

Neurodevelopmental Soft Signs: Implications for Sensory Processing and Praxis Assessment—Part One

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ABSTRACT

Occupational therapy pediatric clients with sensory processing/integration dysfunction often have co-occurring neurodevelopmental conditions, such as autism spectrum, attention deficit hyperactivity, learning, and motor planning/coordination disorders. The research evidence indicates that unique patterns of neurological/neurodevelopmental soft signs (NSS) occur frequently in these populations, and correlated central nervous system structures and processes are increasingly being identified through advances in neuroimaging and other technologies. Integrating clinical observations of NSS with advanced brain-based research expands our understanding of the sensorimotor scaffolding that leads to higher functions of behavior organization, communication, and cognition. This knowledge has the potential to notably enhance our theory, evaluation, interpretation, and intervention strategies for children with sensory processing and integration challenges that ultimately affect occupation and participation.

LEARNING OBJECTIVES

After reading this article, you should be able to:

1. Understand the role of NSS in occupational therapy clinical practice
2. Describe how the presence of NSS relates to sensory processing and integration
3. Identify areas of overlap between NSS and clinical observations in sensory integration
4. Discuss the interpretations of different NSS in the context of sensory integration theory

INTRODUCTION

Neurological soft signs (NSS) are defined as atypical performance on aspects of neuro-developmental assessment of sensory and motor functioning in the absence of specific brain lesions or injury (Deuel & Rauchway, 2005; Patankar et al., 2012). It has been further proposed that determining patterns of motor, sensory, and self-regulatory dysfunction observed in NSS may provide a neurobiological rationale for difficulties with learning and behavior that do not have the overt, “hard” signs of disorders such as cerebral palsy (Alamiri et al., 2018; Gidley Larson et al., 2007; Touwen, 1979). Occupational therapists have included NSS observations as a key component of evaluation for sensory integration/processing dysfunction since the 1970s (Ayres, 1973, 1976; Dunn, 2014; Miller, 1982), and currently continue to refine and standardize them for more effective clinical use.

General examples of NSS include: (1) atypical-for-age subtle neuromotor signs (e.g., “overflow,” involuntary movements, dysrhythmia), (2) immature postural and motor coordination; (3) sensory-perceptual difficulties, (4) problems with complex imitation and motor sequencing, and (5) poor behavioral regulation (Ayres, 1973; Martins et al., 2008; Touwen, 1979, 1987; Zhao et al., 2014). As NSS have been associated with developmental/maturational deficits in the central nervous system (CNS), the authors have chosen the term “neurodevelopmental soft signs” for this article

and will refer to them as NSS going forward. The selection of this term also reflects the major influence of historical theorists, researchers, and clinicians in the field of developmental rehabilitative science, such as A. Jean Ayres (1973, 1981, 2005), Karel and Berta Bobath (1980), and Mary Fiorentino (1975, 1981).

In typical development, the presence of NSS steadily decreases with concomitant expansion in complexity and refinement of volitional movement. The diminishing presence of NSS is also associated with the increasing growth and maturity of CNS structures, connections, and processes from infancy through adulthood (D'Agati et al., 2018; Martins et al., 2008). However, persistence of NSS into later childhood or even adolescence can suggest atypical neurodevelopment, whereas reappearance later in life often indicates a neurodegenerative process (Gidley Larson et al., 2007).

Before the advancement of brain imaging technology, NSS had seemingly diffused anatomical sources, as these origins were mainly inferred from animal research or postmortem studies. However, as the quality and power of neurological imaging technology have advanced, the underlying microanatomy and neurophysiological activity related to NSS have become clearer. Neuroimaging studies of individuals with NSS have found (1) characteristic anatomical patterns of regional cerebral blood flow (Manouilenko et al., 2013); (2) differences in gray matter volume (higher or lower than normal; Liu et al., 2017); (3) variations in white matter volume and density (Chang et al., 2016); and (4) anatomical differences on functional MRI (Dazzan et al., 2006; Hirjak et al., 2016).

