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Evidence-Based Clinical Recommendations for the Administration of the Sequential Motion Rates Task

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Abstract

The sequential motion rates (SMR) task, that involves rapid and accurate repetitions of a syllable sequence, /pataka/, is a commonly used evaluation tool for oro-motor abilities. Although the SMR is a well-known tool, some aspects of its administration protocol are unspecified. We address the following factors and their role in the SMR protocol: (a) selecting the appropriate stimulus for the client—nonword, real word or both, (b) the necessity of a practice round, (c) using visual feedback, (d) using language-specific performance rate norms, and (e) the implications for using different measurements (time-based, rate-based). We also provide rate norms for Hebrew-speaking clients and a pair of simple equations for transforming data from time-based units (seconds) to rate-based units (syllables/s). These recommendations can be considered in the clinical assessment process and may be integrated into the speech-language pathologists' practice, allowing for a more accurate and cost-effective evaluation procedure.

Keywords

oral-diadochokinesis, sequential motion rates, nonword versus real word, practice, visual feedback

The oral-diadochokinesis (oral-DDK) tasks represent some of the most commonly used tools to assess the efficiency of speech motor control in speech-language pathology (SLP) clinics (Duffy, 2012). The tasks refer to maximally rapid syllable repetition (Konstantopoulos, Charalambous, & Verhoeven, 2011; Tjaden & Watling, 2003) and are considered as a highly sensitive measure of motor speech impairments (e.g., dysarthria) as they require maximum articulatory performance (Kent, Kent, & Rosenbek, 1987; Staiger, Schölderle, Brendel, Bötzel, & Ziegler, 2016). Of the various subgroups of the oral-DDK tasks, the sequential motion rates (SMRs) are of specific importance, as they are taken as a useful yet simple-to-administer tool (Bernthal, Bankson, & Flipsen, 2008). The SMR task requires the client to rapidly and accurately repeat a syllable sequence (such as /pataka/). Performance is typically indexed by the rate of syllable repetition. SMRs can gauge the severity and presence of neurological impairments, with slower rates associated with disorders of the central nervous system or peripheral sensory motor functions (Baken & Orlikoff, 2000; Wang, Kent, Duffy, & Thomas, 2009).

Although SMRs are popular and simple tasks, some aspects of their administration protocol are unclear or unspecified. For example, should the administration protocol include a real word repetition as well as the standard nonword repetition? How many practice rounds should be given to a client prior to actual recording? Should visual feedback (using a mirror) be provided? Finally, can English norms be used to evaluate speakers of other languages, or should we adopt language-specific norms? This report aims to answer the above stated questions and provide a guideline for the administration of SMR tasks. We present a critical evaluation of the collective body of published data, along with findings from studies conducted in our labs during the last 4 years. Based on these sources, we present clinical recommendations that can be useful for SLPs in the evaluation process.

Clinical Recommendations for SMR Administration

Matching the Stimuli to the Client: Nonwords, Real Words, or a Dual Protocol With both

The SMR task typically involves repetitions of nonwords (e.g., the tri-syllabic sequence /pataka/). Such nonmeaningful stimuli are often preferred, as the main goal of DDK tasks is

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Table 1. Suggested Real Words in Different Languages That Can Be Used for SMR Testing.

Language (country)	Suggested real words (and their translation to English)
Portuguese (Brazil)	/peteca/, shuttlecock
Greek (Greece)	/pontíki/, mouse
Farsi / Persian (Iran)	/motækΛ/, pillow
Hebrew (Israel)	/bodeket/, examine
English (USA)	/ˈpæt̬ˈkeɪk/, patty cake; /ˈbΛt̬.kΛp/, buttercup

to estimate neuromotor rather than linguistic skills (Tiffany, 1980). Indeed, even though speech phonemes are used, the task is considered a nonverbal oral task (Duffy, 2012). The nonword repetition assesses the ability to access a new (or less familiar) motor program in the absence of linguistic cues (Tiffany, 1980).

However, several researchers suggest that repeating real words can be more suitable for some populations, mainly preschool children (Canning & Rose, 1974; Netsell, 2001; Robbins & Klee, 1987; Zamani, Rezai, & Garmatani, 2016) and older adults (Ben-David & Icht, 2017). Specifically, real words may be more engaging than nonsense, meaningless, syllable strings and thus better reflect oral-motor behaviors and general abilities (for a review, see Heinrich et al., 2016).

