Section 1:
Introduction to the *TVPS-4*

The *Test of Visual Perceptual Skills (4th ed.)* (*TVPS-4*) is an individually administered assessment of two-dimensional visual-perceptual skills for individuals age 5 through 21. The *TVPS-4* assesses visual-perceptual abilities without requiring a motor response and is designed for both diagnostic and research purposes. The test is intended to be used by occupational therapists, school psychologists, educational specialists, optometrists, and other professionals who need a reliable and valid measure of the various aspects of visual-perceptual ability in children, adolescents, and young adults. This section will provide an overview of current functional-based understandings of visual perception, will discuss how some developmental and learning conditions may affect visual-perceptual skills, and finally will review the structure of the *TVPS-4*.

Overview of Visual Perception

Visual perception (sometimes referred to as visual processing or visual information processing) is a set of skills that "provide(s) the perceiver with information about the objects, events and spatial layout in which he or she must think and act" (Kellman & Arterberry, 2006, p. 14). It is a goal-directed process that involves the ability to attend to and identify important visual features in the environment; integrate the visual information with other sensory systems; and interpret and attach meaning to the information to engage with the environment. Therefore, visual perception develops within a complex system that also involves attentional processes, other sensory systems, prior experiences, motivation, and cognitive factors (Coté, 2015; Scheiman, 2011; Schneck, 2010; Schneider & McGrew, 2012).

There are multiple theoretical perspectives on the development of, and processes associated with, visual perception. This section will focus on functional descriptions primarily from the occupational therapy, developmental optometry, and psychology literature. Specifically, two models of visual perceptual skills will be presented: Scheiman's model for visual information processing (2011), and the Cattell-Horn-Carroll (CHC) theory of cognitive abilities. While CHC theory is not specifically a theory or model of visual perception, it does include visual-processing skills as one aspect of a broader understanding of cognitive abilities, and CHC theory is increasingly being used to understand ability and organize assessment in numerous psychological fields (such as school psychology). Both the Scheiman model and CHC theory provide a clinically and educationally relevant context for understanding the skills assessed by the *TVPS-4*.

Scheiman's Model of Visual Information Processing

Scheiman (2011), a developmental optometrist, suggests a comprehensive three-part model for understanding vision: visual integrity, visual efficiency, and visual information processing. The first two components of this model of vision deal with factors beyond the scope of the *TVPS-4*, such as visual acuity. The final component, visual information processing, specifically addresses visual perception and includes three sets of skills: visual spatial skills, visual motor skills, and visual analysis skills. Visual spatial skills involve the ability to "make judgments about location of objects in visual space in reference to other objects and to the individual's own body" (p. 80). Visual spatial skills include directional knowledge (such as left-right and front-back) of both self and objects in three-dimensional space. Visual motor skills involve the integration of visual information and fine motor coordination, and are often assessed using design-copy tasks.

The *TVPS-4* is an assessment of skills in the third category of Scheiman's model of visual information processing: visual analysis skills. This skill set involves "the ability of the child to be aware of the distinctive features of visual forms, including shape, size, color, and orientation" (Scheiman, 2011, p. 80), along with part-whole and visual imagery abilities. In this model, visual analysis includes four types of component skills:

- Visual Discrimination—the ability to discriminate dominant features of objects.
- Visual Figure Ground—the ability to identify an object or particular features of an image within a complex background.
- Visual Closure—the ability to identify a form or image when only some of the details or part of the image is present.
- Visual Memory and Visualization—"the ability … to recognize and recall visually presented information" (p. 81).

Cattell-Horn-Carroll Theory: Visual Processing

CHC theory is a well-supported taxonomy and explanatory model of cognitive abilities (Flanagan, Ortiz, & Alfonso, 2013: Keith & Reynolds, 2010; Schneider & McGrew, 2012). CHC theory includes two distinct types of broad cognitive abilities: domain-free factors, and domain-specific factors. Domain-free factors are not associated with individual sensory systems or specific cortical areas, and include abilities like fluid reasoning, general processing speed, and memory. Domain specific factors 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).

The domain-specific factor of Visual Processing is defined as "the ability to make use of simulated mental imagery (often in conjunction with currently perceived images) to solve problems" (Scheider & McGrew, 2012, p. 129). This factor includes the visual analysis skills identified in Scheiman's model, but also includes a number of other skills, such as length estimation, and closure speed. Of the 11 total narrow skills in Visual Processing, the *TVPS-4* is believed to measure the following three abilities (Flanagan et al., 2013; Schneider & McGrew, 2012):

- Visualization—"the ability to perceive complex patterns and mentally simulate how they might look when transformed" (Schneider & McGrew, 2012, p. 129). This narrow ability encompasses both Visual Discrimination and Visual Closure skills from the Scheiman model and is considered the central skill within the Visual Processing factor.
- Flexibility of Closure—this is analogous to the Visual Figure Ground skill in the Scheiman model.
- Visual Memory—this skill appears to be a little narrower than the Visual Memory and Visualization ability in the Scheiman model, and specifies that visual stimuli must be complex, individual images that are recalled after a short time. Tasks that don't fit these parameters (such as the *TVPS-4* Sequential Memory subtest), are felt to measure aspects of the broad CHC ability of Memory, not Visual Processing (Flanagan et al., 2013).