Brain areas correlated with NSS and atypical behaviors in these and other studies include the (1) posterior cortical sensory association areas of the insula; (2) parts of the cerebellum; (3) thalamus; (4) cingulate gyrus; (5) parts of the basal ganglia, particularly the caudate nucleus and putamen; and (6) splenium of the corpus callosum. These findings have led to well-founded hypotheses about the brain areas and pathways corresponding to patterns and severity of NSS (Chang et al., 2016; Gustafsson et al., 2000; Manouilenko et al., 2013). This growing body of literature suggests that assessing NSS may provide a practical, cost-effective window into the structural and functional integrity of the neural systems governing sensory processing and integration; movement organization and execution; social-emotional responses; and perceptual, communication, and cognitive processes.

Patterns of NSS have been linked with at-risk status in several childhood neurobehavioral and learning conditions, such as attention deficit hyperactivity disorder (ADHD), specific learning disorders (LDs; Ayres, 1973; Patankar et al., 2012; Sheetharaman et al., 2017), autism spectrum disorder (ASD), and several neuropsychiatric impairments (D'Agati et al., 2018). NSS are also inversely correlated with cognition in the general population. For example, when examining NSS in a large sample of school-aged children ($n=35,710$). Alamiri and colleagues (2018) provided solid evidence of the relationship between NSS and low cognitive performance. These associations were not only apparent when using a full-scale IQ, but also along indices measuring overall performance, verbal, arithmetic, spelling, and reading skills. Additionally, in a sample of healthy children ($n=43$), Dazzan and colleagues (2006) reported that higher

rates of NSS were associated with high resolution MRI findings of diminished gray matter in the inferior frontal gyrus, middle and superior temporal gyri, and anterior cingulate gyrus. Subjects with the highest frequency of NSS had reduced white matter along the pathways of the superior longitudinal fasciculus, vital to inter-cerebral communication between frontal motor and dorsal sensory receptive areas (Dazzan et al., 2006). Patankar and colleagues (2012) found that children with the ADHD sub-type of impulsivity and hyperactivity had higher occurrence of NSS "overflow" or "mirror" movements and dysrhythmia errors than the ADD-only participants (who nevertheless had greater frequency NSS than typically developing participants). Overall, the number of NSS was associated with severity of ADHD symptoms, although the additional presence of specific learning disabilities over and above ADHD did not result in greater frequency of NSS (Patankar et al., 2012).

Although there are cross-disciplinary variations, NSS and their examination procedures in children can be divided generally into four main categories: (1) attention, behavior, and social-emotional regulation; (2) sensory functions; (3) motor functions; and (4) communication and cognition. These groupings are often subdivided for greater clarity in interpretation (Martins et al., 2008; Nass, 2005; Touwen, 1979). Pediatric neurologists and therapists often assess NSS within a framework of "clinical observations." Although these observations provide important diagnostic information, a lack of normative data often limits interpretation (Ayres, 1973; Martins et al., 2008; Nass, 2005; Touwen, 1979). However, over the years, many NSS have become formalized into standardized, norm-based, directly administered assessments and behavioral questionnaires, such as the Quick Neurological Screening Test-3R (Mutti et al., 2017), the revised version of the Physical and Neurological Examination for Soft Signs (Denckla, 1985), the Clinical Observations of Motor and Postural Skills (2nd ed.; Wilson et al., 2000), the Observations Based on Sensory Integration Theory (Blanche, 2002/2010), and more recently the Structured Observations of Sensory Integration-Motor (Blanche et al., 2019). Using valid standardized assessments can ensure more consistent, reliable administration procedures, and provide age-based criterion- or norm-referenced data.

As we can see, much of the research on NSS focuses on individuals with conditions such as ADHD, ASD, LDs, and developmental coordination disorder (DCD), and not specifically on sensory processing disorder (SPD)/sensory integration dysfunction (SID), which has not yet become a recognized standalone condition. However, given the rates of comorbidity between SPD/SID and these other neurodevelopmental and learning conditions, the aforementioned studies are relevant to our understanding of NSS in SPD/SID. Increasing evidence is emerging, which supports SPD as a clearly defined, scientifically validated primary diagnostic entity (Chang et al., 2014, 2016; Owen et al., 2013). Thus, the hypothesized organicity underlying NSS that neurodevelopmental theorists such as Ayres and Touwen pursued for many years, is being revealed empirically. Although many questions remain, neuroimaging evidence has

the potential to provide critical scientific support to occupational therapy clinical evaluation and therapeutic interventions for children with sensory integration/processing disorders (Chang et al., 2014, 2016; Owen et al., 2013).

