolution of other rings. Each ring is multidimensional, consisting of several factors. For example, sensation consists of seven subdivisions: tactile, vestibular, proprioceptive, visual, auditory, olfactory, and gustatory stimuli. For the purposes of simplicity in this chapter, subdivisions in internal dimensions are embedded within the three main rings.

The three rotating *internal dimensions* are circular rather than linear. Figure 4.3 depicts each internal dimension with shading to delineate responsivity: hyporesponsivity, normal responsivity, hyperresponsivity, and lability in responsivity.

The literature suggests that pushing an individual beyond the overreactive end of the continuum can result in hypoactive (or "shutdown") responses. For example, Chapman (1966) described a phenomenon in persons with schizophrenia who experienced severe sensory hyperreactivity and shut down both physiologically and behaviorally in what he termed a "blocking reaction." Kimball (1993) cautioned that some children might react in a dangerous way with quick fluctuations from overarousal to physiological "shutdown." She noted that severe physiological reactions might include changes in respiration, cardiac function, blood pressure resulting in decreased consciousness, and shock. This form of severe reaction has been documented medically in at least two cases (Kimball), although she described the more typical "shutdown" pattern as "shut[ting] off input and appear[ing] to be underaroused" (p. 98). Further empirical evidence related to this phenomenon is needed to ascertain with assurance whether extreme sensory overresponsivity *causes* shutdown responses.

When there is an imbalance between the supports and demands of the external dimensions and the adaptive capacities of the internal dimensions, the result is maladaptive behaviors. See Table 4.1 for some of the observable behaviors associated with unmodulated responses in the three internal dimensions.

Table 4.1. Observable Behaviors in Sensory Modulation Dysfunction

Internal Dimensions	Underresponsive	Overresponsive
Attention	Perseveration Unaware	Hyperactivity Impulsivity/Disinhibition Inattention
Emotion	Flat affect Lack of empathy	Hostility, anger Tearfulness Withdrawal
Sensation	Responds slowly Poor discrimination	Responds quickly Intense responses Poor habituation Fight-fright-flight responses

Figure 4.3 depicts the Ecological Model of Sensory Modulation with arrows designating hypothesized directions of effects in SMD. The arrows in the SMD model illustrate the hypothesis that SMD is driven by poor processing of sensation, affecting both emotion and attention.

The hypothesis of the SMD model is that children with this disorder have a core deficit in sensory reception, integration, regulation, or some combination of these. A further hypothesis is that these sensory abnormalities can cause emotional and attentional problems.

This model has a different central focus from other models that attempt to explain childhood disorders. For example, Barkley (1998) hypothesized that children with attention deficits might have a core deficit in the attention dimension. Other researchers hypothesized that people with Autistic Disorder have a core deficit in emotion regulation (Dawson & Lewy, 1989; Dawson, Meltzoff, Osterling, & Rinaldi, 1998). Thus, despite sometimes overlapping symptoms, individual syndromes can have different underlying core deficits in the three internal dimensions.

Study Protocol

Descriptions of the Five Cohorts in This Study

Children Who Are Typically Developing (Typical)

Sources of referral for the 46 typically developing children, ages 3 to 13 years, included parents, faculty, neighbors, and staff of the project. Parents completed a screening regarding potential risk factors at birth (low birth weight, prematurity, other complications) and current status (e.g., school, emotional or medical problems), which had to be negative for a child to be included in this sample.

Children With Fragile X Syndrome (FXS)

Twenty-three children, ages 3 to 12 years, were identified with FXS at The Fragile X Treatment and Research Center at The Children's Hospital in Denver, Colorado, and the diagnoses were confirmed by molecular studies. Most of the children in this group

(~70%) were on medications at the time of this study (~20% on stimulants, ~67% on selective serotonin reuptake inhibitors, and ~13% on anticonvulsants). The average IQ in this group was 70.

Children With Autistic Disorder (Autistic)

These eight children, ages 5 to 13 years, were found to have Autistic Disorder using scales and clinical tests (ADOS, Lord et al., 1989, and ADI-R, Lord, Rutter, & LeCouteur, 1994) to confirm *Diagnostic and Statistical Manual of Mental Disorders* (4th ed.) (*DSM-IV*; American Psychiatric Association, 1994) criteria: impaired social interactions and communication and a markedly restricted, repetitive, or stereotyped repertoire of behavior with restricted interests and activities. Referral sources included The Autism Treatment Center at the University of Colorado Health Science Center and The Child Development Unit at The Children's Hospital in Denver.

Children With Attention Deficit Disorders (AD/HD)

Forty children, ages 5 to 13 years, were referred by several centers in Denver (The Attention and Behavior Center, The Child Development Unit at The Children's Hospital) and by pediatricians and psychologists in private practice. Children's diagnoses were based on *DSM-IV* criteria and include all three Types: Inattentive, Hyperactive-Impulsive, and Combined. The average IQ in this group was 94.

Children With Symptoms of SMD and No Other Disorder (SMD)

Thirty-two children, ages 3 to 9 years, were identified as exhibiting SMD symptoms during occupational therapy assessment at The Children's Hospital in Denver. The criteria included observations during testing and atypical responses on the *Leiter-R Examiner Rating Scale* (Leiter-R; Roid & Miller, 1997) and confirmation by a detailed clinical interview of parents by the first author of this chapter (see Cohn & Miller, 2000, for interview protocol). The average IQ in this group was 108. Table 4.2 provides sample descriptions.

Table 4.2. Description of Samples

Group	*N*	Mean Age (years)	Age Range (years)
Typical	46	7.6	3–13
Females	16		
Males	30		
FXS	23	8.78	3–12
Females	7		
Males	16		
Autistic Disorder	8	8.5	5–13
Females	1		
Males	7		
AD/HD	40	8.27	5–13
Females	9		
Males	31		
SMD	32	5.87	3–9
Females	11		
Males	21		

Figure 4.4. Kalisha and experimenter during the Sensory Challenge Protocol.

Instrumentation

The Sensory Challenge Protocol

Electrodermal reactivity provides quantifiable data about the extent of physiological reactions to sensory stimuli. EDR measures changes in electrical conductance of the skin associated with eccrine sweat gland activity (Andreassi, 1989; Fowles, 1986). EDRs occur in the presence of startling or threatening stimuli or aggressive or defensive feelings (Fowles) and during positive and negative emotional events (Andreassi). An absence of electrodermal habituation to repeated stimuli might be related to defensive reactions to stimuli (Boucsein, 1992).

Previous research has demonstrated that individuals with certain medical or behavioral diagnoses exhibit atypical EDRs:

- Down syndrome (Clausen, Lidsky, & Sersen, 1976; Martinez-Selva, Garcia-Sanchez, & Florit, 1995; Wallace & Fehr, 1970)
- Schizophrenia (Kim, Shin, Kim, Cho, & Kim, 1993)
- Attention Deficit Disorders (Fowles & Furuseth, 1994; Rosenthal & Allen, 1978; Satterfield & Dawson, 1971)
- Conduct Disorder (Zahn & Kruesi, 1993)
- Autistic Disorder (Bernal & Miller, 1970; Stevens & Gruzelier, 1984; van Engeland, 1984)
- Fragile X syndrome (Belser & Sudhalter, 1995; Miller et al., 1999)

Because EDR provides a physiological marker of responses to stimuli, the *Sensory Challenge Protocol* (Appendix 4-B) was designed specifically to measure sensory reactivity in a controlled laboratory paradigm (see Miller et al., 1999, for a full description). The protocol gauges responsivity in a "pretend spaceship" presenting 50 sensory stimuli—ten trials in each of five sensory domains (olfactory, auditory, visual, tactile, and vestibular)—for 3 seconds each. The EDR is recorded at a sample rate of 1000 Hz. throughout the session.

The sample profiles in Figure 4.5a–c demonstrate three types of EDRs. In each figure, the vertical lines represent the administration of a 3-second stimulus (e.g., a 3-second bell sound). The oscillating tracings in Figures 4.5a, b, and c depict the person's EDR. The segments in Figures 4.5a, b, and c are small portions of an individual's full reactions during a Sensory Challenge Protocol lab. For example, in Figure 4.5a there are six vertical lines representing six of the ten movement stimuli presented to one individual.

The typical reaction (Figure 4.5a) shows a large peak after the first stimulus, with only one peak after each stimulus, and habituation by the fifth stimulus. In contrast, hyperreactivity (Figure 4.5b) produces large peak magnitudes, more than one peak after some stimuli, and no habituation. Hyporeactivity (Figure 4.5c) produces very small magnitudes of EDR and almost no peaks.

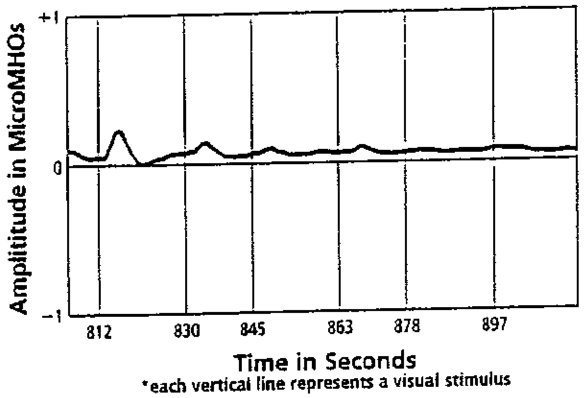


Figure 4.5a. Typical reaction

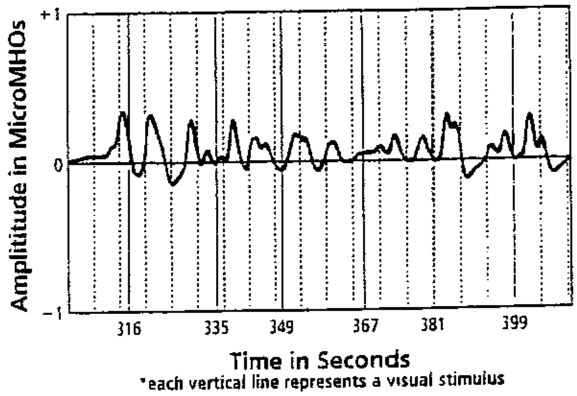


Figure 4.5b. Hyperreactivity

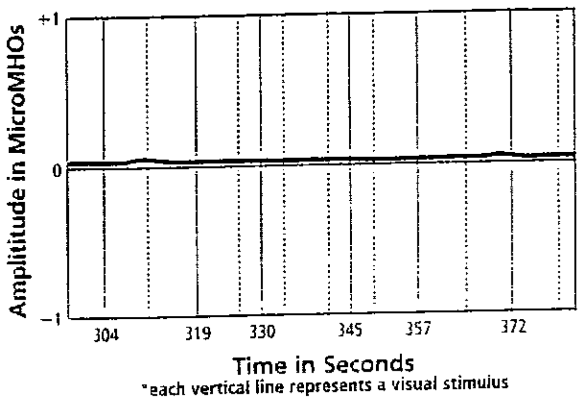


Figure 4.5c. Hyporeactivity

Between each of the vertical lines (i.e., administration of a sensory stimulus) on an EDR tracing, thousands of skin conductance data points occur. Computerized data reduction produced three variables: amplitude of reactions, frequency of reaction, and the number of stimuli administered before habituation occurs. The three variables are highly correlated (see McIntosh, Miller, Shyu, et al., 1999; Miller et al., 1999); therefore, for simplicity, this chapter reports only magnitude of reactions. Magnitude refers to the amplitude of the reaction after the stimulus. High scores represent "more" reactivity (magnitudes are presented in log transformation units). (See previous publications by Miller and McIntosh for more detail on EDR measurement.)