Summary

The Scheiman model and CHC theory provide updated, functional conceptualizations of visual-perceptual skills. It is important to note that both models presented above focus on what Schneck (2010) describes as the visual-cognitive component of visual perception, and do not include visual-receptive functions. The visual-receptive component involves the sensory and motor functions of the ocular system, such as fixation, tracking, and accommodation skills (these types of skills are covered by Scheiman's broader model of vision in the visual integrity and visual efficiency components). Visual-receptive functions are clearly important to the understanding of visual-perceptual skills, and should be assessed whenever there are concerns about visual processing.

Visual-Perceptual Skills in Clinical Groups

It is well-documented that certain medical, developmental, and learning conditions place individuals at higher risk for problems with visual-perceptual skills. Individuals who have cerebral palsy, developmental coordination disorder, and learning disabilities, or who were born prematurely are more likely to do more poorly on assessments of visual perception, such as the *TVPS,* than their non-affected peers (Barca, Cappelli, Di Giulio, Staccioli, & Castelli, 2010; Burtner, Ortega, Morris, Scott, & Qualls, 2002; Crawford & Dewey, 2008; Geldof, van Wassenaer, de Kieviet, Kok, & Oosterlaan, 2012; Molloy et al., 2013; Tsai, Wilson, & Wu, 2008). Furthermore, poorer performance on visual-perceptual assessments correlates with difficulty with both activity of daily living (ADL) skills and various academic tasks (Elbasan, Atasavun, & Düger, 2011; Feder et al., 2005; James, Ziviani, Ware, & Boyd, 2015; Molloy, Wilson-Ching, Doyle, Anderson, & Anderson, 2014).

While the definition/classification system for cerebral palsy (CP) continues to evolve, there is general agreement that CP is a permanent motor disorder caused by brain damage or disturbance occurring in the neonatal period, or during or just after birth (Rosenbaum, Paneth, Leviton, Goldstein, & Bax, 2007; Straub & Orbzut, 2009). Multiple authors note that the brain damage that leads to CP may directly interfere with the development of visual-perceptual skills (Barca et al., 2010; Ego et al., 2015; Mitry et al., 2016; Pagliano et al., 2007; Rosenbaum et al., 2007). Additionally, motor control problems in CP may further interfere with visual-perceptual skills due to "activity limitations that restrict learning and perceptual development experiences" (Rosenbaum et al., 2007, p. 10). Results from studies suggest that up to 40 to 60 percent of children with cerebral palsy demonstrate some degree of visual-perceptual impairment (Barca et al., 2010; Mitry et al., 2016; Stiers et al., 2002). Children with CP who have visual-perceptual difficulties (when compared to children with CP and normal visual-perceptual skills) have lower scores on measures of health-related and social/emotional quality of life (Mitry et al., 2016), more difficulty using school materials and completing written work at school (Burtner, Dukeminier, Ben, Qualls, & Scott, 2006), and demonstrate poorer performance on ADL tasks (James et al., 2015).

Developmental coordination disorder (DCD) is a condition involving delay and difficulty learning and executing coordinated motor skills. DCD is diagnosed when a child has coordination and motor control challenges which interfere with activity participation (including self-care, school, play, and vocational participation) and are not due to a known neurological or genetic condition or another factor such as intellectual disability or visual impairment (American Psychiatric Association [APA], 2013). The etiology of DCD is unclear, although preterm birth and prenatal substance exposure may be risk factors (APA, 2013; Vaivre-Douret et al., 2011). A number of studies have documented that some children with DCD also demonstrate visual-perceptual challenges, and the presence of visual-perceptual challenges can further interfere with individuals' already delayed "movement planning, on-line movement correction, and feedback control" (Tsai et al., 2008, p. 650). The combination of motor and perceptual challenges may reflect a subtype of DCD

(Crawford & Dewey, 2008; Gillberg, 2003; Lalanne, Falissard, Golse & Vaivre-Douret, 2012; Piek & Dyck, 2004; Tsai et al., 2008; Vaivre-Douret et al., 2011). The motor-perceptual DCD subtype may also co-occur frequently with attentional and learning challenges, suggesting that children with this particular set of problems are at high risk for poorer academic, social, and occupational outcomes (Alloway, 2007; Crawford & Dewey, 2008; Gillberg, 2003).