Using NSS in Screening and Evaluating Children

Even when emphasizing important outcomes relative to occupational performance and social participation, caregivers express the need for answers as to why the child is having difficulties with self-care, play, learning, and related physical tasks, as well as peer relationships. Particularly when the child is young, they feel the need to receive interventions that address possible root causes directly, rather than solely through compensatory strategies. The latter may be more appropriate as the child approaches later adolescence, but these approaches need not be mutually exclusive (Malia et al., 2004). Following principles of neuroplasticity, occupational therapy that addresses both the underlying sensory and motor origins of the child's difficulties, as well as the occupational outcome "end products" of sensory-motor processing, may be the most successful approach.

For example, a child's caregivers and teacher report that she is falling out of her desk during seat work, that she fatigues quickly, appears "weak," and resists handwriting tasks. During the assessment, we observe significant postural hypotonicity, poor response to balance and equilibrium challenges, and impairments in proprioceptive and vestibular processing. Occupational therapy intervention can address these difficulties at multiple levels: through directly provided sensory integration treatment procedures, as well as classroom environmental modifications, such as ensuring proper postural alignment while seated at a desk, using a slant board on the desk during writing tasks, or sitting on a ball chair for all or part of the day. A multi-pronged approach such as this one provides more immediate results, but it also affects the child's sensory and motor capacities at a basic level that may be generalized across many activities and environments, rather than addressing one task at a time.

Occupational therapists who work with children and youth affected by sensory processing and motor control dysfunction use a wide array of assessment tools, including caregiver or teacher reports, standardized tests, and skilled observations during testing to evaluate and plan treatment programs for their clients (Richardson, 2015; Stewart, 2005). Including clinical observations for NSS as a vital part of pediatric assessment has a long history, beginning with the research and writings of Ayres and others (Ayres, 1973; Touwen, 1979; Touwen & Prectl, 1970). Indeed, occupational and physical therapists have been recognized by medical practitioners as contributing some of the most detailed and valuable NSS data in an infant or child's health record. Additionally, we as occupational therapists can provide vital interpretive explanations in our reports, demonstrating how the presence of various NSS are affecting the child's daily occupational functioning and participation in different contexts (Cermak & Larkin, 2002; Ismael et al., 2015; Stallings-Sahler, 1998). In our experience, physicians often have relied on the data provided by the occupational therapy

evaluation to determine a child's developmental condition, and make pharmacologic decisions and other patient care recommendations.

However, the value of NSS lies in illuminating the possible underlying neurological system dysfunction that may be causing disruptions in a child's occupational functioning. Examining the nature of caregiver or teacher concerns about the child's occupational difficulties, integrated with careful analysis of environmental, standardized evaluation, and NSS data can enhance the occupational therapist's ability to address both "ends" of the problem—the contributing neurodevelopmental factors, as well as the end-product occupational outcomes.

1. Behavioral dysregulation is applied here to refer to behaviors based on temperamental and physiological factors that may result in atypical arousal and attention patterns; high spontaneous motility; impulsivity and emotional reactivity; and poor soothability. These may be reported by the child's "community"—family or teachers—or directly observed by the occupational therapist during assessment (Karalunas et al., 2014). Distinct neurobiological correlates to these behavioral patterns have been discovered through cardiac physiological measurement and neuroimaging, which implicate differences in (1) parasympathetic versus sympathetic arousal and (2) characteristic connections between amygdala, hippocampus, insula, striatum, anterior cingulate cortex, and prefrontal cortex (Diamond et al., 2012; Karalunas et al., 2014).

Occupational therapists can benefit their child clients by understanding these behavioral factors and their potential negative effect on daily occupations, and by addressing them during screening and assessment. Difficulties in attentional and behavioral regulation may be addressed through a combination of behavioral, sensory-based, and social teaching strategies, as well as supportive environmental modifications (Hilton, 2015).