As stressed by Williams and Stackhouse (2000), "real and nonword stimuli may not be interchangeable . . . repetition of real and non-words and syllable sequences are clearly differentiated" (p. 269). Evidence collected in the literature generally shows that real word repetition is faster and more accurate than nonword repetition (Zamani et al., 2016). Real word repetition assesses a client's ability to access a stored motor program through linguistic cues, rather than forming a novel motor program in a nonword repetition. Most of SMR studies that used real word stimuli (e.g., in English, "buttercup", "patty-cake") evaluated preschool children (3–6 years old, Canning & Rose, 1974; Robbins & Klee, 1987; Yaruss & Logan, 2002). Similarly, Zamani et al. (2016) reported an advantage of about 17% for real word repetition over nonwords for Persian-speaking preschool children. Recent research in our labs expands this pattern of performance to other populations. Specifically, real word stimuli yielded a 14.5% faster performance than nonwords with school-aged Hebrew-speaking children (9–11 years old; Icht & Ben-David, 2015), and a 13.5% advantage with Hebrew-speaking older adults (aged 66–95 years; Ben-David & Icht, 2017).

These findings suggest that adding real words to the standard nonword SMR task may provide a more comprehensive, multidimensional picture of oro-motor abilities. With a dual protocol, the standard nonword repetition measures "pure" speech motor abilities, whereas the real word repetition involves the use of prior linguistic knowledge (Williams & Stackhouse, 2000). Similar conclusions were drawn by Staiger et al. (2016), testing large samples of persons with neurologic movement disorders and controls. In their studies, the rates for a speech task (reading) and for an SMR task (with syllable repetition) were shown to measure separate traits, governed by different task-specific mechanisms. Indeed, several studies revealed dissociations between speaking rates and oral-DDK rates in numerous patient groups (e.g., Ziegler & Wessel, 1996). For example, Staiger et al. (2016) concluded that using real words can augment the assessment of people with cranial nerve pathologies, as the temporal production of oral-motor behaviors and of speech can be differentially affected in neuromotor disease (Ziegler & Wessel, 1996).

Considering the usage of real word stimuli, it must be carefully selected to avoid biases that may affect performance. Words should be frequent and familiar (see Ben-David, Van, Lieshout, & Leszcz, 2011; Phaf & Kan, 2007); it is advised to consider a phonological structure (segmental as well as nonsegmental or prosodic features) as similar as possible to the nonword syllable string used (see a discussion in Ben-David, Moral, Namasivayam, Erel, & Van Lieshout, 2016). The semantic content of the real word is also important, and it is recommended to avoid arousing and emotionally valenced words, as they can slow down performance rate (Ben-David, Chajut, & Algom, 2012; Van Lieshout, Ben-David, Lipski, & Namasivayam, 2014). Listed in Table 1 are some suggested real words in different languages (Portuguese, Greek, Farsi/Persian, English, and Hebrew), where performance norms for nonwords are available in the literature, as presented in Table 2.

As noted above, using a real word may be of special relevance when testing young children and older adults. However, in the presence of some language impairments, using real words may be detrimental to the accuracy of assessment of oral-motor abilities. For example, in the presence of conduction aphasia, the access to stored motor programs is reduced, diminishing the ability to rapidly and accurately repeat real words (Buchsbaum et al., 2011).

In sum, it appears that adding the real word to the nonword SMR may yield a more complete depiction of patients' oral abilities and may be relevant in differential diagnosis process. For example, Stackhouse and Snowling (1992) reported a case study of a school-aged child with developmental verbal dyspraxia, who showed specific difficulties repeating nonwords along with an intact ability to produce real words. Bryan and Howard (1992) reported a case study with the opposite profile: a preschool child with a limited phonological system in word production and naming, who was able to repeat a variety of nonwords. Taken together, it is advised to carefully choose the stimuli to match the client tested, and the goals of the assessment process.

A Single Practice Round Is Recommended

How many SMR training rounds should a client perform before actual recording to obtain results that reliably reflect oral-motor abilities? Reviewing the oral-DDK literature finds no recommendations on the amount of time spent practicing the target movements. The data concerning the effect of a brief motor practice on speech skills are relatively sparse. For example, in a review of the literature, Mass et al. (2008) concluded that ". . . no empirical evidence regarding practice amount is available with respect to speech motor learning" (p. 283). However, pertinent literature on nonspeech motor skills suggests that increasing the amount of practice can improve performance (Park & Shea, 2003, 2005). Indeed, practice provides more opportunities to establish relationships among the various types of information associated with each movement. An increased number of practice trials provides more instances of retrieval of the motor programs, which may automatize performance (Maas et al., 2008). However, at a certain level, increased practice may be detrimental for performance. For example, Giuffrida, Shea, and Fairbrother (2002) suggested that a large amount of constant practice (in which the exact same movement is practiced) results in poorer retention and/or transfer than a small amount of practice. Thus, it is important to find the optimal level, whereas additional rounds have only a limited (if any) effect on performance, and may even have a negative effect due to fatigue (Gates & Dingwell, 2008).

