Section 1:
Introduction to the *TAPS-4*

The *TAPS-4* is an individually administered assessment for individuals aged 5 through 21. It is designed to provide information about language processing and comprehension skills across three intersecting areas: phonological processing, auditory memory, and listening comprehension. These areas are critical to the development of higher order language skills, including reading skills. The *TAPS-4* is intended to be used by speech-language pathologists, psychologists, educational and learning specialists, and other professionals who need a reliable and valid measure of auditory language abilities in children, adolescents, and young adults. This section discusses the difference between language and auditory processing; reviews how the *TAPS-4* subtests are categorized within Cattell-Horn-Carroll theory; and then provides an overview of the structure of the *TAPS-4* and descriptions of the subtests.

Language Processing, Auditory Processing, and the *TAPS-4*

The *TAPS-4* provides critical information about higher order language skills that underpin the development of effective listening and communication abilities. While earlier versions of the *TAPS* were described as measuring auditory perceptual or auditory processing skills, auditory processing is now generally conceptualized in the speech-language pathology and audiology literature as a narrow set of skills specifically related to central nervous system (CNS) processing of the acoustic signal[1] (American Speech-Language-Hearing Association [ASHA], 2014; de Wit et al., 2016). Katz and Tillery (2004) described it as "what the CNS

[1] As will be discussed later in this section, the term *auditory processing* is used in a related but slightly broader way within Cattell-Horn-Carroll theory. Therefore, it is critically important that multi-disciplinary teams are clear on how they are using this terminology when communicating with each other and with service recipients and their families.

does to make what we hear most valuable and efficient" (p. 191). Specifically, auditory processing includes skills such as "sound localization and lateralization, auditory discrimination, auditory pattern recognition, temporal aspects of audition, and auditory decrements with competing/degraded acoustic signals" (Medwetsky, 2011, p. 287). Auditory processing is just one component in the broader set of skills described as oral language processing. Language processing also includes, and is influenced by, a variety of cognitive and linguistic skills, such as phonological awareness, auditory attention, auditory memory, and conceptual knowledge (Kamhi, 2014; Medwetsky, 2011). Given this evolution in thinking, it is more accurate to view the *TAPS-4* as a measure of language processing skills than as a measure of auditory processing skills.

Despite substantial research and discussion, there is no consensus on the specific diagnostic criteria for auditory processing disorder (APD). However, there is general agreement that it is important to rule out higher level cognitive and language deficits as a first step in APD testing, particularly because issues with language processing can impact the way the auditory signal is received and processed (DeBonis, 2015; de Wit et al., 2016; Kamhi, 2011; Medwetsky, 2011; Nittrouer, 2002; Wallach, 2011). Therefore, multiple researchers and clinicians stress that it is important to assess the set of skills included in the *TAPS-4* for any individual who presents with listening and communication challenges (DeBonis, 2015; Kamhi, 2011; Medwetsky, 2011; Wallach, 2011).

Cattell-Horn-Carroll Theory and the *TAPS-4*

Cattell-Horn-Carroll (CHC) theory is a well-supported taxonomy and explanatory model of cognitive abilities (Flanagan, Ortiz, & Alfonso, 2013; Keith & Reynolds, 2010; Schneider & McGrew, 2012). While CHC theory is not specifically a theory or model of language processing, it does include language and memory skills as aspects of a broader understanding of cognitive abilities. CHC theory is increasingly being used to understand ability and organize assessment in numerous psychological fields, and it may provide language and a framework that can be shared across professions to discuss and understand the skills assessed by the *TAPS-4*.

CHC theory includes three distinct types of general cognitive abilities: domain-free abilities (often called *fluid intelligence*), domain-specific abilities, and acquired knowledge (often called *crystallized intelligence*). *Domain-free abilities* are not associated with individual sensory systems or specific cortical areas and include abilities such as fluid reasoning, general processing speed, and memory. *Domain-specific abilities* are connected to specific sensory systems, such as the auditory and tactile systems, and "encompass perception, but also refer to higher-order and goal-directed processing of sensory information" (Schneider & McGrew, 2012, p. 128). Finally, *acquired knowledge* involves "the acquisition of useful knowledge and understanding of important domains of human functioning" (Schneider & McGrew, 2012, p. 122). The abilities in this last cognitive area tend to be culturally bound, rely heavily on language skills, and reflect knowledge stored in long-term memory.

The *TAPS-4* primarily assesses five narrow abilities within three CHC broad ability areas: Short-Term Memory (domain-free), Auditory Processing (domain-specific), and Comprehension-Knowledge (acquired knowledge). Each of these broad ability areas will be discussed below. While they will be presented as discrete skill areas, it is important to note that standardized assessments tend not to be "pure" measures of ability, and there is frequent overlap across or influence from multiple ability areas (Flanagan et al., 2013; Schneider & McGrew, 2012). This will be discussed further below, in Structure of the *TAPS-4*, and in Section 4: Interpretation.