Parent Report Scales

In addition to the EDR measurements of physiologic reactivity, three norm-referenced standardized parent-report scales (described below) were administered to measure behavioral symptoms associated with sensory responses. (See Tables 4.3, 4.4, and 4.5 for content areas of each subtest on rating scales.) These scales have excellent reliability and good validity for measuring the processes of interest in this study. Raw scores have been converted to standardized z-scores, with more Typical performance indicated by higher z-scores.

Sensation

The *Short Sensory Profile* (SSP; McIntosh, Miller, & Shyu, 1999) is a 38-item measure of responses to common events that have sensory components. The subtests are Tactile Sensitivity, Taste/Smell Sensitivity, Visual/Auditory Sensitivity, Movement Sensitivity, Auditory Filtering, Low Energy/Weak, and Under-Responsive/Seeks Sensation. The *Leiter-R* (Roid & Miller, 1997) provides an additional subtest in this dimension, Sensitivity and Regulation.

Emotion

The Leiter-R provides additional measures for the emotion dimension with subtests in Energy and Feelings (measuring depression), Adaptation, Moods and Confidence (measuring anxiety), and Social Abilities. The *Child Behavior Checklist* (CBCL;

Table 4.3. Description of Content Areas Measured by the *Short Sensory Profile* (SSP)

Subtest	Description of Domain Measured	Sample Item
Tactile Sensitivity	Responses to textures	Responds emotionally or aggressively to touch
Taste/Smell Sensitivity	Overresponsive to tastes and smells	Picky eater regarding textures
Under-Responsive/ Seeks Sensation	Tendency to seek out movement stimulation	Seeks all kinds of movement and this interferes with daily routines
Auditory Filtering	Ability to filter out background noise	Is distracted or has trouble functioning if there is a lot of background noise
Visual/Auditory Sensitivity	Overresponsive to visual stimuli and sounds	Responds negatively to unexpected or loud noises (i.e., vacuum, dog-barking, hairdryer)
Low Energy/Weak	Tendency to become tired and have weakness	Poor endurance/tires easily
Movement Sensitivity	Overresponsive to vestibular stimuli	Becomes anxious or distressed when feet leave ground

Table 4.4. Description of Content Areas Measured by the *Leiter-R Parent Rating Scale* (Leiter-R)

Subtest	Description of Domain Measured	Sample Item
Attention	Ability to focus, concentrate and remember	Focuses even if noisy outside
Activity Level	Ability to remain calm and regulated	Appropriate amount of moving
Impulsivity	Ability to wait appropriately	Waits to get your attention; plays alone
Adaptation	Ability to adapt and transition	Transitions between places/activities easily
Moods and Confidence	Ability to regulate fear, worries, moods and anxiety	Confident, steady, and calm
Energy and Feelings	Ability to modulate depressed, melancholic or pessimistic feelings	Feels that can not succeed at anything
Social Abilities	Ability to attain and sustain relationships with peers and adults	Cooperative, agreeable and respectable
Sensitivity and Regulation	Ability to modulate reactions to sensation and regulate ideas and thoughts	"Fight or flight" reaction when hugged

Table 4.5 Description of Content Areas Measured by the *Child Behavior Checklist* (CBCL)

Subtest	Description of Domain Measured	Sample Item
Withdrawn	Behaviors related to isolating oneself	Fears going to school
Somatic Complaints	Issues related to physical problems that do not have a diagnosable cause	Has stomachaches or cramps
Anxious/Depressed	Feelings of worry or extreme sadness	Unhappy, sad or depressed
Social Problems	Interactions with peers and adults	Clings to adults or too dependent
Thought Problems	Propensity toward obsessive or odd ideation	Sees things that are not there
Attention Problems	Difficulty with sustained attention and hyperactivity	Cannot concentrate, cannot pay attention for long
Delinquent Behavior	Behaviors related to destructive or disobedient actions	Steals outside the home
Aggressive Behavior	Externalized symptoms of anger and hostility	Physically attacks people
Sex Problems	Issues related to gender identity or sexuality	Wishes to be of opposite sex

Achenbach, 1991) assesses social and emotional behaviors with the following subtests: Social Problems, Aggressive Behavior, Thought Problems, Anxiety and Depression, Somatic Complaints, Withdrawn, Delinquent, and Sex Problems.

Attention

The Leiter-R has Attention, Activity Level, and Impulsivity subtests, and the CBCL includes an Attention Problems subtest.

SMD in Children With Developmental Disabilities

Relation of Findings to Ecological Model of Sensory Modulation

This section presents findings related to the *internal dimensions* of the EMSM. Findings related to *external dimensions* will be published elsewhere.

The discussion begins with descriptive data, synthesizing results for each clinical group on the three internal dimensions and presenting subtest scores (Figures 4.6–4.8, 4.10–4.12). The figures compare two clinical cohorts to children who are typically developing, first comparing children with Fragile X syndrome (FXS) and children with Autistic Disorder (Autistic) to typically developing children (Typical), then comparing children with Attention Deficit Disorders (AD/HD) and children with sensory modulation dysfunction (SMD) to typically developing children (Typical). The results for each group cover each *internal dimension:* sensation, emotion, and attention. To analyze data, the researchers used analyses of variance (ANOVA), with trial as a within-subjects factor and group as a between-subjects factor.

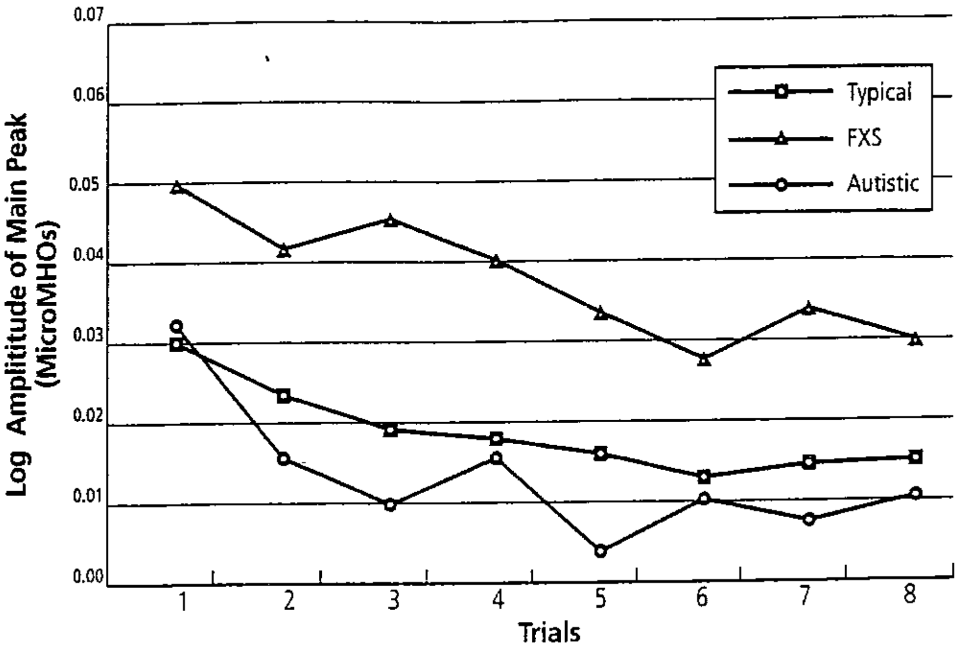


Figure 4.6. Electrodermal reactivity results for children developing Typically compared to children with Fragile X syndrome and children with Autistic Disorder

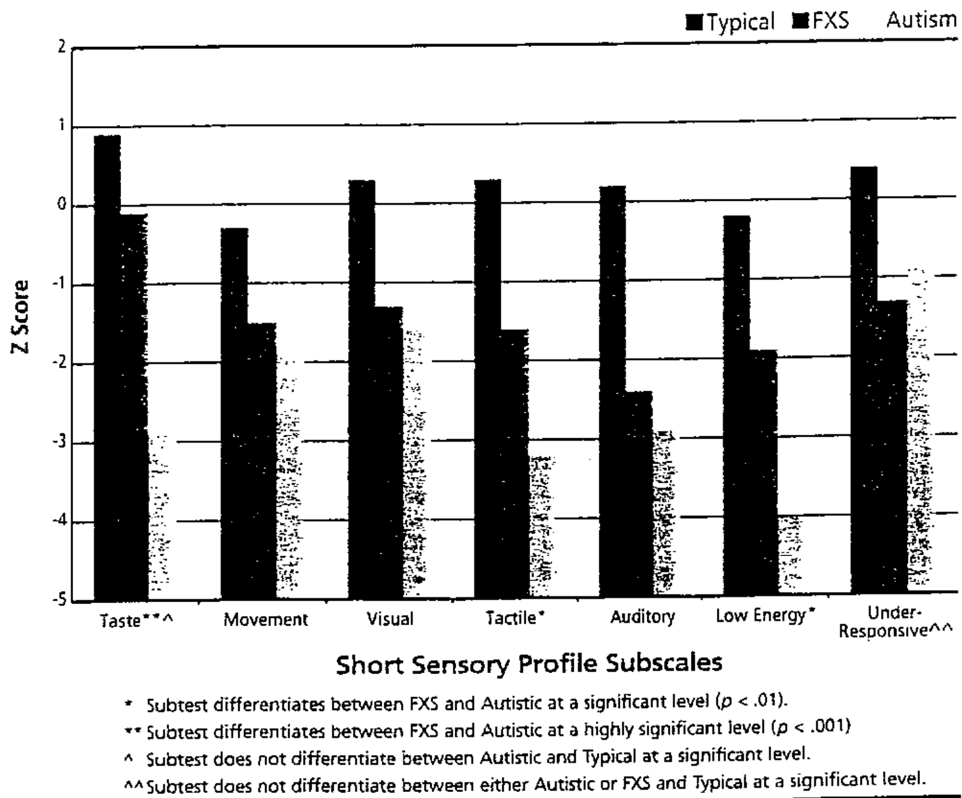


Figure 4.7. *Short Sensory Profile* ratings for children with Fragile X syndrome, children with Autistic Disorder, and children developing Typically

