Chapter 1
Overview
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Purpose

The Verbal Motor Production Assessment for Children – Revised (VMPAC-R) is designed to aid in the systematic assessment of the neuromotor integrity of the speech motor system in children ages 3 through 12 who have speech production disorders. Speech-language Pathologists (S-LPs) can use the VMPAC-R for determining whether or not a speech motor issue underlies a child's speech sound disorder. If a child does have a speech motor issue, clinicians can use the VMPAC-R results to identify the level or levels of disruption to the speech motor control system and to identify modalities (auditory, visual, tactile) that may help the child learn normalized speech motor control. The VMPAC-R also assists clinicians in developing effective intervention protocols and documenting changes in the child's speech motor abilities over time or as a function of intervention.

The VMPAC-R is not a test of articulation or language. It is a step-by-step assessment of the neuromotor integrity of the speech production system at rest and when engaged in vegetative and volitional non-speech and speech tasks. The speech tasks consist of linguistically meaningful and non-meaningful vocal productions.

The VMPAC-R is based on the Motor Speech Hierarchy (MSH; Hayden & Square, 1994; Hayden et al., 2020; Namasivayam, Coleman, et al., 2020). The MSH describes the interactive, synergistic nature and development of the motor speech subsystems (e.g., mandibular, labial-facial, lingual). These motor speech subsystems must be evaluated within the larger context of communication environment and child development, as described in the PROMPTS for Restructuring Oral Muscular Phonetic Targets (PROMPT) Conceptual Framework. The Conceptual Framework of PROMPT (Figure 1.0; Hayden et al., 2020) illustrates the relationships across the physical-sensory, cognitive-linguistic, and social-emotional domains as well as across the environment (including interpersonal) in the development of speech, language and communication. Within the Dynamical Systems Theory (DST; Kelso, 1995; Van Lieshout, 2004) framework development is viewed as emerging from the interactions between these domains. For a complete assessment of a child, the relationships between the domains and subcomponents of the speech motor system must be evaluated.
Role of VMPAC-R in Comprehensive Assessments

The VMPAC-R was developed to complement a total assessment battery for children with speech sound disorders. It is important that the VMPAC-R be considered as only one component of a total assessment battery and never used in isolation. The results of the VMPAC-R must be evaluated by clinicians within the context of information from the following areas:

- Cognition
- Phonology
- Articulation
- Expressive language
- Receptive language
When to Use the VMPAC-R

It is appropriate to administer the VMPAC-R to any child identified with or suspected of having one or more of the following diagnoses:

- Articulation disorder
- Phonological disorder
- Developmental dysarthria
- Developmental delays with concurrent speech sound disorders
- Neurodevelopmental disorders with concurrent speech sound disorders
- Childhood apraxia of speech
- Children with speech sound delay
- Children with speech motor delay
- Autism spectrum disorder with concurrent speech sound disorders
- Receptive/expressive language delay or disorder
- Oral/facial genetic disorders with concurrent speech sound disorders
- Congenital oral/facial structural disorders concurrent speech sound disorders

The VMPAC-R and Childhood Apraxia of Speech (CAS)

The etiology of CAS or developmental verbal dyspraxia (term used in the United Kingdom) is unknown. CAS is currently considered to be a neurological sensorimotor based speech sound disorder (SSD) subtype with a disruption of neurophysiological processes at the level of speech motor planning and/or motor programming of speech movement sequences (American Speech–Language–Hearing Association (ASHA), 2007; Nijland et al., 2003).