Short-Term Memory

Short-Term Memory is a domain-free CHC broad ability that involves "the ability to encode, maintain, and manipulate information in one's immediate awareness" (Schneider & McGrew, 2012, p. 114). Short-Term Memory includes two CHC narrow abilities: Memory Span, which involves an individual's capacity to retain information for immediate access; and Working Memory Capacity, which involves the ability to maintain attention efficiently to manipulate the stored information (Flanagan et al., 2013; Schneider & McGrew, 2012).

The *TAPS-4* measures both narrow abilities in Short-Term Memory. The *TAPS-4* Auditory Memory Index subtests (Number Memory Forward, Word Memory, and Sentence Memory) are measures of Memory Span. The supplemental subtest, Number Memory Reversed, is a measure of Working Memory Capacity. It is important to note that while the easier items on the three Auditory Memory Index subtests are more direct measures of Memory Span, more complex items require increased levels of attentional control and therefore overlap with Working Memory Capacity (Schneider & McGrew, 2012).

Auditory Processing

Auditory Processing is a domain-specific CHC broad ability that involves "the ability to detect and process meaningful nonverbal information in sound" (Schneider & McGrew, 2012, p. 131). Auditory Processing includes eight narrow abilities that measure aspects of oral language processing and non-language-based auditory skills, such as Memory for Sound Patterns, Maintaining and Judging Rhythm, and Absolute Pitch. The range of skills in the CHC Auditory Processing category reflects some overlap and some areas of difference with the audiology/speech-language pathology definition of auditory processing described above.

The *TAPS-4* measures two narrow abilities in Auditory Processing: Phonetic Coding and Resistance to Auditory Stimulus Distortion. The *TAPS-4* Phonological Processing Index subtests (Word Discrimination, Phonological Deletion, and Phonological Blending) and supplemental subtest (Syllabic Blending) are measures of the CHC narrow ability of Phonetic Coding. Phonetic Coding is an important component of oral language comprehension, and Schneider and McGrew (2012) argue that it is the only narrow ability in Auditory Processing specifically related to oral language comprehension.[2] The other narrow ability measured by the *TAPS-4* is Resistance to Auditory Stimulus Distortion. This ability is assessed by the *TAPS-4* supplemental subtest Auditory Figure-Ground. When communicating with other professionals, clients, and families, it is important to clarify that while the *TAPS-4* does measure two aspects of Auditory Processing (as defined within CHC theory), it is not a comprehensive assessment of auditory processing skills.

Comprehension-Knowledge

Comprehension-Knowledge is a CHC broad acquired knowledge ability with six narrow abilities focusing on aspects of receptive and expressive oral language knowledge and skills, including lexical and morphological awareness and ability to use speech to communicate. The *TAPS-4* Listening Comprehension Index subtests (Processing Oral Directions and Auditory Comprehension) are measures of the CHC Comprehension-Knowledge narrow ability of Listening Ability. Listening Ability is defined as "the ability to understand speech. This ability is typically contrasted with reading comprehension" (Schneider & McGrew, 2012, p. 123).

Structure of the *TAPS-4*

The *TAPS-4* measures three areas of language processing skills: Phonological Processing, Auditory Memory, and Listening Comprehension. The organization of the subtests into Indices and supplemental subtests is consistent with current theories of language processing and CHC theory as described above and is supported by factor analysis (see Section 8: Validity). This section will review the three sets of skills and their importance to language and literacy development and will describe each of the subtests.

The *TAPS-4* is designed to be used flexibly. Examiners may administer single subtests as part of a larger test battery, one or two Indices, or the entire assessment. The areas assessed by the *TAPS-4* may be useful in identifying the underlying factors contributing to reading and writing difficulties. For example, multiple authors have argued that there are distinct profiles of reading difficulty (such as poor decoders, poor comprehenders, and individuals with global difficulties) that are related to clear patterns of underlying skill difficulties with phonological processing, language comprehension, or both (Adlof, Klusek, Shinkareva, Robinson, & Roberts, 2015; Berninger, 2008; Berninger & Abbott, 2010; Hogan, Adlof, & Alonzo, 2014; McIntyre, Solari, Gonzales et al., 2017; McIntyre, Solari, Grimm et al., 2017;

[2] Taking this point further, many of the audiology/speech-language pathology understandings of auditory processing as discussed above consider phonological processing a higher level cognitive-language skill, not an auditory processing skill. Therefore, while clinicians using CHC theory (for example, school psychologists) may categorize these skills as auditory processing, many speech-language pathologists and audiologists do not.