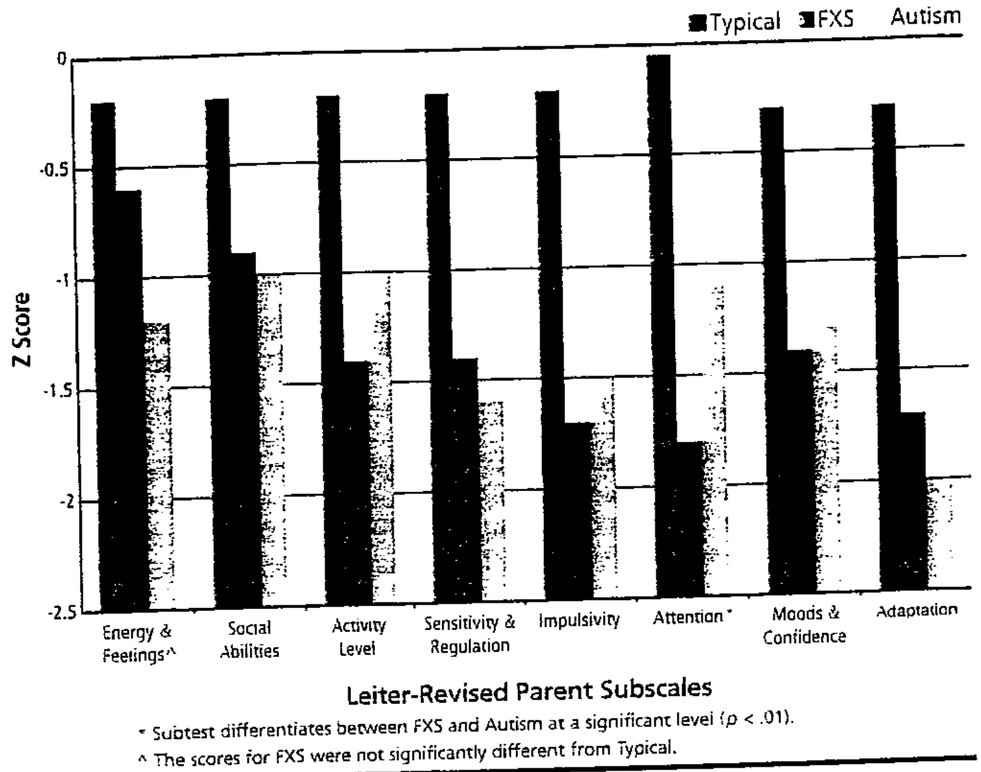


Figure 4.8. *Leiter-R* parent ratings for children with Fragile X syndrome, children with Autistic Disorder, and children developing Typically

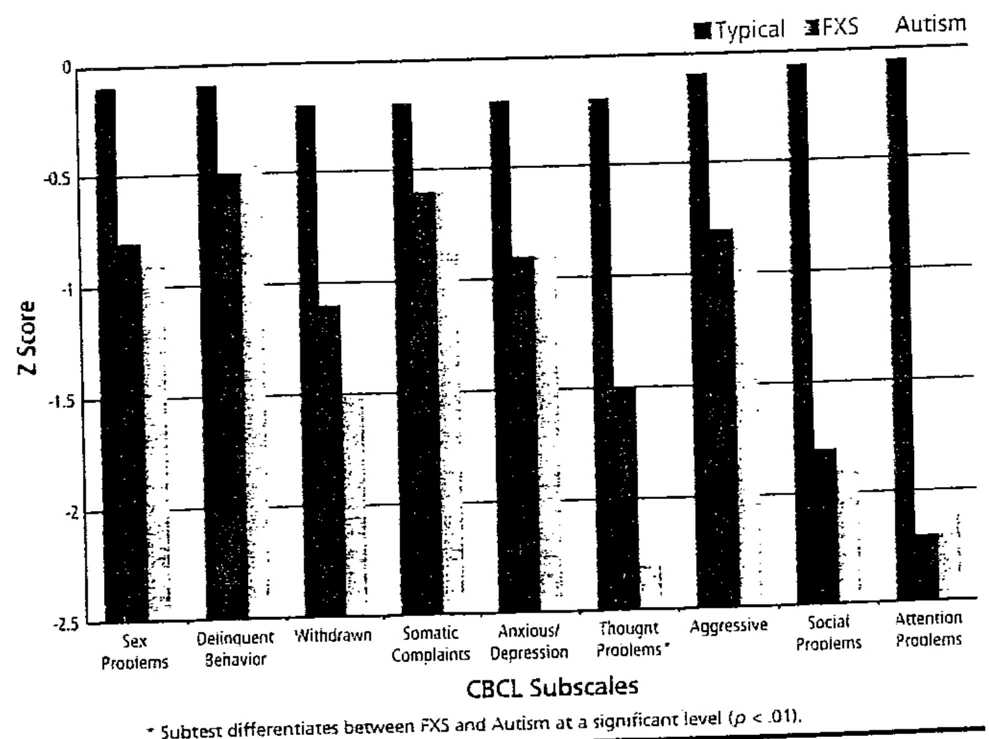


Figure 4.9. *Child Behavior Checklist* results for children with Fragile X syndrome, children with Autistic Disorder, and children developing Typically

After presenting the findings, the discussion moves to the relative role of sensation, compared to emotion and attention, in each disorder and hypothesizes an EMSM model depicting the *internal dimensions* for each disorder based on the preliminary data in this study. The discussion compares children with a diagnosis of FXS to children with a diagnosis of Autistic Disorder, then compares children with AD/HD to those with SMD. These data are preliminary and should form the basis for hypothesis generation and cross-validation only, rather than for drawing definitive conclusions.

Findings: Fragile X Syndrome and Autistic Disorder Compared to Children Who Are Typically Developing

Fragile X Syndrome

FXS is a genetic disorder, and children with this disorder have significant overresponsivity to sensory stimuli (Scharfenaker et al., 1996), attention deficits (Hagerman, 1996), and social-emotional difficulties (Sobesky, 1996). The authors hypothesize that severe difficulties with sensation in FXS might affect both emotion regulation and attention.

Sensation

Physiologically, the FXS group displayed higher magnitudes of EDR than any other group across all sensory domains (see Figure 4.6).The FXS group were behaviorally highly responsive to sensation, significantly different from Typ in all areas except taste/smell sensitivity. Symptoms of SMD were reflected in low scores on Auditory Filtering, Tactile Sensitivity, Movement Sensitivity, and Visual/Auditory Sensitivity (SSP) and on Sensitivity and Regulation (Leiter-R). FXS also had moderately low Under-Responsive/Seeks Sensation scores (SSP), suggesting that some children with FXS are movement seekers whereas others are movement avoiders (see Figure 4.7). Scores in sensation were a bit higher than attention but about the same as emotion.

Emotion

FXS was significantly different from Typical in all areas of emotion except depression (Energy and Feelings; Leiter-R) and Anxious/Depressed (CBCL). Five problem areas were Moods and Confidence (anxiety) and Adaptation (Leiter-R), and Social Problems, Thought Problems, and Withdrawn (CBCL) (see Figures 4.8 and 4.9). Scores in emotion were similar to sensation and higher (better performance) than attention.

Attention

FXS scores were lowest on Auditory Filtering (SSP) and Attention (Leiter-R and CBCL) and, though slightly better on Impulsivity and Activity Level (Leiter-R), still in the moderately impaired range (see Figures 4.7–4.9). Scores on the attention subtests were lower than on the sensation and emotion subscales.

FXS Relation to EMSM

This preliminary information suggests that children with FXS have significant attention regulation difficulties, sensory overresponsivity behaviorally, and sensory hyperreactivity physiologically. In addition, they display emotion regulation problems, particularly in socialization, adaptation, and thought problems. Based on this study, the performance of the children with FXS is not different from typically developing children in Taste/Smell sensitivity or Feelings and Energy (depression).

The extreme deficits in attention and sensation dimensions suggest that these could be core deficits in FXS. Figure 4.10 provides a visual representation of FXS on the internal dimensions of the EMSM. Children with FXS are overresponsive in all three *internal dimensions,* depicted by the dark quadrant of each ring facing forward in

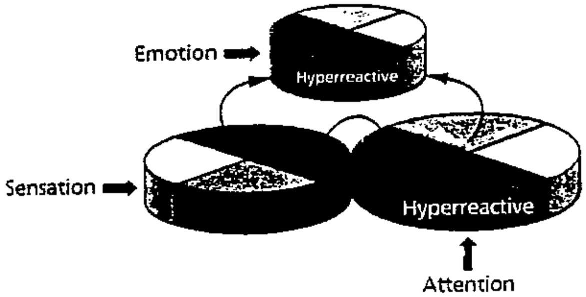


Figure 4.10. Ecological Model of Sensory Modulation in Fragile X syndrome

The arrows depict the findings that sensory reactivity and attention deficits might be affecting the emotion regulation in these children.

Figure 4.10. The arrows depict the findings that sensory reactivity and attention deficits might be affecting the emotion regulation in these children.

Autistic Disorder

The literature suggests that children with Autistic Disorder are hyperreactive to sensation (Bernal & Miller, 1970; Stevens & Gruzelier, 1984), although they do not always react to sensation (van Engeland, 1984). By definition, children with Autistic Disorder have significant difficulties in social-emotional areas (American Psychiatric Association, 1994). Evidence shows that they vary along the dimension of attention (Bryson, Wainwright-Sharp, & Smith, 1990; Buchsbaum et al., 1992; Dawson & Lewy, 1989). The authors thought that children with Autistic Disorder perhaps would have deficits in emotion regulation, affecting their sensory modulation and attentional regulation. Because the group with Autistic Disorder was quite small in this study; extreme caution in interpreting results below is necessary.

Sensation

The EDR data in this study suggest that children with Autistic Disorder are physiologically underreactive to sensation (EDR). They show a depressed magnitude of EDR compared to Typical and all the other clinical groups (see Figure 4.6). This finding is consistent with earlier findings by van Engeland (1984) but inconsistent with studies by Bernal & Miller (1970) and Stevens & Gruzelier (1984).

In contrast, behavioral ratings of sensation modulation demonstrated severe sensory overresponsivity in Tactile Sensitivity and Taste/Smell Sensitivity subtests and moderate hypersensitivities in Movement Sensitivity and Visual/Auditory Sensitivity domains (SSP), confirmed by a low score on Sensitivity and Regulation (Leiter-R) (see Figures 4.7 and 4.8).

The sample of children with Autistic Disorder also had a severe disorder in Low Energy/Weak, denoting a lack of general movement in this sample (−4 SD; SSP). Combined with normal scores on Under-Responsive/Seek Sensation, these scores suggest this sample displayed less movement than the sample of children developing Typically and no sensation seeking in the area of movement (see Figure 4.7). In summary, although depressed sensory reactivity occurred physiologically in this small sample, hyperresponsivity to most sensory stimuli was evident behaviorally.

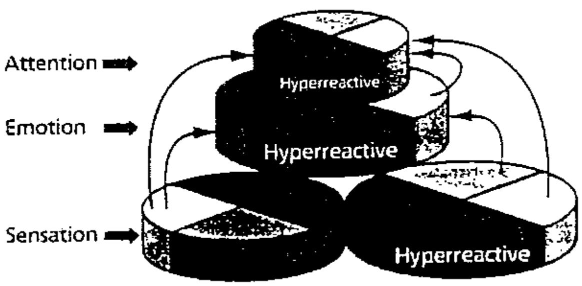


Figure 4.11. Ecological Model of Sensory Modulation in Autistic Disorder

Emotion

The sample of children with Autistic Disorder demonstrated hyperresponsive emotion, with significant deficits in Thought Problems (CBCL) and Adaptation (Leiter-R) and moderate difficulties in Moods and Confidence (anxiety) and Energy and Feelings (depression) (Leiter-R) and Social Problems and Withdrawn behaviors (CBCL) (see Figures 4.8 and 4.9). Though scores in emotion subtests demonstrated significant problems, much lower scores occurred in several sensory areas (movement avoiding [see Low Energy/Weak subtest], tactile, taste, and smell sensitivities).