According to ASHA (2007) there are three core features of CAS: 

“(a) inconsistent errors on consonants and vowels in repeated productions of syllables or words, (b) lengthened and disrupted co-articulatory transitions between sounds and syllables, and (c) inappropriate prosody, especially in the realization of lexical or phrasal stress”. Children with CAS may also present with comorbid dysarthria, language impairments and deficits in complex sensorimotor and sequential memory functioning which may adversely impact their speech production (Ekelman & Aram, 1984; Iuzzini-Seigel et al., 2017; Nijland et al., 2015).
The administration of the VMPAC-R will support clinicians in assessing disruptions in volitional oromotor movements and sequencing. Within VMPAC-R, children with CAS may be characterized by the inability to consistently produce accurate sequencing of speech movements (for use of cut-off scores see Preston et al., 2013), over time, in varying planes of movement (e.g., vertical-horizontal, anterior-posterior). The VMPAC-R helps clinicians organize information from all areas that affect a child's communication. This information assists clinicians when a diagnosis of CAS is being considered.

The VMPAC-R and the Developmental Dysarthrias

Dysarthria is defined as a group of neurogenic speech disorders characterized by "abnormalities in the strength, speed, range, steadiness, tone, or accuracy of movements required for breathing, phonatory, resonatory, articulatory, or prosodic aspects of speech production" (Duffy, 2013, p. 4).

Developmental or Childhood dysarthrias (CD) may be caused by neonatal stroke, traumatic brain injury and cerebral palsy and relate to a group of motor speech disorders that affect neuromotor execution of speech. Neuromotor issues include disruptions to one or more of the following dimensions: Strength, tone, accuracy of movements, range of movement, variability of movement, speed, and the symmetry of the muscles that innervate each side of the face and the oral tract. These neuromotor disruptions can affect all speech subsystems: Respiration, phonation, articulation, resonance, and prosody (Darley et al., 1975; Duffy, 2013; Morgan & Liégeois, 2010; van Mourik et al., 1997). Clinicians can use the VMPAC-R to systematically observe these neuromotor issues in both non-speech and speech movements when evaluating a diagnosis of Developmental dysarthria.

The VMPAC-R and Speech Motor Delay

Speech motor delay (SMD) is a recent clinical entity proposed to classify children with a delay in the development of speech motor control (Shriberg & Wren, 2019). Speech errors in SMD are not due to involuntary movements, deficits in muscle tone/reflexes or errors in higher level linguistic–symbolic/phonological planning. Shriberg and colleagues suggest that the underlying pathophysiology for SMD population is at the level of neuromotor execution, specifically a delay or limitation in the development and maturation of speech motor skills required for precision and stability of speech output (Shriberg, Campbell, et al., 2019). The assessment
findings of these children are consistent with age-inappropriate precision and stability behaviours in speech, prosody and voice domains that do not meet criteria for CAS or CD (Shriberg et al., 2010; Shriberg 2017; Shriberg & Wern, 2019; Shriberg, Kwiatkowski, et al., 2019; Shriberg, Campbell, et al., 2019). Clinicians can use the VMPAC-R to systematically observe delays in the neuromotor control for speech when evaluating a diagnosis of SMD. See Namasivayam, Huynh, et al., (2020) for a recent treatment study with a group of children with SMD. Speech motor skill assessment of the SMD population can be found in Namasivayam et al. (2021).

**Content and Scope of the VMPAC-R**

The VMPAC-R was developed to include parameters of neuromotor integrity typically tested when screening for motor speech disorders (e.g., dysarthria and apraxia of speech). The test items are systematically organized into three main areas and two supplemental areas. The main areas are *Global Motor Control*, *Focal Oromotor Control*, and *Sequencing*; the supplemental areas are *Connected Speech and Language Control* and *Speech Characteristics*.

**Area 1. Global Motor Control**

The Global Motor Control area addresses neuromotor innervation to those peripheral muscles in the torso, neck, head, and oro-facial region required for the efficient production of speech.