Silliman & Berninger, 2011). Better identification of the unique patterns of strengths and weaknesses for the individual with reading and writing difficulties can lead to more effective and appropriate interventions.

Children with a history of specific language impairment or speech-sound disorder are at higher risk of developing reading difficulties and may continue to demonstrate subtle ongoing language processing and comprehension problems (Catts, Bridges, Little, & Tomblin, 2008; Johnson, Pennington, Lowenstein, & Nittrouer, 2011; Leonard, 2014; Lindgren, Folstein, Tomblin, & Tager-Flusberg, 2009; Nippold, 2017). Berninger (2008, p.108) cautions:

> Our data suggest that whereas some of the oral language problems may resolve… so that children no longer qualify for language and communication services, the oral language problems may not have fully resolved at the metalinguistic level, and their diagnosis may require formal testing. … Pervasive metalinguistic problems in phonological, morphological, and syntactic awareness … interferes with their ability to use decontextualized oral language to understand teachers' instructional language [and] learn written language.

In addition, children with attention-deficit hyperactivity disorder (ADHD) are at risk for some degree of language impairment but may not have been diagnosed with a specific language impairment (Hutchinson, Bavin, Efron, & Sciberras, 2012). The *TAPS-4* can help identify ongoing or previously undiagnosed higher order language difficulties.

Phonological Processing Index

Phonological processing is "the combined process of accessing phonological structure and then using that structure for further language processing" (Nittrouer, 2002, p. 238). It is a meta-linguistic skill that includes both phonological awareness and phonemic awareness (Schuele & Boudreau, 2008). *Phonological awareness* is a set of more basic abilities used to analyze the sound structure of language. *Phonemic awareness* is a more complex skill that allows an individual to "isolate and manipulate individual sounds or phonemes" (p. 6). Competence in phonemic awareness tasks such as segmenting and blending is correlated with word decoding abilities, and these particular phonological processing skills are important to the development of reading and writing.

Phonological processing skills influence many aspects of verbal language processing and are a critical component of literacy development. Phonological processing skills contribute to the organization of words in long-term memory and the ability to store auditory signals in working memory (Medwetsky, 2011; Nittrouer, Shune, & Lowenstein, 2011). Therefore, individuals with poor phonological processing may also show difficulties with auditory memory skills (Hachmann et al., 2014). Knowledge of the phonemic code allows individuals to identify where one word ends and another begins in the auditory stream, and poor phonological processing skills can interfere with speech-in-noise processing (Medwetsky, 2011; Nittrouer, 2002). There is substantial evidence that children with specific language impairment, speech-sound disorders, and some forms of reading disability show poorer phonological processing skills than do their typically developing peers. Weaker phonological processing skills are predictive of concurrent and future reading challenges, particularly problems with word decoding (Adlof et al., 2015; Berninger, 2008; Gillam & Hoffman, 2004; Johnson et al., 2011; McIntyre, Solari, Grimm et al., 2017; Nittrouer et al., 2011; Pennala et al., 2013; Plaza & Cohen, 2007).

The Phonological Processing Index consists of three subtests and one supplemental subtest. All the Phonological Processing subtests are presented on CD to ensure consistent pacing and pronunciation.

- **Subtest 2—Word Discrimination:** The individual hears a word pair and is asked to identify whether the words are the same or different. Word discrimination is a basic phonological awareness skill.
- **Subtest 3—Phonological Deletion:** The individual hears a word and is asked to say the word again without an identified syllable or a phoneme. Phonological deletion is a phonemic awareness skill important for the development of reading and spelling.
- **Subtest 4—Phonological Blending:** The individual hears a series of phonemes and is asked to combine them into a word. Phonological blending is a phonemic awareness skill important for the development of reading and spelling.
- **Subtest 5—Syllabic Blending (supplemental):** The individual hears a series of syllables and is asked to combine them into a nonsense word.

Auditory Memory Index

The ability to encode, store, retrieve, and manipulate words in memory is critical for language development and use (Kamhi, 2014; Schwartz, 2011). Both short-term memory and working memory contribute to the development of reading and writing and support academic success. For example, Montgomery, Magimairaj, and Finney (2010) found that auditory short-term memory skills were an important predictor of new word learning in children under 8 years of age. Auditory short-term memory also may support listening comprehension, particularly when working memory demands are high, such as with a more syntactically complex sentence (Montgomery, Gillam, & Evans, 2016; Nittrouer, 2002; Robertson & Joanisse, 2010). To understand a spoken sentence, an individual must temporarily store words (short-term memory) and then process them (working memory). As will be discussed more in the next section, listening comprehension is a predictor of later reading comprehension skills. Therefore, difficulties with auditory memory can have significant direct and indirect impacts on academic performance and success. "Children with poor working memory find it difficult to hold and manipulate information, a skill that is vital for classroom learning" (Hutchinson et al., 2012, p. 202).