Attention

The sample of children with Autistic Disorder demonstrated moderate problems in Auditory Filtering (SSP), Impulsivity and Activity level (Leiter-R) and Attention Problems (CBCL). Though not as severe as sensation, attention in Autistic was notably different from Typical (see Figures 4.7–4.9). Attentional problems other than Thought Problems and Adaptation were less severe in this Autistic Disorder sample than sensation and emotion problems.

Autistic Relation to EMSM

In this study, the most severe problems in the Autistic group appeared to occur in sensation, with significant physiological hyporeactivity and severe behavioral overresponsivity to taste, smell, tactile, visual, and movement stimuli. Significant emotional overresponsivity also was evident, with particular problems with thought processes, adaptation, socialization, and withdrawn/depressed behaviors. Attention was moderately impaired, but less so than the other EMSM internal dimensions.

Figure 4.11 depicts Autistic Disorder according to the EMSM. Because these preliminary data indicate that sensation might be more deficient than emotional regulation, a question arises about whether sensory modulation disorders form a core deficit affecting both emotion and attention. Figure 4.11 reflects the data that emotion regulation was more impaired than attention, with the arrow pointing from emotion toward attention. The model depicts both physiological hyporeactivity and behavioral hyperresponsivity in sensation.

Sensation

An interesting difference occurred in physiological sensory modulation: children with Autistic Disorder had underreactivity to sensory stimuli, whereas children with FXS had extreme hyperreactivity physiologically. Behaviorally, both groups displayed overresponsivity to sensation, although the Autistic group was significantly more atypical on Taste/Smell ($p < .003$) and Tactile Sensitivity ($p < .05$) (SSP) than the FSX group. The FSX group sought movement activities (atypical scores on Under-Responsive/Seeks Sensation), whereas the Autistic group demonstrated low energy and avoided movement (see Figure 4.7).

Emotion

The Autistic and FXS groups demonstrated similar impairments in the emotion dimension, with hyperresponsivity in five similar domains. The one domain of significant difference was Thought Problems, which was a more troubling problem in Autistic than in FXS (see Figure 4.9).

Attention

The FXS group demonstrated more impairment in Attention and Activity Level than did the Autistic group, although both groups demonstrated impairments (see Figure 4.8).

Relation to Model

These data suggest that both FXS and Autistic groups have impaired sensation. However, the impairments can be characterized differently, with FXS having hyperreactive physiological responses and Autistic having hyporeactive physiological responses. In Autistic the lowest behavioral subtests were sensory; in FXS the poorest subtest results were in attention. In both groups, the emotion dimension was the least impaired.

Findings: AD/HD and SMD Compared to Typical

AD/HD

The defining mark of AD/HD is impaired attention, with three subtypes in the *DSM-IV*: Predominately Inattentive Type, Predominately Hyperactive-Impulsive Type, and Combined Type.

Attention

This study confirmed the hypothesis that children with AD/HD would have deficits in the attention dimension. The AD/HD group exhibited more severe deficits in Auditory Filtering (SSP) than any other group, along with significant difficulties in Attention, Impulsivity, and Activity Level (Leiter-R), and Attention Problems (CBCL) (see Figures 4.12–4.14). In addition, the low scores on Under-Responsive/Seek Sensation (SSP) might be related to hyperactivity. Of note is a subgroup within the AD/HD sample that had Low Energy (SSP), indicating that some children in this sample were movement avoiders.

Emotion

The AD/HD group had significant problems in Adaptation (Leiter-R) and moderate problems with Social Problems and Aggressive Behavior (CBCL). Difficulties with Thought Problems (CBCL), Moods and Confidence (Leiter-R), and Anxious/Depression (CBCL) occurred to a lesser degree (see Figures 4.13 and 4.14). Scores in emotion were similar to scores in sensation, with many in the moderately impaired range.

Sensation

Physiologically, the AD/HD group had intriguing results. Children demonstrated an extremely large orienting reaction on the first trial of each sensory domain, followed by an immediate and significant decrease in reactivity almost to the reaction level of the Typical group for subsequent trials. Though the orienting reaction was larger than typically developing children's, clear habituation to sensory input was evident (see Figure 4.15).

Behaviorally, the AD/HD group displayed significant overresponsivity in Tactile and Visual Sensitivity (SSP) but almost normal scores on Movement Sensitivity (SSP). Both a movement-seeking subgroup (SSP, Under-Responsive/Seeks Sensation) and a movement-avoiding subgroup (SSP, Low Energy/Weak) were distinguishable (see Figure 4.12). The sensation and emotion domains exhibited about the same level of function, with sensation scores less impaired than attention scores.

AD/HD Relation to EMSM

The children with AD/HD showed significant problems in subtests measuring attention, impulsivity, and activity level. Excessive sensory responsivity was especially notable in tactile and visual domains, with a tendency toward either movement seeking or avoiding. Although these children demonstrated a large orienting response physiologically, they quickly habituated. Emotion problems were notable in adaptation and sociability.

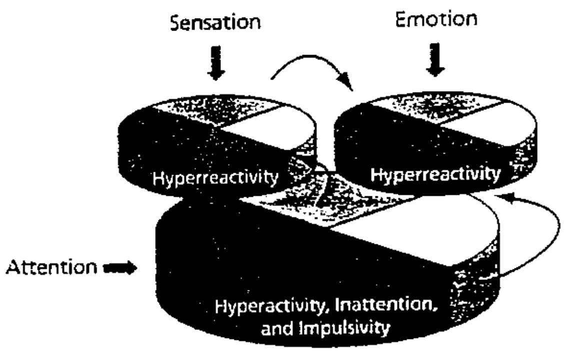
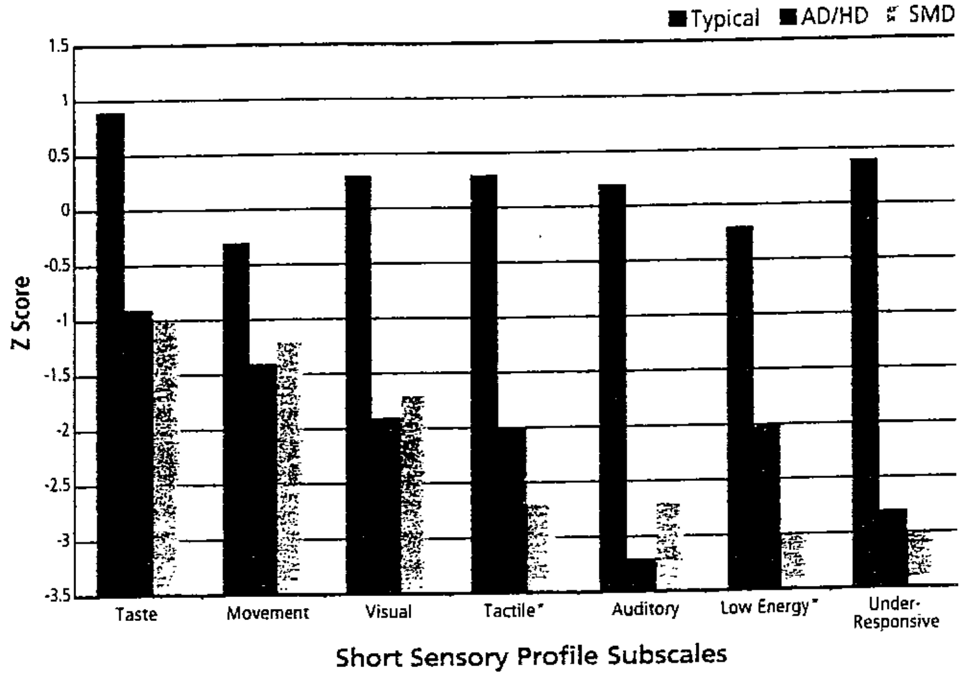


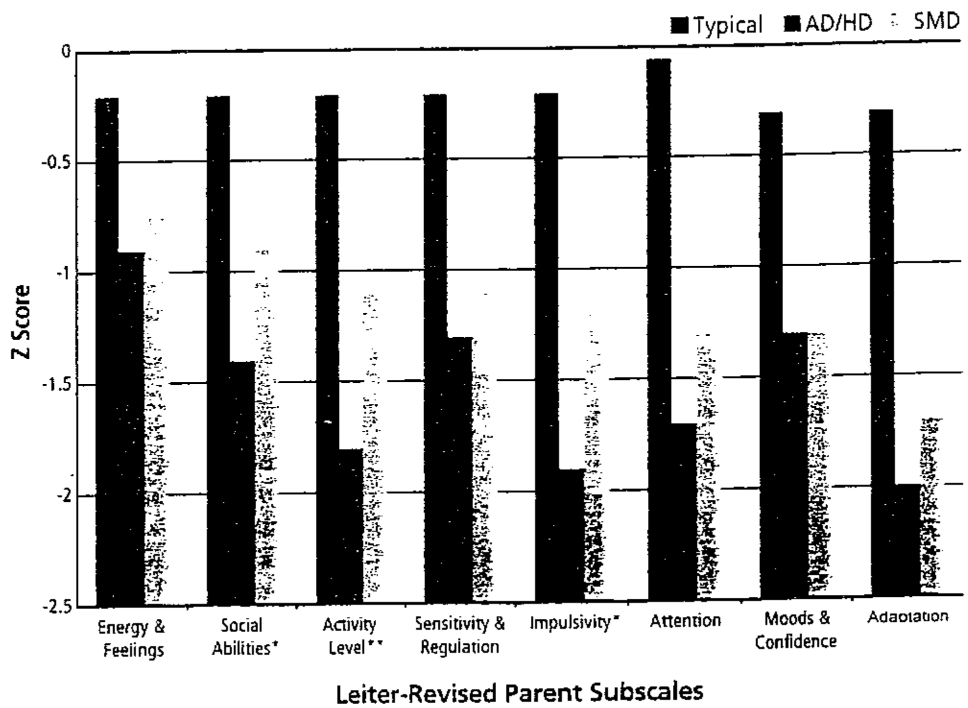
Figure 4.16. Ecological Model of Sensory Modulation in AD/HD

In a visual representation of AD/HD on the *internal dimensions* of EMSM (Figure 4.16), attention is the core deficit with arrows from attention toward sensation and emotion. Because sensation is more impaired than emotion, the arrow from



* Subtest differentiates between AD/HD and SMD at a significant level ($p < .01$).