The twenty items in this area are in two sections of the test and are arranged in several categories:

- **General Motor Control** (13 items: item #1 to 13)
  - Tone
  - Respiration/Phonation
  - Reflexes
  - Vegetative Functions
- **Oromotor Integrity** (7 items: item #26 to 32)

**General Motor Control**

The first section of the test includes items that enable the clinician to assess postural, respiratory, and phonatory support, as well as the cerebral inhibition of oral reflexes and the development of coordinated vegetative functions.
**Tone**

Four items (item #1 to 4) assist the clinician in evaluating head, neck, and trunk tone and posture as they relate to the neurological system's ability to sustain the driving forces of speech. Head and neck alignment with the trunk is assessed at rest, during movements, and during phonation. Postural control and tone are observed during ambulation.

**Respiration/Phonation**

Three items (item #5 to 7) enable the clinician to assess the motor substrates necessary to support the driving forces of speech: vegetative breathing, speech breathing, and phonatory control. Respiratory muscles are observed for coordination of diaphragmatic and thoracic breathing and for their ability to sustain phonation. One item specifically addresses phonatory control.

**Reflexes**

Four items (item #8 to 11) are used to test the following oromotor reflexes: The rooting reflex, Babkin's reflex, the mouth-opening reflex, and the bite reflex. The presence of any of these reflexes indicates abnormal oromotor function for children in the 3- to 12-year age range assessed with the VMPAC-R.

**Vegetative Functions**

Two items (item #12 and 13) assist the clinician in assessing the adequacy of the vegetative oromotor functions of chewing and swallowing.

**Oromotor Integrity**

The seven items (item #26 to 32) in this section enable the clinician to assess the muscular symmetry of each side of the face, the strength, tone, range, and smoothness of movement of the oral structures, and the presence of abnormal oral-facial movement such as tremor or involuntary contraction.

**Area 2. Focal Oromotor Control**
The Focal Oromotor Control area consists of 46 items that the clinician uses to assess the age appropriateness of a child's volitional oromotor control for three individual speech subsystems: Mandibular (jaw), labial-facial (lips and face), and lingual (tongue) control—both in isolation and in combination with each other. The items in this area include non-speech oromotor movements and speech oromotor movements. The items are located throughout several sections of the test and are grouped as follows:

Non-Speech Oromotor Movements (17 items)

- Single Oromotor Movements
  - Mandibular Control
  - Labial-Facial Control
  - Lingual Control
- Double Oromotor Movements

Speech Oromotor Movements (29 items)

- Single Oromotor-Phoneme Movements
- Multiple Oromotor-Phoneme Movements
  - Double Oromotor-Phoneme Movements
  - Triple Oromotor-Phoneme Movements
- Oromotor Production in Word Sequences and Sentences

Non-Speech Oromotor Movements

Non-speech oromotor movement items are traditionally included on tests for oro-bucco-facial apraxia. The difference between these items on traditional assessments of oro-bucco-facial apraxia and those on the VMPAC-R is the scoring methodology. When scoring the VMPAC-R items, the examiner must carefully attend to the precision, smoothness, and symmetry of the movements, and to the appropriateness of the range and grading (control) of the movements. These items are divided into single and double oromotor movements.

Single Oromotor Movements

The twelve items (item #14 to 25) in this section of the test enable the clinician to assess the subsystems of mandibular, labial-facial, and lingual control individually by having the child produce one oromotor posture at a time.

Double Oromotor Movements
In this section, five items (item #33 to 37) are used to assess the subsystems of mandibular, labial-facial, and lingual control in combination with each other by having the child produce two oromotor postures in succession.

Administration of the items in both the Single and Double Oromotor Movements sections begins by assessing the child's ability to produce each posture in response to an auditory command. If a precise production is not achieved after one attempt, the stimulus is presented visually. If a precise production is not achieved after the visual attempt, the stimulus is given via auditory, visual and tactile modalities. The tactile cues signal the place of muscle contraction, duration of the contraction for each posture, and the muscle tension required to produce each posture. Stimulation that combines all three modalities provides a means of discerning whether a tactile approach to treatment may be beneficial to the child (See the "Administration and Scoring" chapter for specific examples.)

