Section 1:

INTRODUCTION TO THE *QNST-3R*

The *QNST-3R* is an individually administered, standardized assessment of motor planning and control, and integration of sensory information, for individuals age 5 through geriatric. Specifically, the *QNST-3R* is designed to assess neurological soft signs (NSS), which are "minor, non-localizable, and objective abnormalities that are considered to reflect disturbances in connections between subcortical and cortical regions or between cortical regions" (Chan et al., 2009, p. 1). Soft signs reflect both developmental and neurological processes, and ongoing NSS are related to problems with learning, neurocognitive performance, and general daily functioning (Fellick, Thomson, Sills, & Hart, 2001; Martins et al., 2008).

This is the latest adaptation of the *QNST*, first published in 1974. The *QNST* was originally developed to detect the persistence of neurological soft signs into early school-age years, as it was noted that such motor and sensory deficits were predictors of learning difficulties. When such signs can be observed early in young children, appropriate remediation can be started, increasing the chance that learning difficulties can be mitigated or avoided altogether.

The *QNST-3* (Mutti, Martin, Spalding, & Sterling, 2012) extended the assessment age range through adulthood. A growing body of evidence suggests that soft signs may be an early indicator of risk for schizophrenia and other psychotic disorders, and for Alzheimer's disease and other neurodegenerative diseases in adults. The *QNST-3R* includes updated functional category scores, based on a nationally representative sample; revisions and clarifications of the Record Form, administration procedures, and scoring guidelines; and an updated review of the literature on NSS. The *QNST-3R* provides an easy and reliable way to quantify, over time, the presence and extent of NSS that may be of clinical importance.

Description of the *QNST-3R*

The *QNST-3R* consists of a series of 11 administered tasks, and two additional items that score particular elements (left-right skills and behavior) of the administered tasks. The *QNST-3R* items have been adapted from traditional neurological exams and developmental scales. They are the same tasks as used in the previous edition (*QNST-3*), although administration directions and scoring have been clarified, one item has been shifted to a warm-up activity with qualitative observations only, and one item has been eliminated. The *QNST-3R* can be completed and scored in approximately 30 minutes.

The *QNST-3R* provides opportunities to document and interpret a number of processes in an organized and systematic way, including:

- Motor maturity and development
- Tactile and kinesthetic processing
- Gross and fine motor control
- Motor planning and sequencing
- Sense of rate and rhythm
- Spatial organization
- Visual and auditory perception
- Balance and vestibular function
- Inhibition of associated movements
- Attentional control

QNST-3R Task Descriptions

The tasks used in the *QNST-3R* will look familiar to many clinicians, as the tasks are often encountered in routine doctor's office exams or in bedside observations. The scoring of each is described in the next section. The tasks are:

- *Task 1: Figure Recognition and Production*—the examinee is asked to identify five geometric shapes and then copy the shapes onto the page.
- *Task 2: Palm Form Recognition*—the examinee is asked to close his or her eyes and identify numbers that the examiner traces onto the examinee's palm (using a blunt stick or finger).
- *Task 3: Eye Tracking*—the examinee is asked to follow (with eyes only) the motion of a pencil as it moves horizontally and vertically.
- *Task 4: Sound Patterns* (used only if the examinee has no hearing loss)—the examinee is asked to imitate, by tapping or clapping, the sound patterns made by the examiner.
- *Task 5: Finger to Nose*—the examinee is asked to use a finger to touch his or her nose, then the examiner's palm, in a repeating sequence.

- *Task 6: Thumb and Finger Circle*—the examinee is asked to make a series of circles, successively, by touching a thumb to fingers in sequence.
- *Task 7: Rapidly Reversing Repetitive Hand Movements*—the examinee is asked to replicate a series of forearm rotations that start slowly, then accelerate.
- *Task 8: Arm and Leg Extension*—the examinee extends arms, legs, and tongue while seated.
- *Task 9: Tandem Walk*—the examinee walks along a straight line, forward and backward, first in both directions with eyes open, then forward with eyes closed.
- *Task 10: Stand on One Leg*—the examinee balances first on one leg, then the other, with eyes open, then with eyes closed.
- *Task 11: Skipping*—the examinee skips across the room.
- *Task 12: Left-Right Discrimination*—the examiner rates evidence of left-right discrimination challenges on Tasks 5, 6, and 10.
- *Task 13: Behavioral Irregularities*—the examiner rates evidence of behavioral irregularities in Tasks 1 to 11.