Figure 4.12. *Short Sensory Profile* ratings for children with AD/HD, children with SMD, and children developing Typically



* Subtest differentiates between AD/HD and SMD at a significant level ($p < .01$).
** Subtest differentiates between FXS and Autistic at a highly significant level ($p < .001$)

Figure 4.13. *Leiter-R* parent ratings for children with AD/HD, children with SMD, and children developing Typically

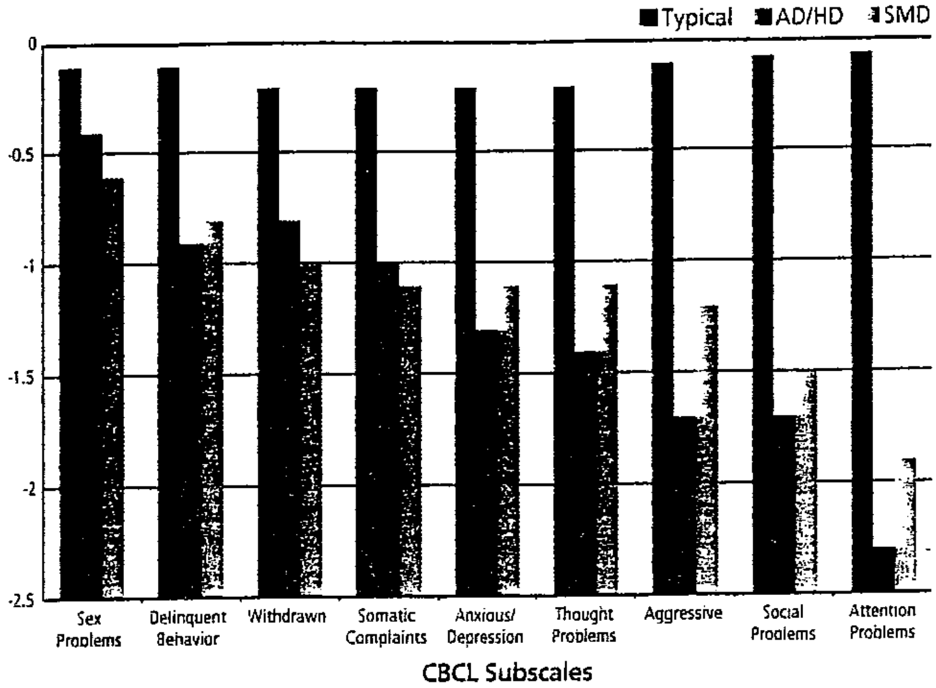


Figure 4.14. *Child Behavior Checklist* ratings for children with AD/HD, children with SMD, and children developing Typically

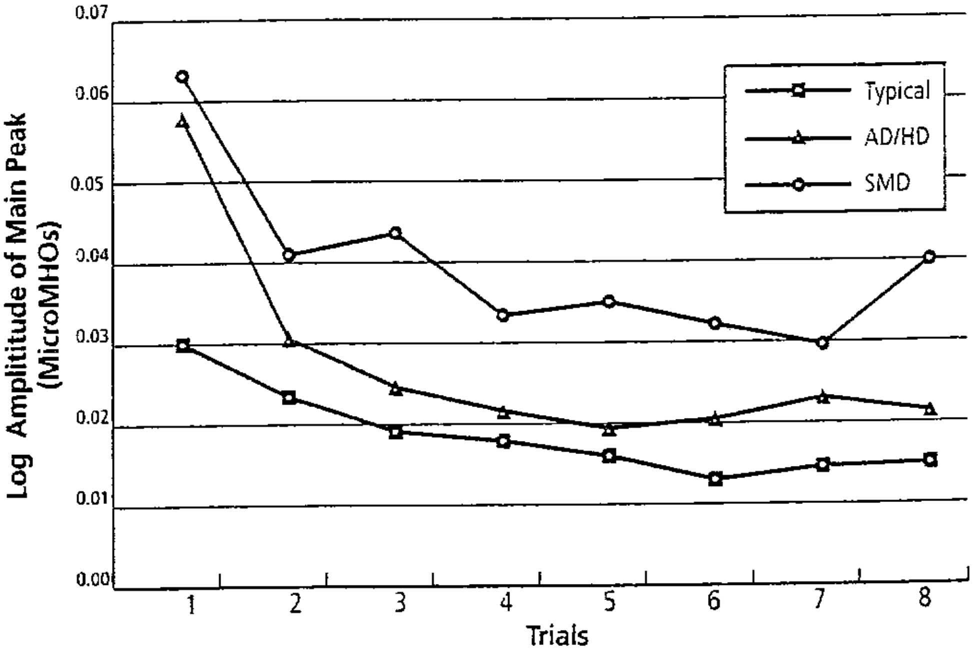


Figure 4.15. Electrodermal reactivity results for children developing Typically compared to children with AD/HD and children with SMD

sensation points toward emotion. The children with AD/HD demonstrate hyperresponsivity (dark shading) in all three dimensions.

Sensory Modulation Dysfunction

Scores less than −3.0 SD on SSP and the assessing occupational therapist's referral of SMD were the criteria for inclusion of children in the SMD group.

Sensation

Children in the SMD group showed extreme hyperresponsivity on behavioral measures, particularly on subtests of Tactile and Visual sensitivity (SSP). In addition, this group demonstrated a pattern of Under-Responsiveness/Seeks Movement sensation and Low Energy (movement avoiding) (SSP). Although the literature identifies "gravitational insecurity" (Fisher, 1991) as a potential concomitant of SMD, few children in this sample exhibited symptoms of overresponsivity to movement stimuli (SSP) (see Figure 4.12). Physiologically, children with SMD demonstrated extreme hyperreactivity, with high magnitudes of responses, multiple peaks, and poor habituation (see also McIntosh, Miller, Shyu, et al., 1999). The EDR responses of the SMD group appeared more hyperreactive than any other group except FXS.

Attention

The children in the SMD group showed impairment in attention, particularly on the Auditory Filtering subtest (SSP) and Attention Problems (CBCL), though less impairment than the AD/HD group. Moderate levels of inattention were evident (Leiter-R and CBCL), and Impulsivity and Activity were significantly impaired compared to the Typical group (Leiter-R) (see Figures 4.13 and 4.14).

Emotion

In the emotion dimension, moderate problems occurred in Adaptation and Social Abilities (Leiter-R) and Social Problems (CBCL), with lesser impairments in Moods and Confidence (depression) (Leiter-R), and Aggressive Behavior, Thought Problems, and Anxious/Depression (CBCL) (see Figures 4.13 and 4.14).

SMD Relation to EMSM

These data suggest that sensation might be the core deficit in children with SMD, including extreme physiological hyperreactivity after sensation, and extreme behavioral overresponsivity to sensation, particularly in tactile and visual domains (see Figure 4.12). Significant problems occurred in Auditory Filtering (SSP), probably related to attention deficits, which were in the moderate range (often without hyperactivity or impulsivity). Children demonstrated difficulty with adaptation and socialization in the emotion dimension. This preliminary evidence suggests that sensory problems might be the core deficit in SMD, contributing to both the attentional and the emotional problems. Because attention scores were lower than emotion scores, the arrows point from sensation toward emotion and attention, with another arrow from attention to emotion (Figure 4.17).

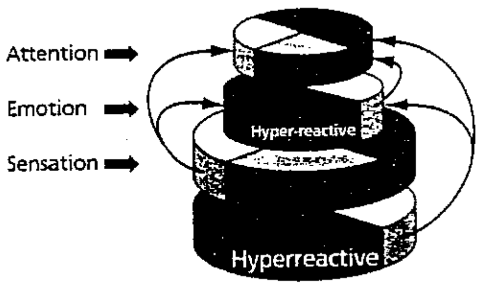


Figure 4.17. Ecological Model of Sensory Modulation in SMD

Comparison of AD/HD and SMD

Several domains differentiate these two clinical groups. Physiologically, the SMD group had more severe hyperreactivity with poor habituation, whereas the AD/HD group had a large initial orienting reaction, then habituated quickly. Overall mean sensory responsivity scores showed greater impairment for SMD than for AD/HD, with a significant difference on Low Energy (avoiding movement). The SMD group also displayed more impairment in movement seeking (Under-Responsive/Seeks Sensation), though not significantly more impaired (see Figure 4.12).

In the attention dimension, the AD/HD group showed greater impairment, with significantly more impairment on Activity Level, Impulsivity, and Social Abilities (see Figure 4.13) than the SMD group. In the emotion dimension, there were no clear differences, although the AD/HD group had lower scores, but not significantly lower, in Aggressive Behavior and Thought Problems than did the SMD group. Both groups had extremely impaired Auditory Filtering scores (~ −3 SD below the mean).

Moving From Data Back to Model

With preliminary data providing a baseline about the *internal dimensions* of these five groups of children, a plethora of research questions arise related to the model. These questions can help shape future research. The overarching question for each group is, Considering the three dimensions hypothesized in the model, does a core deficit exist in one *internal dimension* of each clinical disorder that directly affects function in the other two dimensions, and if so, in which internal dimensions does the deficit occur? The answer to this question will have a direct affect on intervention. Is a sensation deficit core in SMD and Autistic Disorder? Is an attention deficit core in AD/HD? Are both sensation and attention core deficits in FXS?

Because so little is known about sensory modulation dysfunction, the EMSM model can help guide future questions. However, a determination of whether SMD is a valid syndrome will be possible only after numerous studies describe the etiology, brain mechanisms, neuropsychological features, and behavioral symptoms of SMD and evaluate the degree of similarity with and difference from other disorders (e.g., AD/HD and anxiety disorders).

Limitations of This Study and Additional Questions

An important limitation to this study was the sample. The FXS sample was the most defined, given that FXS is a genetic disorder confirmed with molecular tests. The Autistic Disorder sample was quite specific because all participants met the criteria for Autistic Disorder specified in the *DSM-IV* and were tested using the ADOS and ADI. However, because the Autistic Disorder criteria are behavioral rather than genetic, subjective judgments form the basis of diagnosis. The evaluators were experienced professionals at The Autism Center at the University of Colorado who used standardized tests to classify the sample; therefore confidence exists that children in the sample did have Autistic Disorder, though the sample size was too small for generalization of results.

The AD/HD and SMD samples are more problematic. The *DSM-IV* describes three Types of attentional disorders, and this sample contained all three subtypes. Because an objective genetic marker of AD/HD does not exist, the accuracy of diagnosis depends on the diagnostic skills of the referring sources. The children with SMD were identified by master occupational therapy clinicians and had no other diagnosis at the time of referral. It is possible that some members of the SMD sample had undiagnosed AD/HD or Anxiety Disorders and that some members of the AD/HD sample had undiagnosed SMD. Future studies will need clear markers to construct nonoverlapping AD/HD and SMD groups. Perhaps poor habituation, using EDR as a dependent measure, can serve as a marker for SMD, and a large orienting response with good habituation can demarcate AD/HD. Empirical investigation of the comorbidity of SMD and AD/HD using standard diagnostic criteria for both groups is essential.

Current research in AD/HD supports the proposition that the core deficit in AD/HD is impulsivity (Barkley, 1998). These data support this suggestion. Is it possible to differentiate AD/HD from SMD by objective tests of impulsivity and sustained attention? To evaluate this, scales such as Logan's Stop Task (Logan, 1994), and the Attention Sustained and Attention Divided subtests from the Leiter-R might be helpful. Will these objective performance-based measures provide the clarity for subject inclusion needed to study the difference between AD/HD and SMD? Additional empirical evidence is certainly requisite before more definitive conclusions are possible.

Questions raised by this study include: Are there two groups of children within AD/HD, one with SMD and one without? Might it be possible to discriminate the groups within AD/HD based on EDR patterns after sensory stimulation? Would the two types of AD/HD groups (with and without sensory dysfunction) respond differently to medication and to OT using a sensory integration framework?

Another interesting finding was the significant difference physiologically between the FXS and Autistic Disorder groups. Children in the FXS group were extremely hyperreactive to sensory stimulation; individuals in the Autistic Disorder group were hyporeactive. These preliminary findings raise interesting theoretical questions. Clearly, the presence and impact of sensory processing disorders in both groups need further study.