To directly identify the number of practice rounds advisable for use in the clinic, a recent study in our labs (Ben-David & Icht, 2017) tested the impact of one versus two SMR practice rounds with younger and older adults. We found that one round of practice could significantly improve performance (faster rates) for both younger (by about 4%) and older adults (by about 5%). However, an additional second practice round did not significantly alter performance, in either group. A similar conclusion was drawn by Konstantopoulos et al. (2011), analyzing data on multiple sclerosis dysarthric patients.

The data above support adopting a protocol that includes a single practice round and a single test round. These findings are of clinical importance, as SLPs are generally advised to adopt cost-effective evaluation protocols (Drummond, Sculpher, Claxton, Stoddart, & Torrance, 2015). Noting that the SMR task is only a minor portion of a full assessment battery (Law, Zeng, Lindsay, & Beecham, 2012), a cost-effective protocol should provide sufficient practice to reflect actual oral-motor abilities, while avoiding time waste and client's fatigue.

Visual (Mirror) Feedback Is Not Recommended

Multiple feedback modalities are commonly used to enhance performance in speech and language therapy. Indeed, in a review of the relevant literature, Ruscello (1995) concluded that combining visual, tactile, or auditory feedback can increase the effectiveness of therapy (see also Bashir, Grahamjones, & Bostwick, 1984; Sigrist, Rauter, Riener, & Wolf, 2013). Of the various feedback modalities, *visual* feedback (especially mirror feedback, VanderWoude, 2013) was noted to improve correct speech production in articulation (Roth & Worthington, 2015) and voice therapy (Boone & Plante, 1993). For instance, Rosenbek, Lemme, Ahern, Harris, and Wertz (1973) recommended using mirror feedback with apraxic patients to achieve greater phonemic accuracy. Similarly, the ASHA Practice Portal (American Speech-Language-Hearing Association [ASHA], 2017) recommends the use of a mirror to increase awareness of target sounds and to provide feedback about placement and movement of the articulators.

A recent study in our labs (Ben-David & Icht, 2017) examined the benefit of the mirror-feedback method in the SMR task for younger (20–40 years old) and older adults (over 65). For younger adults, visual feedback (using a mirror) was detrimental, eliminating the advantage reaped from a single practice round. For older adults, visual feedback did not alter the effect of a practice round, presumably due to age-related sensory degradation (Ben-David & Schneider, 2010). We concluded that adding visual feedback does not improve performance rates for either age group, yet it could counteract the benefits reaped from the practice round.

We can thus assume that there is sufficient somatosensory feedback (proprioceptive, tactile) when performing the oral-DDK task, similar to the sensory information received in everyday speech production (Postma, 2000). Presumably, the visual feedback may add redundant information that strains cognitive resources, hence impairing performance (Ben-David & Algom, 2009; Ben-David, Eidels, & Donkin, 2014). These findings are in accord with the *resource allocation theory* (McNeil, Odell, & Tseng, 1991). Rapid and accurate syllable production may already be demanding, requiring large amounts of attentional resources. When high levels of detailed feedback are provided (such as visual mirror feedback), it may draw from the limited pool of resources needed to successfully complete the SMR task, resulting in a poorer (slower and less accurate) performance.

Using Language-Specific Performance Rate Norms Is Called For

The language spoken may be an important factor in the rate of syllable production. Icht and Ben-David (2014) reviewed studies that provided SMR data for the nonword /pataka/ in four different languages (English, Portuguese, Greek, and Farsi) and found that the rates differ significantly between languages. The review concluded that the SMR rate is sensitive to variations in language (and potentially culture). Possibly, the rates do not only represent a physiological

Table 2. Normative Data Set for the Nonword SMR Task (Syllables/s) for Younger Adults in Different Languages.

Language (country)	*N* (participants)	Age range (years)	SMR rate, syllables/s	
			M	*SD*
Portuguese (Brazil)	98 (81 females)	19–54	6.54	.91
Greek (Greece)	27 (gender not provided)	20–65	6.97	.85
Farsi (Iran)	15 males	15–18	7.12	.52
English (USA)	141 (70 females)	15–43	6.23	.82
Hebrew (Israel)	115 (53 males)	20–45	6.37	.8

Source. Adapted from Icht and Ben-David (2014).

Table 3. SMR Mean Rates (Syllables/s) and Standard Deviations Across the Different Age Groups of Hebrew Speakers.