2. Atypical Sensory Registration and Modulation. Children with sensory processing difficulties demonstrate several self-regulatory-related NSS identified through caregiver, teacher, or self-report as well as direct therapist observation (Ayres, 2005; Kimball, 1999a, 1999b). These include behaviors reflecting sensory registration and modulation irregularities of hypo-responsiveness, sensory-seeking, or hyper-responsiveness (Ayres, 1981; Dunn, 2014; Dunn & Fisher, 1983; James et al., 2011) and other aspects suggesting poor sensory perception or discrimination at higher, cortical levels. *Perception* is distinguished from modulation and is defined as "the conscious recognition and interpretation of sensory stimuli that serve as a basis for understanding, learning, and knowing; or for motivating a particular action or reaction" (Mosby, 2013). We note that some disorders of bilateral movement and dyspraxia have been correlated with inefficient processing of vestibular-proprioceptive, somatosensory, and/or visual sensations from within the body or the external environment (Miller et al., 2007).

The behavioral observations and underlying neurophysiology of sensory defensiveness (now termed sensory hyper- or

over-responsiveness) were first hypothesized by Ayres (1973) and Knickerbocker (1980) because of the condition's more overt pattern of aversive, aggressive, or fearful responses to (1) social and environmentally induced light touch; (2) vestibular experiences of perceived height and movement (termed *gravitational insecurity*); (3) aspects of auditory amplitude, frequency or timing; and (4) various features of the visual environment, such as bright light, complex visual scenes, and faces. Gustatory and olfactory over-response seem to occur less frequently, but they do exist and may relate to medical problems such as chronic gastric reflux as well as occupational disruption in feeding and socio-cultural routines and emotions surrounding mealtime with family and peers (Stallings-Sahler, 2000). These are types of NSS that occupational therapists probe in the caregiver/teacher interview or completing SPD report questionnaires and observe during either the evaluation or an unstructured free play period.

The condition of poor sensory registration was first presented by Ayres (1981) based on her clinical study of children with autism, and the neurophysiological literature highlighting the hypothesized roles of the limbic system and basal ganglia in orienting to and acting on sensations from the environment. The involvement of these structures in sensory registration has been supported through several neuroimaging studies (Chaddad et al., 2017; Manouilenko et al., 2013) as well as the finding of aberrations in the integrity of myelin microstructure in the posterior cerebral tracts subserving sensory processing and integration (Chang et al., 2016; Owen et al., 2013). These findings overlap with those of children with autism, excepting the pathways subserving social-emotional function (Chang et al., 2014).

The phenomenon of sensory-seeking or sensory craving is characterized by extreme behaviors that appear to reflect the child's need to take in highly intense levels of sensory stimulation, which is more disorganizing, and does not satisfy their drive for more input (STAR Institute for Sensory Processing Disorder, 2016). This subtype may take the form of "crashing" play, excessive spinning, rocking or jumping, or oral stimulation by constant chewing on objects, for example. The neurological origins of this behavior are less well understood, but statistically this behavior tends to cluster with low registration in children who are more active (Dunn, 2007).

As sensory discrimination/perceptual functions across all modalities are processed primarily at the cortical level (although sub-cortical support is crucial), they are discussed later along with cognition and communication.

3. Atypical Neuro-Motor Maturity/Development. Neuro-motor soft signs are distinguished from motor "skill" signs, in that their origins are not under conscious cortical control, although they can notably influence the quality of skilled execution (Touwen, 1979; Patankar et al., 2012). Many aspects of neuromotor development in children have a long history of use in occupational therapy assessment of sensory integrative dysfunction (Bundy, 2002a). However, in recent years investigators have successfully measured their association with various neurodevelopmental diagnoses—even their ability to identify risk factors

for some conditions when detected in infancy (Gosselin et al., 2002; Majnemer et al., 2000; Teitelbaum et al., 1998). Occupational therapists are distinguished from other disciplines in that we take our application of these NSS a step further by analyzing their negative effect on occupational performance and participation, then intervening through treatment activities designed to enhance the underlying sensory capacities that support neuro-motor development (Bundy, 2002b).