Conclusion

This program of research in SMD is continuing, addressing questions of syndrome validity and intervention effectiveness as well as issues related to the underlying neurological, physiological, and biochemical mechanisms that could be disordered in SMD. The studies described in this chapter have not proven that SMD is a disorder; however, preliminary empirical evidence suggests that this might be true. Occupational therapy literature persistently discusses SMD as a syndrome. Because, as yet, syndrome validation is unproven, the use of a more conservative label such as "sensory modulation dysfunction" (SMD) would probably be more appropriate. Until additional evidence with cross-validation from different laboratories comes forth that demonstrates convergence (e.g., reliable characteristics in SMD) and divergence (e.g., differences in SMD and other disorders), it is premature to label SMD a syndrome.

In a larger venue, the field of occupational therapy is replete with articles, chapters, and newsletter columns discussing sensory integration theory and practice. Dozens of workshops elucidate components of sensory integration intervention. Ongoing controversy abounds related to intervention effectiveness.

One of the issues demonstrated by the studies discussed in this chapter is how little is known about SMD. The data raise profound questions about the nature of the dysfunction, including whether it is in fact a discrete syndrome, and highlight the importance of additional empirical research. Researchers must examine the effectiveness of treating children who receive their diagnoses based upon reliable, operationally defined methods, use specific and replicable interventions, and utilize relevant outcome measures that are tied to predicted hypotheses. Studies that address questions related to the neurological, physiological, and biochemical mechanisms and processes in children who manifest symptoms of SMD are crucial. Compelling research that links deficits at the neurophysiological or biochemical level to problems in meaningful occupations and quality of life is fundamental.

This research is complex, time-consuming, and expensive. It requires a committed and knowledgeable multidisciplinary team including therapists and scientists. Limited professional resources should be used not to argue about the effectiveness of sensory integration intervention or the "best" methods of assessment and intervention of these complex disorders but rather to collaborate in defining critical research questions and in funding and implementing scientific studies to answer those questions. Only in this way will the therapeutic disciplines best serve the children and families affected by sensory integrative dysfunction.

Acknowledgments

We would like to acknowledge the tremendous support of Dr. Marshall Haith, who reviewed this manuscript and provided consultation on the constructs. In addition, the lab director and lab assistants Jude McGrath, Kelly Church, Julie Bonnell, and Todd Ognibene devoted countless hours gathering data for this chapter. Dr. Randi Hagerman provided leadership on issues related to Fragile X syndrome and Dr. Sally Rogers on issues related to Autistic Disorder. This complex work could not be completed without the dedication of the treating occupational therapists: Clare Summers, Sharen Trunnell, Nicki Pine, Robin Seger, Lisa Waterford, Becky Greer, and Julie Butler. The administrative support of Dr. Dennis Matthews, director of Pediatric Rehabilitation at The Children's Hospital in Denver, Colorado, is also gratefully acknowledged. Finally, we appreciate the contributions of Judy Benzel, who provided administrative support, and Kimberley Dohren and the Photography/Computer Graphics Department at The Children's Hospital in Denver for assistance with figures.

Primary funding for this work was provided by the Wallace Research Foundation. Additional support has been provided by a NIH Career Award to the first author (# 1 K01 HD01183-01). The overhead expenses were supported in part by a grant from Maternal and Child Health (MCH grant # MC J 08941301).

References

Achenbach, T.M. (1991). *Manual for the Child Behavior Checklist/4–18 and 1991 Profile.* Burlington, VT: University of Vermont, Department of Psychiatry.

American Psychiatric Association. (1994). *Diagnostic and statistical manual of mental disorders* (4th ed.). Washington, DC: Author.

Andreassi, J.L. (1989). *Psychophysiology: Human behavior and physiological response.* Hillsdale, NJ: Lawrence Erlbaum Associates.

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

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

Banaji, M.R., & Prentice, D.A. (1994). The self in social contexts. *Annual Reviews in Psychology, 45,* 297–332.

Barkley, R.A. (1998). *Attention deficit hyperactivity disorder: A handbook for diagnosis and treatment* (2nd ed.). New York: Guilford Press.

Belser, R.C., & Sudhalter, V. (1995). Arousal difficulties in males with Fragile X syndrome: A preliminary report. *Developmental Brain Dysfunction, 8,* 270–279.

Bernal, M.E., & Miller, W.H. (1970). Electrodermal and cardiac responses of schizophrenic children to sensory stimuli. *Society for Psychophysiological Research, 7*(2), 155–168.

Boucsein, W. (1992). *Electrodermal activity.* New York: Plenum Press.

Bryson, S.E., Wainwright-Sharp, J.A., & Smith, I.M. (1990). Autism: a developmental spatial neglect syndrome? In J.T. Enns (Ed.), *The development at attention: Research and Theory* (pp. 405–419). North-Holland: Elsevier Science Publishers B.V.

Buchsbaum, M.S., Siegel, B.V., Jr., Wu, J.C., Hazlett, E., Sicotte, N., Haier, R., Tanguay, P., Asarnow, R., Cadorette, T., Donoghue, D., Lagunas-Solar, M., Lott, I., Paek, J., & Sabalesky, D. (1992). Brief report: Attention performance in autism and regional brain metabolic rate assessed by positron emission tomography. *Journal of Autism and Development Disorders, 22*(1), 115–125.

Chapman, J. (1966). The early symptoms of schizophrenia. *British Journal of Psychiatry, 112*, 225–251.

Clausen, J., Lidsky, A., & Sersen, E.A. (1976). Measurement of autonomic functions in mental deficiency. In R. Karrer (Ed.), *Developmental psychophysiology of mental retardation* (pp. 39–91). Springfield, IL: Thomas.

Cohn, E., & Cermak, S.A. (1998). Including the family perspective in sensory integration outcomes research. *American Journal of Occupational Therapy, 52*(7), 540–546.

Cohn, E., & Miller, L.J. (2000). Parental hopes for therapy outcomes: Children with sensory modulation disorders. *American Journal of Occupational Therapy, 54*(1), 1–8.

Dawson, G., & Lewy, A. (1989). Arousal, attention, and the socioemotional impairments of individuals with autism. In G. Dawson (Ed.), *Autism: Nature, diagnosis, and treatment* (pp. 49–74). New York: Guilford.

Dawson, G., Meltzoff, A., Osterling, J., & Rinaldi, J. (1998). Neuropsychological correlates of early symptoms of autism. *Child Development, 69*(5), 1276–1285.

DiPietro, J., & Porges, S.W. (1991). Vagal responsiveness to gavage feeding as an index of preterm status. *Pediatric Research, 29*(3), 231–236.

Dunn, W. (1997). The impact of sensory processing abilities on the daily lives of young children and their families: A conceptual model. *Infants & Young Children, 9*(4), 23–35.

Dunn, W., Brown, C., & McGuigan, A. (1994). The ecology of human performance: A framework for considering the effect of context. *American Journal of Occupational Therapy, 48*(7), 595–607.

Fisher, A.G. (1991). Vestibular-proprioceptive processing and bilateral integration and sequencing deficits. In A.G. Fisher, E.A. Murray, & A.C. Bundy (Eds.), *Sensory integration: Theory and practice* (pp. 71–107). Philadelphia: F.A. Davis Company.

Fisher, A.G., & Murray, E.A. (1991). Introduction to sensory integration theory. In A.G. Fisher, E.A. Murray, & A.C. Bundy (Eds.), *Sensory integration: Theory and practice* (pp. 3–26). Philadelphia: F.A. Davis Company.

Fisher, A.G., Murray, E.A., & Bundy, A.C. (1991). *Sensory integration: Theory and practice.* Philadelphia: F.A. Davis Company.

Fowles, D.C. (1986). The eccrine system and electrodermal activity. In M.G.H. Coles, E. Donchin, & S.W. Porges (Eds.), *Psychophysiology: Systems, processes, and applications* (pp. 51–96). New York: Guilford Press.

Fowles, D.C., & Furuseth, A.M. (1994). Electrodermal hypo-reactivity and antisocial behavior. In D.K. Routh (Ed.), *Disruptive behavior disorders in childhood* (pp. 181–205). New York: Plenum Press.

Hagerman, R.J. (1996). Physical and behavioral phenotype. In R.J. Hagerman & A. Cronister (Eds.), *Fragile X syndrome: Diagnosis, treatment, and research* (2nd ed., pp. 3–87). Baltimore, MD: The John Hopkins University Press.

Hanft, B.E., Miller, L.J., & Lane, S.J. (2000). Toward a consensus in terminology in sensory integration theory and practice: Part 3: Observable behaviors: Sensory integration dysfunction. *Sensory Integration Special Interest Section, 23*(3), 1–4.

Kandel, E.R. (1991). Cellular mechanisms of learning and the biological basis of individuality. In E.R. Kandel, J.H. Schwartz, & T.M. Jessell (Eds.), *Principles of neural science* (3rd ed., pp. 1009–1031). East Norwalk, CT: Appleton & Lange.

Kim, D.K., Shin, Y.M., Kim, C.E., Cho, H.S., & Kim, Y.S. (1993). Electrodermal responsiveness, clinical variables, and brain imaging in male chronic schizophrenics. *Biological Psychiatry, 33*, 786–793.

Kimball, J.G. (1993). Sensory integrative frame of reference. In P. Kramer & J. Hinajosa (Eds.), *Frames of reference for pediatric occupational therapy* (pp. 87–167). Baltimore, MD: Williams and Wilkins.

Lane, S.J., Miller, L.J., & Hanft, B.E. (2000) Toward a consensus in terminology in sensory integration theory and practice: Part 2: Sensory integration patterns of function and dysfunction. *Sensory Integration Special Interest Section, 23*(2), 1–3.

Logan, G.D. (1994). On the ability to inhibit thought and action: A user's guide to the stop signal paradigm. In D. Dagenbach & T.H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 189–239). San Diego, CA: Academic Press.

Lord, C., Rutter, M., Goode, S., Heemsbergen, J., Jordan, H., Mawhood, L., & Schopler, E. (1989). Autism Diagnostic Observation Schedule: A standardized observation of communicative and social behavior. *Journal of Autism and Developmental Disorders, 19*, 185–212.

Lord, C., Rutter, M., & LeCouteur, A. (1994). Autism Diagnostic Interview—Revised: A revised version of a diagnostic interview for caregivers of individuals with possible pervasive developmental disorders. *Journal of Autism and Developmental Disorders, 24*, 659–685.

Mangeot, S.D. (1999). *The relationship between disruptions in sensory modulation and attention deficit hyperactivity disorder in children.* Unpublished doctoral paper, University of Denver, Denver, CO.

Martinez-Selva, J.M., Garcia-Sanchez, F.A., & Florit, R. (1995). Electrodermal orienting activity in children with Down syndrome. *American Journal on Mental Retardation, 100*(1), 51–58.

McIntosh, D.N., Miller, L.J., & Shyu, V. (1999). Overview of the Short Sensory Profile (SSP). In W. Dunn (Ed.), *The Sensory Profile: Examiner's manual* (pp. 59–73). San Antonio, TX: The Psychological Corporation.

McIntosh, D.N., Miller, L.J., Shyu, V., & Hagerman, R. (1999). Sensory-modulation disruption, electrodermal responses, and functional behaviors. *Developmental Medicine and Child Neurology, 41*, 608–615.