**Speech Oromotor Movements**

These items are designed to assist the clinician in assessing a child's ability to maintain motor control in speech-like utterances, words, phrases, and sentences. While some children are able to produce movements that are precise as isolated items (e.g., jaw control while opening the mouth), movements may degrade in the context of an utterance (i.e., multiple movement strings). In other words, a child may be able to open his or her jaw precisely, smoothly, and with finely graded movements in a non-verbal task and also for the production of single vowel sounds (single trajectory or plane of movement). However, in the context of connected speech, the child may experience difficulty with the trajectory of the movement, especially when jaw movements must be coordinated with lip and tongue movements, respiration, voicing, and velopharyngeal closure (multiple planes of movement).

**Important:** Because assessment of oromotor control is based on the precision of movement of the oral articulators and not on the acoustic outcome, examiners must closely observe the speech articulators throughout the requisite movements.

**Single Oromotor-Phoneme Movements**

In this section (item #38 to 42; #50 to 55), the clinician assesses focal oromotor control of the jaw, face and lips, and tongue during the child's production of 11 isolated phonemes (4 vowels and 7 consonants). The child is asked to produce each phoneme four consecutive times, returning to a resting posture between productions. Each set of four responses is assessed for consistency and accuracy of motor control.
Multiple Oromotor-Phoneme Movements

In this section of the test, the child is asked to produce double and triple oromotor-phoneme movements. As with non-speech items, production of these non-meaningful speech items is assessed under the following three modalities of stimulation: The auditory model, the auditory plus visual model, and the combination of auditory and visual models with tactile stimulation. Again, the tactile input consists of cues that are similar to the muscle contractions required. In this way, the child is successively offered increasing support throughout the assessment, enabling the clinician to determine the effects of sensory input on their speech motor production.

Double Oromotor-Phoneme Movements
Six items (item #43 to 45; #56 to 58) assist the clinician in assessing precision of articulator movements and airstream management during production of different double oromotor-phoneme movement sequences.

Triple Oromotor-Phoneme Movements
Six items (item #46 to 49; #59 and 60) enable the clinician to assess precision of jaw, lip, and tongue movements, and airstream management during production of different triple oromotor-phoneme movement sequences.

Oromotor Production in Word Sequences and Sentences

The six items (item #61 to 66) in this section consist of three- and four-word sequences and five-word sentences. These items are constructed so the clinician can observe the precision of speech motor control in meaningful words in a sequence and in simple sentences. Focal movements of the jaw, lips, and tongue are evaluated for precision, range, symmetry of movement, and general control. Note: Production of the word and sentence sequences is supported with picture stimuli in the appropriate sections.

Area 3. Sequencing

The third area of the VMPAC-R is designed to aid in the assessment of a child's ability to produce non-speech and speech movements in the correct sequential order (i.e., sequence maintenance), following a model produced by the clinician. (Note: The 23 items in this area were introduced in Area 2, Focal Oromotor Control, where the focus is on speech motor control.) In the Sequencing area (Area 3) the focus shifts to sequence maintenance. As before, the items in this area consist of both non-speech and speech oromotor movement sequences, and are grouped as follows:
Non-Speech Oromotor Movement Sequences (5 Items)

- Double Oromotor Movement Sequences

Speech Oromotor Movement Sequences (18 Items)

- Multiple Oromotor-Phoneme Movement Sequences
  - Double Oromotor-Phoneme Movement Sequences
  - Triple Oromotor-Phoneme Movement Sequences
- Oromotor Production in Word Sequences and Sentences

Non-Speech Oromotor Movement Sequences

Double Oromotor Movement Sequences

As noted in the Focal Oromotor Control area, the five non-speech movement sequences in this section are used to assess the subsystems of mandibular, labial-facial, and lingual control in combination with each other. The task is the same (i.e., the child is asked to produce two oromotor postures in succession), but for the Sequencing area, the clinician must determine if the correct order or sequence of movements is produced.