Occupational therapy evaluators are advised to consider not only age differences on neuro-motor soft signs, but also that gender differences in performance and rates of maturity also exist. Gidley Larson and colleagues (2007) found in their sample of typically developing children ($N=144$) that most NSS reach adolescent/adult levels by around age 7, but that girls showed fewer subtle motor signs (such as involuntary movements); had higher scores on gait and stationary balance tasks; and were faster, with greater proficiency on timed patterned tasks (Gidley Larson et al., 2007). Larger samples of typically developing children have reported similar findings. For example, Alamiri and colleagues (2018) reported a more pronounced association between NSS and spelling scores among girls. Further, girls seem to reach overall motor maturity about 2 years faster than boys (Martins et al., 2008). These gender variations may be accounted for by MRI data showing differing rates of growth in frontal and parietal gray matter, white matter, and corpus callosum volume (Giedd et al., 1999).

With some variation across different measures, the most meaningful to therapists are neuro-motor NSS/clinical observations that examine for:

- Deficits in postural tone of "core" muscles
- Poor resistance to passive movement
- Presence/influence of residual postural reflexes
- Inadequate ability to assume and maintain whole-body anti-gravity positions in supine and prone
- Inadequate protective, righting, and equilibrium responses to perturbation of body or support surface
- Incoordination of bilateral-reciprocal extremity movements
- Tendency not to cross the body midline during activities
- Immature patterns of lateral dominance (see Table 1 on page CE-5).

Occupational therapists also note other neuro-motor NSS, such as motor overflow/"mirror" movements, choreiform movements or tremors in the hands/fingers, dysdiadochokinesia, dysmetria, and dysrhythmia during timed upper extremity tasks, any of which may be observed during structured or unstructured observations (Ayres, 1973; Blanche et al., 2019; Majnemer et al., 2000) and can detrimentally affect occupational performance. These NSS are detailed in the following paragraphs. *Postural hypotonia* is characterized by decreased resting muscle tension, lowered ability to generate volitional muscle force, and excessive joint laxity, all of which produce poor overall tonic postural stability, particularly in the extensor groups (Bundy, 2002a; Howle, 2002). It can be observed throughout the evaluation by visually examining the child's alignment of neck/head, thoracic and lumbar spine, pelvis, knees, and ankles during any

Table 1. Types of Neurodevelopmental Soft Signs (NSS) in Occupational Therapy Evaluation and Underlying Brain Areas Implicated in the Literature

Areas Targeted by NSS Research	Examples of Observations During NSS Assessment	Relationship to “Clinical Observations”	Relationship to Sensory Processing and Integration
Attention, behavior, and social-emotional functions	General disorganization of behavior for the situation at hand, low motivation, uncooperative, poor self-soothing, inattention, impulsivity, hyper-activity, impulsivity	Often elicited during administration of most structured and unstructured observations	Self-regulation skills and overall modulation of sensory experience Poor ideation and praxis abilities
Sensory functions (through structured screening procedures)	Poor graphesthesia, touch localization, astereognosis, poor auditory processing, visual perceptual, and spatial confusion	Important to discern if related to detection, modulation, or discrimination, and perception of sensory functions	Most NSS literature focus on proprioception (“position sense”) and less on tactile discrimination
Automatic neuro-motor maturity/development (not under volitional control)	Low postural tone, hyper- & hyporeflexia, persistence of primitive reflexes, protective, righting, and equilibrium responses to perturbation; static and dynamic balance; overflow/associated movements	Relates to multisensory processing basis for neuromotor skills such as postural control and primitive reflexes	May not relate to sensory processing and integration issues May have a relationship to vestibular, proprioceptive or vestibular-proprioceptive functions
Atypical bilateral organization and lateralization	Often associated with increased frequency of NSS on the left side of the body or significant dysdiadochokinesia, dysmetria, ataxia, left-right identification; lack of distinct pattern of hand-eye-foot preference	May relate to decreased bilateral organization and integration; may be lack of typical hemispheric symmetry (L>R in R handers)	Vestibular-proprioceptive-based disorders
Immature execution of symbolic representations	Imitation with and without objects; or following command, “Show me how you would [action] with a [object].”	Link to praxis and play skills	Determine if related to sensory processing and integration (e.g., sensory-based dyspraxia) vs. immaturity
Oculomotor Control	Smooth pursuits, vergence, saccades, gaze holding, VOR	Important to discern overall cooperation/avoidance vs. difficulty with specific skill	Relates to specific sensory processing and integration issues affecting overall postural and ocular control Overall postural control, vestibular and proprioceptive functions, and praxis
Communication and Cognition	Executive functions, memory, expressive and receptive language, attention, and intelligence	Not traditionally referred to as NSS. However, studies relate NSS with poor scores in communication, cognition, and overall executive functions	Overall sensory processing and integration may provide a scaffold for the development of, and have a direct effect on language, communication, and cognitive functioning

positions requiring extension against gravity; or by manually palpating the muscles, which have a soft, “mushy” feel.