Purpose and Use

The *QNST-3R* quantifies the degree of difficulty a person may have with sensory processing, and motor planning and control. It is intended to be used only as a screening instrument, by education and health professionals such as psychologists, rehabilitation specialists, occupational therapists, and special educators.

As with any assessment tool, the *QNST-3R* alone cannot be used to make any type of diagnosis. NSS are nonspecific symptoms that may indicate risk for or presence of a variety of conditions. Diagnoses should always be made after a confluence of information has been gathered and analyzed. Significant discrepancies among *QNST-3R* task scores can direct the examiner to recommend a sensitive and specific diagnostic strategy, and appropriate remediation can then be pursued. The *QNST-3R* may also be used to track changes in function over time or in response to medication, and it can also be used in research studies.

Background

The following sections will provide an overview of NSS in normal development, and then will discuss the presence of NSS in developmental, learning, and behavioral conditions; schizophrenia; and Alzheimer's disease and other age-related cognitive impairments.

Soft Signs in Normal Development

Throughout early childhood, the brain structures governing voluntary motor skills show rapid growth and refinement (Cole, Mostofsky, Gidley Larson, Denckla, & Mahone, 2008). As a child matures through adolescence, motor and sensory systems become more finely tuned and the soft signs that might have been apparent earlier disappear (Fellick et al., 2001; Gasser, Rousson, Caflisch, & Jenni, 2010; Gasser, Rousson, Caflisch, & Largo, 2007). The persistence or reappearance of NSS can indicate atypical neurological development or a neurodegenerative condition (Gidley Larson et al., 2007; Martins et al., 2008).

While younger children demonstrate wide variability in their motor development and movement quality, by age 7 children can generally perform most basic motor tasks smoothly and with appropriate speed (Gidley Larson et al., 2007; Largo et al., 2001). NSS continue to diminish through adolescence, albeit at different rates, depending on the nature or complexity of the task (Gasser et al., 2007). For example, Martins et al. (2008) suggest that motor inhibition skills may develop more slowly than other aspects of motor development. Therefore, it is possible that different types of NSS tasks may be more diagnostically sensitive at different points in development (Gasser et al., 2007). NSS typically disappear by 15 to 18 years of age (Gasser et al., 2010; Martins et al., 2008).

A number of authors note the relationships between NSS and cognitive skills in a variety of clinical populations (as will be discussed below). However, numerous studies also indicate a negative relationship between NSS and cognitive performance throughout the life span in the general population. In other words, individuals without an identifiable learning, neurological, or other diagnosis who receive higher scores on tests of NSS typically demonstrate lower performance on measures of IQ and cognitive function, even controlling for such factors as age and educational background (Chan et al., 2009; Chan et al., 2011; Dazzan et al., 2006; Fellick et al., 2001; Kikkert, de Jong, & Hadders-Algra, 2013; Martins et al., 2008). In fact, Semenov, Bigelow, Yue, du Lac, and Agrawal (2016) found that vestibular function (a component of NSS assessment) partially mediates the relationship between age and cognitive skills in older adults. They suggested that "vestibular loss associated with aging may contribute to the far more common cognitive deficits observed in older individuals" (p. 248). Furthermore, they reported that such vestibular-influenced cognitive decline contributed to an increased risk of falling and poorer performance in activities of daily living (ADL). Monitoring NSS in healthy older adults may allow for early identification of, and intervention for, emerging balance and vestibular difficulties.

Interestingly, Dazzan et al. (2006) also found that adults with NSS, particularly problems with sensory integration such as right-left confusion or difficulties with tactile, visual, or auditory processing, had reductions in gray matter volume in cortical areas associated with attention and sensory processing. Thus, soft signs may provide a window into the structural and functional integrity of the neural pathways that govern sensory processing, and motor planning and execution.

Figures 1.1 and 1.2 provide definitions of NSS and examples of tasks used in assessments.

FIGURE 1.1
Types of NSS Defined

Overflow (also called "associated" or "extraneous") movements are co-occurring movements of body parts not specifically needed to complete a particular motor task; also includes mirror movements (also referred to as synkinesis); these movements may reflect the immaturity of neural systems involved with automatic inhibition.

Involuntary movements may consist of limb tremor, odd posturing, or choreiform movements, which are involuntary random, jerking motions, most often in the extremities; these may interfere with the ability to write.

Dysrhythmia is an abnormality in an otherwise normal pattern of movements; it can be seen as an improper rhythm or timing of the movement; it may indicate cerebellar dysfunction.