Speech Oromotor Movement Sequences

Multiple Oromotor-Phoneme Movement Sequences

The speech sequences are the same double and triple oromotor-phoneme movements discussed in the Focal Oromotor Control area. To determine the child's ability to maintain the sequence over time, the child is asked to repeat the speech sequences four consecutive times.

Double Oromotor-Phoneme Movement Sequences

Six items assist the clinician in assessing the child's ability to maintain a double oromotor-phoneme sequence across four repetitions.

Triple Oromotor-Phoneme Movement Sequences

Six items assist the clinician in assessing the child's ability to maintain a triple oromotor-phoneme sequence across four repetitions.
Oromotor Production in Word Sequences and Sentences

As mentioned in the Focal Oromotor Control area, the six items in this section consist of three-and four-word sequences and five-word sentences. In the Sequencing area, these items are designed to assist the clinician in evaluating the child's ability to sequence oromotor movements across different movement planes within a linguistic context.

Area 4. Connected Speech and Language Control

This supplemental area of the VMPAC-R is used to assess the child's speech motor control as it varies with the complexity of language formulation. That is, the items in this area are used by clinicians to evaluate the child's ability to control speech motor precision in the context of language that requires higher-level formulation. Items in this area (corresponding to the Oromotor Production in Connected Speech and Language section of the test) require the child to formulate a story that corresponds to four sequenced pictures. The precision and coordination of jaw, lip, and tongue movements and their interactions (coarticulation) are closely observed during this expressive language task.

Area 5. Speech Characteristics

The second supplemental area of the VMPAC-R is used to evaluate the child's overall speech characteristics. Clinicians observe the child's speech with regard to pitch, resonance, vocal quality, loudness, prosody, intonation, and rate throughout the administration of the VMPAC-R. An additional item requires the clinician to focus attention on the child's speech production in an automatic speech task. The clinician is asked to judge if the child's speech precision is better for automatic speech or for self-formulated speech. These items are located in the final two sections of the test, the Oromotor Production in Automatic Verbal Sequences section and the Overall Speech Characteristics section.

The supplemental areas are not meant to replace any other test of speech and language function. As stated previously, the VMPAC-R should be given as part of a total assessment battery. In the speech area, an articulation test, a phonological test, and a structural examination (i.e., oral peripheral) also need to be undertaken. With regard to language assessment, a standardized, norm referenced test of receptive and expressive language and a standardized language sampling protocol is recommended.
The Motor Speech Hierarchy

The three main areas of the VMPAC-R (Global Motor Control, Focal Oromotor Control, and Sequencing) relate directly to the Motor Speech Hierarchy (MSH) proposed by Deborah Hayden (1986). The hierarchy was developed as a way to approach assessment of the speech motor system and to plan intervention. The arrows indicate the hierarchical, yet interactive, nature of the different areas of the model. Currently, both observational and empirical data from several speech motor studies support the synergistic and hierarchical development of the speech motor system (Cheng et al., 2007; Green et al., 2000, 2002; Green & Nip, 2010; Grigos et al., 2005; Hayden et al., 2020; for a data-driven timeline of speech motor development see Namasivayam et al., 2020).

Important: The Global Motor Control area of the VMPAC-R relates to Stages I and II of the MSH; the Focal Oromotor Control area of the VMPAC-R relates to Stages III, IV and V; and the Sequencing area of the VMPAC-R relates to Stage VI.

Stages I and II of the hierarchy are tone of the trunk and phonatory control. These are the first functions assessed with the VMPAC-R because they provide the infrastructure for speech respiration and phonation. Test items in the Global Motor Control area of the VMPAC-R relate directly to these physiological foundations of speech.