Children with specific language impairment, learning disabilities, autism spectrum disorder, and ADHD are at risk for auditory short-term and working memory impairments (Archibald & Gathercole, 2006; Archibald & Joanisse, 2009; Berninger, 2008; Conti-Ramsden, Ullman, & Lum, 2015; Hachmann et al., 2014; Hutchinson et al., 2012; Leonard, 2014; McIntyre, Solari, Grimm et al., 2017; Montgomery et al., 2016; Robertson & Joanisse, 2010). As noted in the previous section, reduced phonological skills may also impair auditory memory. Therefore, it is important to assess both memory and language skills in children who are demonstrating literacy and language learning difficulties to determine if there are issues with linguistic knowledge and competence, auditory memory, or both (Montgomery et al., 2010).

The Auditory Memory Index consists of three subtests plus one supplemental subtest.

- **Subtest 7—Number Memory Forward:** The individual hears a series of single-digit numbers and is asked to repeat them in the same order. Number Memory Forward taps short-term memory and may also require working memory for the longer sequences.
- **Subtest 9—Word Memory:** The individual hears a series of words and is asked to repeat them in the same order. Word Memory is also primarily a measure of short-term memory, and it may also require working memory for the longer sequences.
- **Subtest 10—Sentence Memory:** The individual hears a sentence and is asked to repeat the sentence exactly as it was said. Sentence Memory also relies strongly on syntactical knowledge.
- **Subtest 8—Number Memory Reversed (supplemental):** The individual hears a series of single-digit numbers and is asked to repeat them in the correct reversed order. Number Memory Reversed is a measure of working memory skills.

Listening Comprehension Index

For the purposes of the *TAPS-4*, listening comprehension is defined as the "ability to understand text read aloud" (Hogan et al., 2014, p. 202). This narrow, specific definition recognizes that there are different types of listening tasks and that the demands of listening in normal conversation are different from the demands of listening to more structured, perhaps decontextualized, grammatically correct sentences. As noted above, listening comprehension predicts reading and writing skills (Berninger & Abbott, 2010; Catts, Adlof, & Weismer, 2006; Silliman & Berninger, 2011). "Linguistic comprehension, or the oral language processing that creates meaning from words, has a profound effect on the comprehension of written text" (McIntyre, Solari, Grimm et al., 2017, p. 1088).

Some children with reading difficulties may demonstrate a profile of normal phonological processing skills but poorer auditory memory and listening comprehension. These children have normal decoding abilities but poor comprehension of what they read (Berninger & Abbott, 2010; Catts et al., 2006; McIntyre, Solari, Gonzales et al., 2017; McIntyre, Solari, Grimm et al., 2017; Silliman & Berninger, 2011). Children with specific language impairment, autism spectrum disorder, and ADHD may be at higher risk for listening comprehension difficulties (Leonard, 2014; McIntyre, Solari, Gonzales et al., 2017; Silliman & Berninger, 2011).

The Listening Comprehension Index consists of two subtests and a supplemental Auditory Figure-Ground subtest. Subtests 1 and 6 are presented on CD and have complementary items with similar sentence difficulty and structure. Therefore, it is possible to compare performance on the two subtests to determine if an individual is having specific difficulties with listening comprehension when there is competing background noise. Speech-in-noise deficits are consistently noted in children with listening difficulties. These deficits may be related to phonological processing difficulties or may reflect other types of auditory processing challenges (DeBonis, 2015; de Wit et al., 2016; Nittrouer, 2002).

- **Subtest 1—Processing Oral Directions:** The individual hears a short scenario that contains a direction and then is asked what the person in the scenario is supposed to do.
- **Subtest 11—Auditory Comprehension:** The individual hears a short passage and is then asked questions about the passage. This subtest contains items that test a variety of "wh" and "how" questions, along with items that include inferential and figurative language.
- **Subtest 6—Auditory Figure-Ground (supplemental):** This subtest has a similar structure to Subtest 1 (Processing Oral Directions), but the scenarios are presented against competing background noise.

Conclusion

Language processing deficits are common in a variety of developmental and learning conditions. Language processing skills influence academic outcomes, and there is increasing recognition of the importance of early identification of language processing challenges. The *TAPS-4* is the latest update of this popular assessment tool. The *TAPS-4* includes new and revised subtests; standard audio administration of some subtests to improve consistency and reliability of administration; and updated and expanded norms that now include individuals with specific language impairment, ADHD, learning disabilities, and hearing impairment.