Thus, postural hypotonicity also detrimentally affects the quality of voluntary, functional movements or when sustained upright positions are required to participate in an activity, such as standing to paint at an easel, sitting upright at the dinner table or school desk, or walking slowly around a grocery store or museum with a caregiver. From a sensory support perspective, Ayres (1973), Blanche and colleagues (2012), Fisher (1991), and others have hypothesized that low postural tone originates in deficient processing of vestibular utricular and proprioceptive inputs, both of which are required to support the extensor muscles of the cervical, thoracic, and lumbar spine, through their contributions to vestibulo-spinal activation (Lundy-Ekman, 2017).

Poor resistance to passive movement. Some neurological or sensory-based clinical evaluations call for the child to have

their head/neck or upper extremity resistance challenged by the examiner to, “Hold as still as you can ... don’t let me move you!” while the examiner attempts to lightly but firmly press in the opposite direction of the holding extremity or head/neck. This procedure provides a brief view both of postural tone and volitional muscle strength.

Residual (poorly integrated) postural reflexes. The presence of retained primitive postural reflexes, the interpretation of their meaning, and their value in intervention were frequently considered in the 1960s and 1970s as part of a set of clinical observations typically performed by occupational therapists, and in some cases, their resolution or integration was recommended as part of the child’s intervention plan (Ayres, 1973; Fiorentino, 1981).

Currently, the importance of these residual reflexes is considered controversial by some clinicians, though still believed by others to be meaningful. Over time, these have been eliminated

by many from the occupational therapy clinical evaluation. This is perhaps in the interest of evaluation time and because of their relatively low frequency of occurrence.

However, a subgroup of adults with DCD and reading disabilities have been found to have residual reflex effects, particularly of the asymmetrical tonic neck reflex (ATNR; McPhillips & Jordan-Black, 2007). Thus, its importance as a possible indicator of vestibulo-proprioceptive function has been revived. Teitelbaum and colleagues (1998) suggested that a persistent ATNR and very poor head righting response to tilt could be important early neurodevelopmental indicators of autism. Citing a double-blind randomized controlled trial, some in the field of learning disorders believe that treatment aimed at integrating these reflexes has a salutary effect on learning and reading skills (McPhillips et al., 2000). However, this study only reported a post-treatment decrease in frequency of the primitive reflex, not an increase in reading skill.

Early in her writing, Ayres (1973) presented testing procedures of placing the child in a reflex “challenge” quadruped position, where passive movement of the head laterally toward each shoulder (eliciting ATNR) then in a flexion-extension motion (eliciting symmetrical TNR [STNR]) are administered by the examiner. Later Ayres stated informally that the residual presence of these reflexes might suggest more about insufficient inhibition from higher cortical centers than about vestibular-proprioceptive function per se (Ayres, personal communication, Fall 1983).

The link between retained reflexes, motor and cognitive development, and intricate basal ganglia and cerebellar processing in children with history of very low birthweight and later ADHD has been highlighted by various researchers (Melillo, 2011). More brain imaging studies, like those mentioned earlier, are needed to examine whether retained infant reflexes have distinct neuroanatomical or neurophysiological correlates (Ellison & Daily, 2005).

Occupational therapists should distinguish between correlation and causality in considering intervention strategies to address learning and behavior problems. The fact that soft signs (such as retained reflexes or poor lateral dominance) are associated with attention and learning problems does not imply they are the cause of these impairments. Intervention approaches claiming to change the brain by establishing lateral dominance, or “integrating” residual reflexes, have little supportive evidence in the scientific literature. Signs are sequelae of brain dysfunction—not causes of it.