Stages III, IV, and V of the hierarchy relate to focal oromotor control of the jaw, lips/face, and tongue, respectively. In this model adequate control of the jaw is considered essential to the emergence of lip and tongue movements sufficient for speech and/or for the development of normalized jaw, lip, and tongue movement coordination. The items in the Focal Oromotor Control area of the VMPAC-R follow the hierarchy: Assessment of the jaw (Stage III); assessment of the lips (Stage IV); and assessment of the tongue (Stage V).

Stage III of the model, mandibular control, is addressed by the first items in the Focal Oromotor Control area of the VMPAC-R. These items are designed to enable the clinician to assess precision and control of jaw movement in various non-speech and speech motor contexts.

Stage IV of the hierarchy is labial-facial control. The next group of items in the Focal Oromotor Control area of the VMPAC-R relate to this stage and enable the clinician to systematically assess the function of the labial-facial muscles, especially the rounding, retraction, and labial closure movements frequently used in speech.

Stage V, lingual control, is assessed by the last group of items in the Focal Oromotor Control area of the VMPAC-R. These items enable the clinician to systematically assess lingual actions in the anterior and posterior plane and the inferior and superior plane.
Stage VI of the Motor Speech Hierarchy represents the ability to sequence movements in more complex contexts over time, while maintaining precision and accuracy of coordinated movements. At this level of the hierarchy, it is assumed that the physiological support for speech (Stages I and II) and focal oromotor control of individual articulatory sub-systems (Stages III, IV, and V) are solidly established so that accurate sequencing of movements in more complex contexts can occur. Items in the Sequencing area of the VMPAC-R relate to this stage.

The final stage of the hierarchy, Stage VII, relates to the highest level of prosodic control that begins to develop during pre-speech vocal play and is coordinated with jaw movement in infancy. Because it is the final stage of speech refinement in treatment, prosody appears at Stage VII in the hierarchy. Although the VMPAC-R is not designed for the systematic, in-depth assessment of prosody, an overall impression can be recorded in the two supplemental areas.
Figure 1.1 Motor Speech Hierarchy (MSH©). The MSH reflects the hierarchical, non-linear, and interactive development of speech motor control. Figure used with permission from The PROMPT Institute, Santa Fe, NM, USA. (Hayden et al., 2020)

Components
The VMPAC revised edition (VMPAC-R 2020) is a web application and requires a subscription based log-in. VMPAC-R features on-line training videos, instructions and fully automated scoring. Following the completion of online VMPAC-R administration a report is generated with percent scores for each area (Focal Oro-motor Control, Sequencing, etc.), severity ratings, intervention progress (when administered pre- and post-intervention) and a measure of intervention effectiveness (relative to published literature- update coming soon).

Note: The VMPAC-R does not require any Record Forms. The web application includes administration, training video clips, stimulus pictures and scoring directions for all items. Additionally, the VMPAC-R web application also includes several sections designed to assist the clinician in gathering information about the child, interpreting the results of the assessment, and making treatment decisions.

Examiner’s Manual

The Examiner's Manual contains detailed information about the administration, scoring, and interpretation of the test, as well as information about its development, standardization research, and technical qualities. Case studies are included to help the clinician interpret results and make efficacious treatment decisions.

Training Video Clips

Training Video Clips are included for each item so the clinician can familiarize themselves with the test administration. In addition, all of the tactile stimuli or cues that are necessary for the clinician to use if a child does not respond to the auditory or visual stimuli in certain items are demonstrated. Important: Part of the standardized procedure of the VMPAC-R administration includes viewing the Training Video Clips before testing any child.

Stimulus Pictures

Administration Time

The average administration time of the VMPAC-R is between 30-45 minutes, although this will vary with the age and ability level of the child being tested. The test may also be administered over 2 sessions (within one week), if required.

Scores Reported

Each VMPAC-R item contributes to one or two of five area scores. These area scores are also expressed as percentages that can be plotted on an age-based profile for comparison. The profile is automatically generated and plotted in the Results tab.

References:


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