There is mounting evidence that children who were born prematurely, even those considered at low-risk for negative developmental outcomes, have a higher likelihood of specific visual-perceptual and visual memory deficits, despite otherwise normal cognitive and motor development (Caravale, Mirante, Vagnoni, & Vicari, 2012; Davis, Burns, Wilkerson, & Steichen, 2005; Geldof et al., 2012; McAnulty et al., 2010; Molloy et al., 2013; Molloy et al., 2014). Children who were born prematurely are at risk for neurological insults such as intraventricular hemorrhage and periventricular leukomalacia, which can lead to cerebral palsy and related visual-perceptual problems as discussed above. However, even in the absence of such concrete neurological damage, children born prematurely often demonstrate white matter abnormalities and neurophysiological changes. Visual and spatial abilities may be particularly susceptible to these types of neurological differences (McAnulty et al., 2010; Ortibus, De Cock & Lagae, 2011). Visual-perceptual deficits are "milder and more subtle disabilities, which are typically not identified" (Davis et al., 2005, p. 364). However, without early identification and remediation, visual-perceptual deficits persist into adulthood and may be a significant contributor to poorer long-term educational outcomes for children born prematurely (Davis et al., 2005; Feder et al., 2005; Geldof et al., 2012).

Visual-perceptual deficits may also play a critical role in learning disabilities. There is increasing evidence that individuals with reading or math learning disabilities have significantly lower scores than their peers on measures of visual-perceptual skills, visual-spatial attention, and visual memory (Facoetti et al., 2009; Kulp, Edwards, & Mitchell, 2002; Menghini et al., 2010; Murphy, Mazzocco, Hanich, & Early, 2007; Pieters, Desoete, Roeyers, Vanderswalmen, & Waelvelde, 2012; van Garderen, 2006). Furthermore, preschool children who are at familial risk for learning disabilities do more poorly on visual-perceptual tasks, and visual-perceptual skills in preschool and kindergarten are predictive of later math and reading abilities, even after controlling for other contributing factors such as IQ and language skills (Bull, Espy, & Wiebe, 2008; Facoetti, Corradi, Ruffino, Gori, & Zozi, 2010; Franceschini, Gori, Ruffino, Pedrolli, & Facoetti, 2012; Krajewski & Schneider, 2009).

The exact contribution of visual-perceptual skills to reading and math development is not entirely clear. However, researchers have begun to propose that poor visual-perceptual abilities have a causal role in learning disabilities, and deficits in these skills may interfere with the development of reading and math through a variety of channels. For example, Gabrieli and Norton (2012) suggest that "visual-spatial mechanisms support the growth of visual coding of print (orthography)" (p. R299), a more direct route of influence. On the other hand, Vidyasagar and

Pammer (2009) propose that dyslexia (which is generally conceptualized as caused by phonological deficits) may be caused by an even deeper primary problem in visual processing. “It is possible that the development of phonological awareness itself might be at least partially dependent upon a normal input from the visual system” (Vidyasagar & Pammer, 2009, p. 59). Regardless of the mechanism, Silver et al. (2008) suggest that IQ and achievement testing alone is inadequate when assessing individuals with suspected learning disabilities, and that measures of specific sensory-based and cognitive functions (such as visual-perceptual skills) must also be included in LD testing batteries.

Structure of the *TVPS-4*

The *TVPS-4* utilizes the 112 black and white designs from the *TVPS-3*, plus an additional 14 new images. The new images were added to expand the range of easier items and improve the discriminative ability of the test for younger or more impaired individuals. The *TVPS-4* includes seven subtests as follows:

- **Visual Discrimination:** the individual is asked to find the one image, in a field of five similar images, that exactly matches the presented target image.
- **Visual Memory:** the individual is presented with a target image for five seconds, is asked to remember it and then find the image, in a field of four images, on the following page.
- **Spatial Relationships:** the individual is asked to find the one image, in a field of five images, that is different from the rest.
- **Form Constancy:** the individual is asked to find the one image, in a field of four or five images, that matches the presented target image. The matching image may be larger, smaller, rotated, and/or embedded within a larger design.
- **Sequential Memory:** the individual is presented with an image of a sequence of elements for five seconds, is asked to remember it and then find the image with the same sequence, in a field of four images, on the following page.
- **Visual Figure-Ground:** the individual is asked to find a target image that is embedded in one of a field of four complex designs.
- **Visual Closure:** the individual is asked to match an incomplete target image to the correctly completed image in a field of four.

Each of the seven subtests starts with two unscored example items which are followed by 18 test items arranged in order of difficulty. The *TVPS-4* retains the familiar multiple-choice format of the previous versions.

Conclusion

Visual-perceptual deficits are common in a variety of developmental, neurological, and learning conditions. Visual-perceptual skills influence functional and academic outcomes, and there is increasing recognition of the importance of early identification of visual-perceptual challenges. The *TVPS-4* is the latest update of one of the most consistently used assessments in pediatric occupational therapy practice (Alotaibi, Reed, & Nadar, 2009; Bagatell, Hartmann, & Meriano, 2013; Mulligan, White, & Arthanat, 2014). The *TVPS-4* includes additional items to improve sensitivity at younger ages, age-based start points to reduce testing burden, and updated and expanded norms, while maintaining an easy multiple-choice format and the flexibility to administer the entire assessment or individual subtests as needed.