Miller, L.J. (1988, 1982). *Miller Assessment for Preschoolers (MAP).* San Antonio, TX: The Psychological Corporation.

Miller, L.J., & Lane, S.J. (2000). Toward a consensus in terminology in Sensory Integration theory and practice: Part 1: Taxonomy of neurophysiological processes. *Sensory Integration Special Interest Section, 23*(1), 1–4.

Miller, L.J., McIntosh, D.N., McGrath, J., Shyu, V., Lampe, M., Taylor, A.K., Tassone, F., Neitzel, K., Stackhouse, T., & Hagerman, R. (1999). Electrodermal responses to sensory stimuli in individuals with Fragile X syndrome: A preliminary report. *American Journal of Medical Genetics, 83*(4), 268–279.

Mini Mitter Company. (1999). *Mini-Logger Series 2000.* Sunriver, OR: Author.

Moen, P., Elder, G.H., & Luscher, K. (1995). *Examining lives in context: Perspectives on the ecology of human development.* Washington, DC: American Psychological Association.

Parham, L.D., & Mailloux, Z. (1996). Sensory integration. In J. Case-Smith, A.S. Allen, & P.N. Pratt (Eds.), *Occupational therapy for children* (3rd ed., pp. 307–355). St. Louis: Mosby-Year Book, Inc.

Pennington, B.F. (1991). Issues in syndrome validation. In B.F. Pennington (Ed.), *Diagnosing learning disorders: A neuropsychological framework* (pp. 23–31). New York: Guilford Press.

Porges, S.W. (1985). *Method and apparatus for evaluating rhythmic oscillations in aperiodic physiological response systems.* U.S. Patent #4,510,944.

Porges, S.W. (1992). Vagal tone: A physiologic marker of stress vulnerability. *Pediatrics, 90*, 498–504.

Porges, S.W. (2000). *MX Edit (Version 2.19)*. Bethesda, MD: Delta Biometrics, Inc.

Rogoff, B. (1982). Integrating context and cognitive development. *Advances in Developmental Psychology, 2*, 125–170.

Roid, G.H., & Miller, L.J. (1997). *Leiter International Performance Scale—Revised*. Wood Dale, IL: Stoelting Company.

Rosenthal, R.H., & Allen, T.W. (1978). An examination of attention, arousal, and learning dysfunctions of hyperkinetic children. *Psychological Bulletin, 75*, 689–715.

Royeen, C.B., & Lane, S.J. (1991). Tactile processing and sensory defensiveness. In A.G. Fisher, E.A. Murray, & A.C. Bundy (Eds.), *Sensory integration: Theory and practice* (pp. 108–136). Philadelphia: F.A. Davis.

Satterfield, J.H., & Dawson, M.E. (1971). Electrodermal correlates of hyperactivity in children. *Psychophysiology, 8*, 191–197.

Scerbo, A.S., Freedman, L.W., Raine, A., Dawson, M.E., & Venables, P.H. (1992). A major effect of recording site on measurement of electrodermal activity. *Psychophysiology, 29*(2), 241–246.

Scharfenaker, S., O'Connor, R., Stackhouse, T., Braden, M., Hickman, L., I& Gray, K. (1996). An integrated approach to intervention. In R.J. Hagerman & A. Cronister (Eds.), *Fragile X syndrome: Diagnosis, treatment, and research* (2nd ed., pp. 349–411). Baltimore: The Johns Hopkins University Press.

Sobesky, W.E. (1996). The treatment of emotional and behavioral problems. In R.J. Hagerman & A. Cronister (Eds.), *Fragile X syndrome: Diagnosis, treatment, and research* (2nd ed., pp. 332–348). Baltimore: The Johns Hopkins University Press.

Stevens, S., & Gruzelier, J. (1984). Electrodermal activity to auditory stimuli in autistic, retarded, and normal children. *Journal of Autism and Developmental Disorders, 14*(3), 245–260.

van Engeland, H. (1984). The electrodermal orienting response to auditive stimuli in autistic children, normal children, mentally retarded children, and child psychiatric patients. *Journal of Autism and Developmental Disorders, 14*(3), 261–279.

Vygotsky, L.S. (1962). *Thought and language*. Cambridge, MA: MIT Press.

Wallace, R.M., & Fehr, F.S. (1970). Heart rate, skin resistance, and reaction time of mongoloid and normal children under baseline and distraction conditions. *Psychophysiology, 6*, 722–731.

Zahn, T.P., & Kruesi, M.J.P. (1993). Autonomic activity in boys with disruptive behavior disorders. *Psychophysiology, 30*, 605–614.

APPENDIX

4A Definitions of Terms

Magnitude of electrodermal response: A measure (from high to low) of the amount of response to sensory stimuli in the Sensory Challenge Protocol. An extremely high magnitude might correspond to hyperreactivity; an extremely low magnitude might correspond to hypo-reactivity.

Attention: One of the three *internal dimensions* of the Ecological Model of Sensory Modulation; refers to an individual's ability to sustain performance for task completion or interpersonal relationships, including impulse control and activity level.

Behavioral sensory modulation: The ability of an individual to regulate and organize reactions to sensations in a graded and adaptive manner, congruent with situational demands.

Culture: One of the four *external dimensions* of the Ecological Model of Sensory Modulation; refers to the societal mores and expectations surrounding the person.

Electrodermal response (EDR): A physiological measurement that provides quantifiable data about the extent of response to sensory stimuli by measuring changes in electrical conductance of the skin associated with eccrine sweat gland activity. It is an index of sympathetic nervous system activity.

Emotion: One of the three *internal dimensions* of the Ecological Model of Sensory Modulation; refers to an individual's ability to accurately perceive emotional stimuli and regulate affective and behavioral responses.

Environment: One of the four *external dimensions* of the Ecological Model of Sensory Modulation; refers to the physical and sensory milieu in which the individual finds himself or herself.

External Dimensions: One of the two major divisions of the Ecological Model of Sensory Modulation; refers to the effect of context and task on behavior.

Good fit: Results in adaptive performance (e.g., completed tasks or processes) that occurs when the external dimensions provide the appropriate supportive "scaffolding" for the child and if the external dimensions do not interfere with performance.

Internal Dimensions: One of the two major divisions in the Ecological Model of Sensory Modulation; refers to an individual's temperamental and capability characteristics that vary with learned or constitutional individual differences.

Just-right match: Occurs when there is a good fit between the supports or demands of: task, relationships, environment, and culture, and the individual's capacity for sensory processing and emotional and attentional responses.

Just-right challenge: Occurs when there is good fit between external dimensions and internal dimensions, that is, the individual is engaged and challenged and the structures and supports needed for activity or action completion are not too much or too little.

Physiological sensory modulation: Cellular mechanisms of habituation and sensitization used to alter the structure and/or function of nerve cells, affecting synaptic transmission.

Relationships: One of the four *external dimensions* of the Ecological Model of Sensory Modulation; refers to the interactions and connections that one has with other people.

Scaffolding: The "just-right" support that encourages an individual to attempt a task or activity that is a little hard for the person.

Sensory Challenge Protocol: A controlled laboratory paradigm that gauges an individual's responsivity to 50 sensory stimuli (10 trials in five sensory domains) by continuously sampling the individual's electrodermal reactivity.

Sensory Processing: One of the three *internal dimensions* of the Ecological Model of Sensory Modulation; refers to the individual's ability to receive and manage the sensory information that comes into the nervous system from the outside world.

Task: One of the four *external dimensions* of the Ecological Model of Sensory Modulation; refers to the occupations in which the individual engages. For children, this includes activities of daily living, play, school, sleep, and social relating.

APPENDIX

4B Sensory Challenge Protocol

The Sensory Challenge Protocol uses measurements of electrodermal reactivity and vagal tone to gauge individuals' physiological reactions to sensory stimulation. The Sensory Challenge Protocol uses two rooms. The first room is the "spaceship" lab (8 by 9.5 feet) in which the experimenter, a lab technician (e.g., a graduate student, project staff member, clinician who is working to obtain research experience, or an occupational therapist who receives special technical training and who is not involved in treatment of children in the study) administers the stimuli to the child. Figure 4-B.1 depicts the exact lab setup for the Sensory Challenge Protocol.

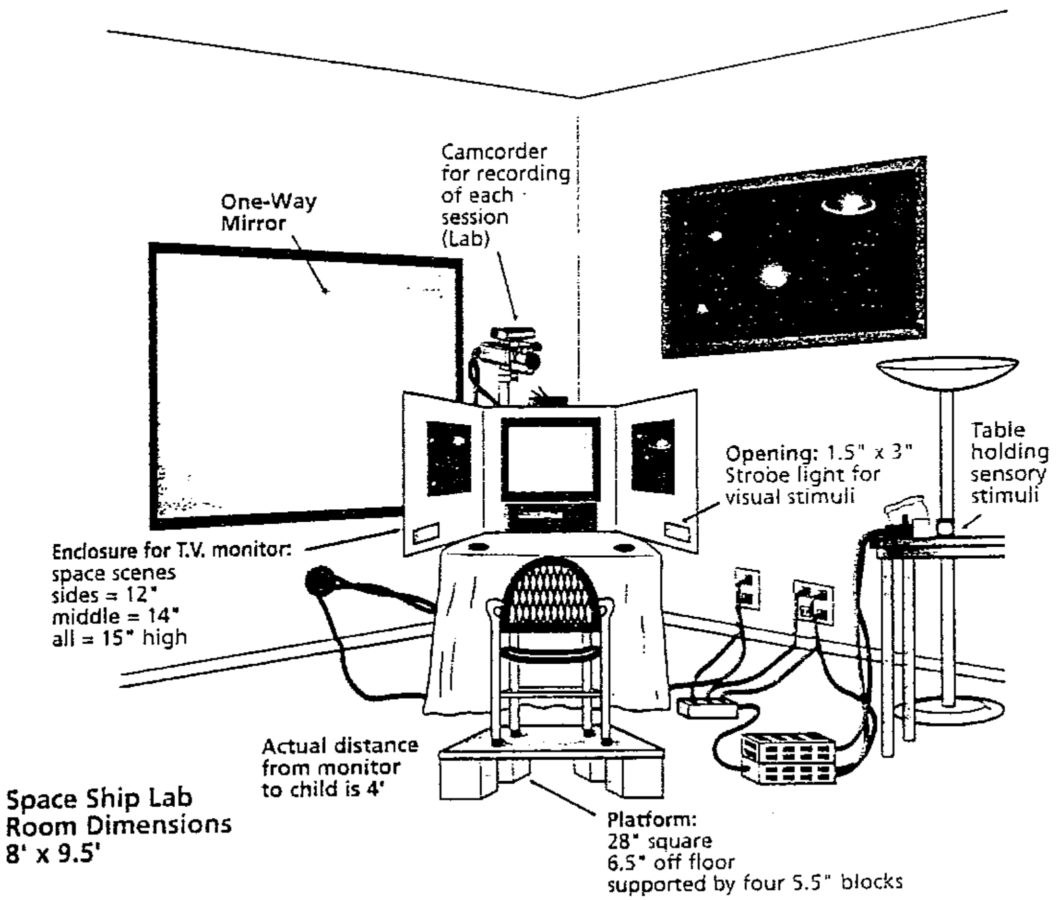


Figure 4-B.1. Laboratory layout for SCP

The second room (4 by 5 feet or larger) contains the computer, all physiological equipment, and the computer operator. The rooms are connected visually either by a one-way mirror into the spaceship or by a video camera in the lab that connects to a monitor in the computer room. The experimenter and the operator can communicate through headsets (Radio Shack Plantronics telephone headset PLX 500) that are hooked up through existing telephone lines in both rooms and are not audible to the child. Consequently, halting or adjusting the proceedings is easy for either the experimenter or the operator with a minimum of disruption to the session. Experimenters and computer operators should be blind to participants' diagnoses.