Dysmetria is the failure to focus the trajectory of an intentional movement (coordination of extremity limbs) and may indicate cerebellar dysfunction.

Dysdiadochokinesia is an impairment in smooth production of rapid alternating movements; it may indicate cerebellar dysfunction.

Dysgraphesthesia is an inability to recognize (without visual stimulus) letters or numbers traced on the hand by the examiner.

Intention tremor is produced during goal-directed motor movements and involves increased rhythmic oscillation at a right angle to the line of movement as the target is approached; these may indicate cerebellar dysfunction.

Astereognosis is an inability to identify objects by touch (without visual stimulus), even when tactile and other sensory functions are intact.

Impaired fine-motor coordination is often seen as overly large (or small) imitations of motor movements, or irregularly copied shapes or letters, or "awkward" or "clumsy" movements; these may indicate cerebellar dysfunction.

Adapted from Gidley-Larson et al., 2007; Jansiewicz et al., 2006; Sattler & Hoge, 2006.

FIGURE 1.2
Some Types of NSS Tasks Included in Various Assessments

Gait	Includes heel walking, toe walking, walking on the sides of the feet, and tandem gait.
Balance	Standing and hopping on one foot.
Repetitive timed movements	Hand patting, finger tapping, and foot tapping.
Patterned timed movements	Hand pronation–supination, finger apposition (tapping the thumb to each of four other fingers on each hand in a fixed sequence), and heel-toe tapping.

Soft Signs in Learning Disabilities, Autism, and ADHD

NSS are common in a variety of neurodevelopmental and learning problems, including learning disabilities, autism, and ADHD (Van Hoorn, Maathuis, Peters, & Hadders-Algra, 2010; Zhang, 2007). While NSS are not diagnostically specific, their presence may indicate the need for a full psychoeducational evaluation of children who have early learning or behavioral challenges or who are at risk for them due to genetic predisposition or other biological factors such as prematurity or low birth weight (Ferrin & Vance, 2012; Kroes et al., 2002; Viholainen et al., 2006). Additionally, screening for NSS as part of the diagnostic/evaluation process may identify children who would benefit from further assessment of sensory and motor skills.

Children with a diagnosed learning disability are significantly more likely than their peers to demonstrate NSS, particularly difficulties with postural control and fine motor coordination (Breslau, Chilcoat, Johnson, Andreski, & Lucia, 2000; Punt, de Jong, de Groot, & Hadders-Algra, 2010; Viholainen et al., 2006; Westendorp, Hartman, Houwen, Smith, & Visscher, 2011). Furthermore, children with learning disabilities continue to show delays in motor skills throughout the elementary school years (Westendorp et al., 2014). While the exact nature of the relationship between motor development and academic performance is not entirely clear, Westendorp et al. (2011) argue that motor skills facilitate cognitive development and learning, and therefore it is important to pay attention to motor skills when children are identified with cognitive or academic challenges.

Multiple recent studies document the presence of NSS, sensory processing deficits, and motor dysfunction in individuals with autism spectrum disorder (Abu-Dahab, Holm, Rogers, Skidmore, & Minshew, 2013; Biscaldi et al., 2015; de Jong, Punt, de Groot, Minderaa, & Hadders-Algra, 2011; Mayoral et al, 2010; Tani et al., 2006). In fact, motor coordination difficulties are so common in individuals with ASD that Fournier, Hass, Naik, Lodha, and Cauraugh (2010) suggest that they should be considered a "cardinal feature" of autism (p. 1227). NSS and motor incoordination in children with ASD are correlated with poorer socialization skills and higher levels of social withdrawal (Freitag, Kleser, Schneider, & von

Gontard, 2007; Summer, Leonard, & Hill, 2016). Dowell, Mahone, and Mostofsky (2009) suggest that "impairments in motor functioning are key players in a large constellation of associated features of ASD" (p.569), highlighting the importance of assessing these skills.

Numerous studies have demonstrated that children with ADHD are at increased risk for persistent NSS, motor skill deficits, and developmental coordination disorder. Children with ADHD are more likely to demonstrate motor overflow, poor motor timing, difficulties with right-left coordination, and balance problems, even after controlling for factors such as age and IQ (Biscaldi et al., 2015; Cole et al., 2008; Ferrin & Vance, 2012; Patankar, Sangle, Shah, Dave, & Kamath, 2012; Udal et al., 2009). It may be particularly important to evaluate for the presence of NSS in children diagnosed with ADHD because some researchers have suggested that children with both ADHD and high levels of NSS or motor dysfunction also show higher levels of behavioral, cognitive, and social difficulties than individuals with ADHD and no NSS (Ferrin & Vance, 2012; Gustafsson et al., 2010).