Difficulty in assuming/maintaining antigravity positions in prone and neck in supine. During sensory integration evaluation, occupational therapists use a clinical observation procedure originated by Ayres (1973, 1989) known as “prone extension” as an effective indicator of the child’s integrated vestibular-proprioceptive processing (Fisher, 1991). This procedure asks the child to lie prone on a flat, lightly padded surface, then simultaneously lift their entire body away from the surface in a total extension pattern and hold for up to 30 seconds. There are procedural variations in administration and measurement, but generally therapists examine qualitative factors such as the degree of involvement of neck, trunk, and extremities in the extension posture and its duration in seconds (Blanche et al., 2019). Children with

low postural tone have great difficulty executing and holding this position with good quality for more than a few seconds.

The prone extension response has not been examined in other disciplines as NSS, and more research is needed to confirm its ability to discriminate between children with and without sensory processing dysfunction, or between children with different types of SPD. Fisher (1991) hypothesized that the ability to fully flex the neck during the supine flexion challenge was also mediated by the vestibular system and neck proprioceptors and should be noted during occupational therapy evaluation. Inadequate flexion of trunk, hips, and lower extremities in anti-gravity supine flexion has been associated with both static and dynamic balance (Sellers, 1988), and seems to occur more frequently with somatodyspraxia than with bilateral integration issues (Bundy, 2002a).

Inadequate protective, righting, and equilibrium responses to displacement of the body over the base of support. This group of NSS is used across many disciplines to examine the robustness of the postural reflex system that undergirds not only gross motor control, but also serves to stabilize the visual field and provide anticipatory “readiness to respond” (Norré, 1990; Shumway-Cook & Woollacott, 2017; Zafeiriou, 2004). Eliciting righting responses is performed by a slower tilt of the support surface (e.g., therapy ball, rocker board) in various directions, while observing the adaptive postural changes made by the head/neck, trunk, pelvis, and extremities (Fisher, 1991).

Finally, equilibrium responses are usually elicited by providing a visual target for the client to reach toward, which necessitates them to reduce the base of support to one foot (if standing), one knee (if kneeling), or one hip/thigh (if sitting). Equilibrium reactions are considered the most mature of the three balance maneuvers and include counter-rotation of the head and trunk away from the direction of displacement, and the continued use of the extremities to assist in maintaining the position in space. Protective reactions intervene to protect the body from injury if the more mature righting and equilibrium responses fail to activate in time (Howle, 2002). Clinical testing procedures for protective reactions involve a sudden displacement of the child’s body over the center of gravity in various directions to elicit a protective response in the direction of the movement (Lundy-Ekman, 2017).

These responses, which are aspects of the total balance system, have been investigated using kinematic analysis of laboratory electromyography and posturography, and are believed to be the result of interaction between vestibular, somatosensory, and visual sensory inputs. A hypothesized hierarchy of sensory “weighting” is among these sensations, which varies depending on the surrounding environment and the availability of the sensations for cuing the head, trunk, and extremities on how to adjust in the most efficient manner to stay upright (Shumway-Cook & Woollacott, 2017). For more in-depth exploration of these complex mechanisms, the reader is referred to the works of Nashner, Horak, Shumway-Cook, and Woollacott. 📖

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Final Exam

Article Code CEA0919

Neurodevelopmental Soft Signs: Implications for Sensory Processing and Praxis Assessment—Part One

To receive CE credit, exam must be completed by
September 30, 2021.

Learning Level: Intermediate to Advanced

Target Audience: Occupational Therapy Practitioners

Content Focus: Domain: Client Factors; OT Process: Occupational Therapy
Evaluation and Interventions