Introduction

The experimenter greets the child and the parent in the waiting room and explains to the child that he or she is going on a pretend "spaceship" trip. (Previous explanation via phone encourages the parents to prepare the child for this "fun time.") The parent and the child (if he or she is 8 or older) sign an informed consent. The experimenter slowly and gently transitions the child to the laboratory, the pretend spaceship. The lights in the lab are low, and two walls are painted to look like three-dimensional spaceship control panels. A third wall contains a one-way mirror through which the computer operator (and parents) can observe the session and make appropriate notations and adjustments on the electronic record, if needed. (Alternatively, the operator can use the video camera in the spaceship lab that feeds to a monitor in the computer room.) A small wooden frame painted to look like a spaceship control panel (approximately 14 inches wide and hinged on the left and the right sides to 12-inch-wide arms; all three pieces are 15 inches high) sits on a 12-inch-deep table approximately 4 feet in front of the child. A hole in the control panel allows the child to see the screen of a 13-inch video monitor directly ahead. A strobe light is visible through a cutout hole (1.5 by 3 inches) on the right side of the frame.

The experimenter conducts the child into the room and asks the child to step up onto a 28-inch-square board 6.5 inches off the floor. The child sits in a sturdy armchair that is permanently fastened to the board (actually a tilt board that rests on four 4-inch-square by 5.5-inch high wooden cubes). The ambient light in the room remains at a low level throughout the protocol. The child watches a section of the *Apollo 13* video depicting astronauts being "hooked up" as the experimenter attaches the child's electrodes. The specific segment of *Apollo 13* was selected to be entertaining while not emotionally charged. The segment helps the children to be involved, interested, and comfortable with the application of the electrodes.

Instrumentation

Autogenics 5-mm diameter electrodes, filled with electrode paste before the child arrives, are applied to the thenar and hypothenar eminences of the palm of the left hand (Scerbo, Freedman, Raine, Dawson, & Venables, 1992). The experimenter secures the electrodes with a 1.5-inch standard electrode collar.

A Coulbourn Isolated Skin Conductance Coupler (S71-23) applies a constant 0.5 V potential across the electrode pair to condition the electric signal. Because reactions to each stimulus (EDR) are of interest, not the changes in the slower fluctuating tonic skin conductance level, the coupling is AC (alternating current), which corrects for drifts in baseline conductance level over the extended time of the presentation of stimuli (see Boucsein, 1992). A low-cut filter set to 0.2 Hz passes signals above 0.2 Hz without distortion in amplitude. A computer samples the signals at 50 Hz, then digitizes and stores the data.

On-line monitoring of interbeat cardiac output using the Mini-Mitter polar XR (Mini Mitter Company, 1999), a small unit attached to the child's chest with a band, collects vagal tone variables. A separate unit, the Mini-Logger, collects the data and must be located within 18 inches of the Mini-Mitter to detect peak R waves for each cardiac cycle. Collection of time-sequential R-to-R intervals to the nearest millisecond follows the recommendations of Porges (1992). The procedure is noninvasive and painless. A computer (located in the adjacent room) continually amplifies, displays, and records the ECG data for later analysis. This procedure produces an estimate of heart period by minimizing confounding influences and is sensitive to small increments of change over short time periods (DiPietro & Porges, 1991).

Researchers later download the Mini-Logger data into the computer program (Mini Mitter Company, 1999) and manually edit each vagal tone file for artifact by (a) comparing long or short R-R intervals to adjacent values, to identify R-waves that might be errors, and (b) performing integer division of the long intervals and sequential addition of the short intervals. Cardiac vagal tone is estimated according to the patented procedure (DiPietro & Porges, 1991; Porges, 1985) using MX-Edit Software (Porges, 2000):

- converting heart periods to time-based data by sampling during successive 250 ms intervals
- detrending time-based data using a 21-point moving polynomial to remove the trend and periodicities of heart rates slower than the respiratory sinus arrhythmia
- processing the detrended data using a band-pass filter to remove sources of variance of heart period outside the frequency band characteristic of spontaneous breathing for the child (i.e., 0.24 to 1.04 Hz or approximately 15 to 60 breaths per minute) and calculating the natural logarithm of the band-pass variance

When the team has tested the equipment and the computer operator has set the skin conductance sensitivity so that the child's baseline is at 0, the operator signals the experimenter to begin the protocol and records a 2-minute baseline. Then 10 contiguous trials occur in each of 5 sensory systems. The experimenter presents the stimuli for 3 seconds each according to a standard, pseudorandom schedule 15 or 19 seconds apart, with 20 seconds between each sensory modality. A recorded set of instructions to which both the experimenter and the computer operator listen simultaneously through earphones directs the presentation of all stimuli. To control for possible order effects, two audiotapes alternate the order in which the sensory stimuli are presented. The order for tape one is olfactory, auditory, visual, tactile, and vestibular; the order for tape two is tactile, visual, auditory, olfactory, and vestibular. Both tapes present vestibular stimuli last in case the vestibular stimuli disrupt the child to the extent that he or she is not able to complete the protocol.

Presentation of Sensory Stimuli

The experimenter says to the child, "Now we are going to go on a pretend spaceship trip. You are going to smell some funny things, hear and see some funny things, and feel some funny things. Here we go! The first thing is a smell. Take a big breath and smell in now!" The experimenter times the word *now* to correspond with the first olfactory trial on the experimenter's audiotape.

Olfactory: The olfactory stimulus is wintergreen oil kept about half an inch deep in a small vial with a cotton ball. The wintergreen is commercially available in the extract sections of grocery and drug stores (e.g., Walgreen's wintergreen oil, synthetic methyl salicylate n.f.). Wearing a sterile glove, thumb covering the opened vial, the experimenter times his or her movements so that as the tape says "Ready, set, go," the experimenter is ready to uncover the vial and place it about 1 inch from the participant's nose, centered between nose and lips. The experimenter then moves the vial in a 1-inch path from the child's left (on 1), to the child's right (on 2), and to the child's left (on 3) with 1 second for each excursion from side to side. The experimenter tells the child to "smell in" with each excursion. The experimenter then places a thumb over the top of the vial to try to retain any lingering odors in the bottle and drops the vial to his or her side. At the conclusion of the 10 olfactory stimuli, the experimenter turns the glove inside out to trap odors inside the glove before discarding it and reseals the vial.

Auditory: After the 20-second wait period following olfactory stimulation, the experimenter says, "Now we are going to hear some funny things" and starts a tape recorder beginning the series of audio presentations. The stimuli are professionally recorded fire engine siren sounds played at 90 decibels. The tape presents 10 stimuli 8 or 12 seconds apart.

Visual: After the 20-second wait period following auditory stimulation, the experimenter says, "Now we are going to see some funny things." A commercially available 20-watt strobe light set at 10 flashes per second is built into the right "arm" of the spaceship console slightly below eye level. The strobe connects to an Able-Net Incorporated power link so that the experimenter, using a foot pedal, can turn the strobe on and off as directed by the audiotape. The strobe is on for 3 seconds, then remains off until the next trial.

Tactile: After the 20-second wait period following visual stimulation, the experimenter says, "Now we are going to feel some funny things." The experimenter uses the "Mr. Thumbuddy" cloth finger puppet with a 2.5-inch feather (*Miller Assessment for Preschoolers;* Miller, 1982, 1988) for the tactile stimuli. The experimenter gently places the feather outside the participant's right ear canal, then gently draws the feather along the chin line to the bottom of the chin, and finally raises the feather to the child's left ear canal. The experimenter times each movement to correspond with the "1-2-3" on the audiotape.

Vestibular: The participant's chair is securely fastened to the top surface of a 28-inch-square tilt board (Achievement Products, Inc., Canton, Ohio) supported by a 5.5-inch cube at each corner. A 4 inch high board rests under the back of the tilt board so that when the examiner tilts the chair backwards, the chair goes back 30 degrees before gently touching the board on the floor. After the 20-second wait period following tactile stimulation, and before administering the movement stimuli, the experimenter removes the two blocks located behind the participant's seat while holding the platform steady. Then the experimenter smoothly and slowly tips the child backward until the platform touches the board on the floor. The entire tip back occurs over 3 seconds and the return to upright also takes 3 seconds, both in time to the "1-2-3" on the audiotape, one continuous smooth and gentle movement. Children are often startled by the first tip, but typically developing children experience the movement as "fun." After the first tip back, the experimenter says, "[Child's name], I'm here and I will be here the whole time." After the 10 excursions of the chair are complete, the experimenter replaces the blocks under the platform so it becomes a stable surface once again. Then the experimenter starts a short cartoon videotape that plays for 2 minutes, during which the operator records "recovery" data for EDR and vagal tone.

If at any point the child experiences severe discomfort or verbally indicates that he or she wishes to stop, the experimenter terminates the particular stimulus but then makes every reasonable effort to coax the child to complete the remaining stimuli in the session. At the end of the session, the experimenter thanks the child and the parent for participating, and the child chooses a gift. The parent receives a small stipend for participating.

Library of Congress Cataloging-in-Publication Data

Understanding the nature of sensory integration with diverse populations / editors, Susanne Smith Roley, Erna Imperatore Blanche, Roseann C. Schaaf.

p. ; cm.

Includes bibliographical references.

ISBN 0-7616-1515-6 (pbk.)

1. Physical therapy. 2. Sensorimotor integration. 3. Children--Diseases--Physical therapy.

[DNLM: 1. Occupational Therapy--methods--Child. 2. Sensation--Child. 3. Developmental Disabilities--Child. WL 702 U55 2001] I. Smith Roley, Susanne, 1954- . II. Blanche, Erna I. III. Schaaf, Roseann C. (Roseann Cianciulli), 1958- .

RJ53.P5 U53 2001

615.8'2'083--dc21

2001001992

Therapy Skill Builders®

A Harcourt Health Sciences Company

Cover photo by Shay McAtee. Photos in chapters 13, 16, 17, 18, 19, and 20 by Shay McAtee.

0761615156

1 2 3 4 5 6 7 8 9 10 11 12 A B C D E

Printed in the United States of America

Please visit our Web site at www.PsychCorp.com.
Please go to www.psychcorp.com/catg/pdf/survey.pdf to comment on this or any of our products. Your feedback is important to us.

Understanding the Nature of

SENSORY INTEGRATION WITH DIVERSE POPULATIONS

Editors

Susanne Smith Roley, M.S., OTR

Erna Imperatore Blanche, Ph.D., OTR, FAOTA

Roseann C. Schaaf, M.Ed., OTR/L, FAOTA

Foreword by

Florence Clark, Ph.D., OTR, FAOTA

Therapy Skill Builders®

A Harcourt Health Sciences Company