Soft Signs in Schizophrenia

Over the last two decades, researchers have compiled a substantial body of evidence documenting the presence of NSS in individuals who have been diagnosed with schizophrenia. Individuals with schizophrenia frequently present with motor coordination difficulties, poorer tactile processing, and associated and involuntary movements. There is a positive correlation between the presence of NSS and severity of psychiatric symptoms, particularly negative symptoms, such as motor slowing and apathy (Bachmann, Degen, Geider, & Schröder, 2014; Behere, 2013; Chan, Geng et al., 2015; Mayoral et al., 2012; Zhao et al., 2013). NSS tend to decrease as clinical symptoms improve, but even after symptom reduction or remission, individuals with schizophrenia continue to present with more NSS than would be expected for their age (Bachmann et al., 2014). Furthermore, individuals with schizophrenia and higher levels of NSS also have more attentional and memory difficulties and overall worse functional outcomes (Behere, 2013; Chan, Dai et al., 2015).

Individuals who are at high risk for developing schizophrenia (including individuals with early symptoms or with a strong family history) also show higher levels of NSS (Bachmann et al., 2014; Barkus, Stirling, Hopkins, & Lewis, 2006; Kaczorowski, Barrantes-Vidal, & Kwapil, 2009; Mittal et al., 2014). Children and adolescents with more NSS are at increased risk of developing schizophrenia, even controlling for family history (Mittal et al., 2014; Schiffman et al., 2009). Given the strong relationship between NSS and schizophrenia symptoms, and the fact that NSS do not appear to be affected by antipsychotic medication, numerous authors recommend using NSS assessments like the *QNST-3R* to screen individuals who are at risk, and to monitor disease progression (Bachmann et al., 2014; Behere, 2013; Chan, Geng et al., 2015; Mittal et al, 2014).

Soft Signs in Alzheimer's Disease

Although "Alzheimer's disease (AD) is the most commonly acquired neurodegenerative disease in elderly people" (Li et al., 2012, p. 1), it can be difficult to diagnose in the primary stages, as early symptoms may be indistinguishable from normal age-related cognitive changes (Pettersson, Olsson, & Wahlund, 2005). However, there is growing interest in the relationship between NSS and the development of cognitive impairment and dementia, and in the emerging evidence that NSS may be predictive of Alzheimer's disease.

Individuals who have been diagnosed with AD have higher levels of NSS than individuals with mild cognitive impairment (considered an intermediate stage between normal age-based cognitive decline and AD), and NSS are correlated with both cognitive and behavioral symptoms (such as apathy) of AD (Seidl, Thomann, & Schröder, 2009; Urbanowitsch, Degen, Toro, & Schröder, 2015). NSS increase as AD progresses but do not appear to be a side effect of medication, and individuals with AD and NSS are at higher risk for falls and subsequent injury and functional limitations (Seidl et al., 2009).

Similar to what was discussed in the previous section on schizophrenia, individuals who are at risk for AD (due to genetic susceptibility or the presence of mild cognitive impairment) have more motor-based NSS, and the presence of NSS is correlated with lower scores on cognitive assessments (Lautenschlager et al., 2005; Li et al, 2012). Additionally, in individuals with mild cognitive impairment, the severity of motor dysfunction is predictive of the risk of developing AD (Aggarwal, Wilson, Beck, Bienias, & Bennett, 2006). Li et al. (2012) argue that assessment of NSS may "capture the similar information measured by conventional neurocognitive tests" (p. 2). Because NSS assessments like the *QNST-3R* are easy to administer, and NSS are highly correlated with the cognitive symptoms of AD, a number of authors recommend their use to support early identification of AD and for ongoing monitoring of symptoms (Lautenschlager et al., 2005; Li et al., 2012; Seidl et al., 2009; Urbanowitsch et al., 2015).

Conclusion

Neurological soft signs are observed in a variety of developmental, psychiatric, and neurodegenerative conditions, and the presence of NSS has been linked with increased risk of cognitive, motor, social, and functional challenges. NSS can be easily observed and may provide a window into the functional integrity of neural structures that underlie and are necessary for many human behaviors. Including a measure of NSS as part of a comprehensive assessment battery is increasingly recommended for conditions such as ADHD, schizophrenia, and Alzheimer's disease, and the *QNST-3R* can provide a reliable, valid, low-cost, and noninvasive way to detect and monitor neurological dysfunction.