- 1. How are neurological soft signs (NSS) in the areas of sensory-motor function different from abnormal neurological findings such as spasticity?**
 - A. NSS include all neurological findings in children.
 - B. NSS are non-focal and non-injury related.
 - C. NSS are different from sensory motor functions.
 - D. NSS and neurological findings are related to brain injury.
- 2. Which of the following statements is true concerning NSS in typically developing children?**
 - A. NSS may be present in a typically developing child and diminish with growth and development.
 - B. Neuromotor NSS, such as retained primitive reflexes, could be caused by the social environment.
 - C. No typically developing child would be expected to still show NSS.
 - D. Reappearance of NSS in adulthood is not a cause for concern.
- 3. New brain imaging technology has increased our understanding of what aspects of NSS?**
 - A. What changes will occur in NSS as the child grows older
 - B. How to evaluate for NSS in occupational therapy clinical situations
 - C. Which NSS are the best indicators of sensory processing disorders (SPDs)
 - D. Their relationship to specific areas of the brain
- 4. Which of the following is *not* a common area of study by researchers investigating the role of NSS?**
 - A. Attention, behavior, and social-emotional functions
 - B. Sensory functions
 - C. Motor functions
 - D. NSS as the cause of learning disorders
- 5. Which of the following is *not* an example of NSS?**
 - A. Sensory-perceptual difficulties
 - B. Poor behavioral regulation
 - C. Seizures
 - D. Motor sequencing
- 6. In a sample of children with attention deficit hyperactivity disorder, Patankar's study found that children with the impulsivity and hyperactivity sub-type had higher frequency of:**
 - A. Specific learning disabilities
 - B. Mirror movements/overflow and dysrhythmia
 - C. Anger and oppositional behavior
 - D. Persistence of the asymmetrical tonic neck reflex and symmetrical tonic neck reflex
- 7. A young child presents with neurodevelopmental soft signs that appear to be worsening. He is being seen in an outpatient private practice setting. This situation requires that an occupational therapist:**
 - A. Increases the frequency of intervention and prepares a home program
 - B. Waits—neurodevelopmental soft signs will decrease with the growth of the child
 - C. Completes a standardized motor coordination assessment
 - D. Initiates a referral to his primary care physician or neurologist
- 8. In recent studies of microstructural integrity of white matter in brain pathways, children with autism spectrum disorder (ASD) and SPD have been found to differ from children with SPD-only in what way?**
 - A. Both groups had aberrations in white matter integrity of the posterior cerebral tracts, but children with autism had additional involvement of the brain pathways subserving social-emotional function.
 - B. Children with SPD-only had thinner myelin on the cerebellar tracts subserving eye movements, while ASD/SPD participants did not.
 - C. Children with ASD-only (without SPD) had normal white matter microstructure compared with the two other groups.
 - D. Children with ASD and SPD had larger amount and density of gray matter in the cerebellum.

9. **Based on the results of an assessment of clinical observations (CO) and NSS, it is critical that occupational therapists provide a report detailing:**
- How they affect cognitive skills and memory
 - How CO and NSS relate to daily function and participation
 - The regions of the brain that have been affected
 - All of the above
10. **With regard to the NSS findings of residual, or “retained” primitive postural reflexes, such as the ATNR or STNR, occupational therapists should be aware that:**
- They may be causing additional damage or dysfunction to the nervous system by trying to integrate primitive reflexes.
 - There are no CPT® codes for this type of treatment.
 - The association between the frequent occurrences of these reflexes in children with learning disabilities does not necessarily imply that intervention aimed at reducing the reflexes will also improve learning and skills such as reading.
 - Addressing sensory-perceptual and motor skills in the child will be more helpful for learning and reading skills.
11. **A 7-year-old child who is having difficulty participating in family meals because she becomes fatigued and uncomfortable, wanting to stand rather than sit, and lying on one arm while eating, may benefit from occupational therapy intervention that addresses:**
- Postural alignment while seated only; sensory strategies probably will not help.
 - The need for enhanced vestibular (gravitational) and proprioception sensory input to support postural tone, as well as environmental modifications to improve seating support and postural alignment at the dinner table.
 - Sensory integration procedures to address possible food and texture aversions and wearing a weighted vest while at the dinner table.
 - Evaluating the child for a retained ATNR, which may be causing her to lie on one arm.
12. **Which of the following statements is most correct concerning the meaning and importance of making observations of NSS reflecting protective, righting, and equilibrium responses?**
- They provide an assessment of the postural system’s robustness and anticipatory readiness-to- respond, as well as make adaptive responses of trunk and extremities to changes in the center of gravity.
 - They provide a direct assessment of vestibular, cerebellar, and oculo-motor function during equilibrium changes.
 - They give a more accurate picture of the motor system’s readiness to respond, as well as of somatosensory- and visually-based praxis.
 - They are helpful in discriminating between attention deficit hyperactivity disorders, ASDs, and SPDs.

Now that you have selected your answers, you are only one step away from earning your CE credit.



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