Group	Age range in years (*M*)	*n*	SMR rate, syllables/s	
			M	*SD*
School-age children Icht and Ben-David (2015)	8.9–11.3 (9.9)	60 (30 males)	4.55	1.16
Younger adult Icht and Ben-David (2014)	20–45 (31.4)	115 (53 males)	6.37	0.8
Older adults Ben-David and Icht (2017)	60–95 (73.7)	88 (40 males)	5.07	1.16

ability but also a language-bound trait. For example, the incidence of phonemes and syllabic structures differs between languages (Maddieson, 2013), which may affect the SMR rates.

Table 2 gives normative data set for the SMR task for different languages. A review of the table reveals interlanguage differences, even in nonword repetition. Possibly, phonotactic patterns and constrains of each language can explain these differences in nonword repetitions. Phonotactic features refer to the lexical constraints of acceptable phonetic combinations in a given language, thus defining permissible syllable structure, consonant clusters, and vowel sequences (Frisch, Large, & Pisoni, 2000). As phonotactic constraints are language specific, they may influence SMR rates. For example, the common SMR stimulus is made of a trisyllabic sequence. The frequency of trisyllabic words varies across languages (e.g., higher in Spanish than in French; Lleó & Demuth, 1999), which may influence SMR rates. Indeed, Vitevitch and Luce (1998) showed that higher probability patterns facilitate repetition of nonwords by adults.

Table 2 clearly shows that using norms set in one language to assess performance in another may bias the correct diagnosis of patients. For example, a performance rate of 6.0 syllables/s is within the boundaries for clinically normal performance for English speakers (with 1 *SD* around the mean, 5.41–7.05 syllables/s). However, the same rate is below the lower boundary for clinically normal performance for Farsi speakers (6.6 syllables/s). These differences emphasize the importance of testing SMR performance in different languages (and even dialects), setting language- and culture-sensitive norms. From a broader perspective, the results stress the need for validating clinical tools across languages, constructing a language-sensitive protocol, rather than "importing" tests or norms.

Performance Rate Norms for Hebrew-Speaking Clients

As presented above, comparing the performance of a non-English speaker to the English-based norm may be inaccurate, as one's spoken language affects SMR rates. Clearly, it is essential to evaluate the task performance in different languages, determining language (or culture)-sensitive norms. The lack of such language-specific normative data set impairs the ability to perform a precise evaluation of speech motor abilities. Table 3 provides such normative data set for Hebrew speakers. Hebrew is a West Semitic language of the Afro-Asiatic language family. It is spoken by the vast majority of Israelis as L1 or L2. The total number of Hebrew users (as L1) worldwide is about five million (Paul, Simons, & Fennig, 2016). SMR rates for Hebrew speakers can be related to performance in other West Semitic languages, for example, Ethiopic, South Arabian (often grouped as South Semitic), and Arabic, which is widely used across the Middle East and northern Africa. Interestingly, Icht and Ben-David (2014) found no significant difference between SMRs for Hebrew- and English-speaking younger adults. But, when testing older adults (Ben-David & Icht, 2017), significant English–Hebrew differences were noted. These data further stress the importance of setting SMR norms for different age groups and different languages.

Carefully Interpret the Different Reported Measures

SMR tasks are gauged by either counting the number of repetitions produced in a specified time frame (e.g., 10 s or 5 s), "count-by-time," or by measuring the time taken for producing a fixed number of repetitions, "time-by-count" (Fletcher, 1972; Kent et al., 1987). Both systems are in wide use in the clinic and in the lab. Thus, transforming data from one system to the other may be necessary for comparison of the obtained rates to available norms. Possible sources for miscalculations must be considered. First, one should note that time-by-count averages are given in time units (seconds) per repetitions of the syllable string (of three syllables), whereas the count-by-time averages are given as the number of *syllables* per time, rather than strings per time. This introduces a factor of 3 in possible miscalculations. Second, the units used in each measure are reversed, time divided by number versus number divided by time. This can mislead the interpretation of standard deviations necessary to evaluate whether a client's performance significantly deviates from published norms.

To assist in understanding and using different published data sets, we present below suggested equations for the transformation of data from one form to the other. To transfer averages from time-by-count (seconds/strings) to a count-by-time (syllables/s) measure, we suggest Equation 1.

$$Estimate\text{-}of\text{-}M_{count\text{-}by\text{-}time} = \frac{N\ of\ repetitions\ tested \times 3\left(syllables\ in\ a\ string\right)}{M_{time\text{-}by\text{-}count}}. \quad (1)$$

For example, Zamani et al. (2016) provide SMR data in a time-by-count scale. Specifically, they report full syllable string production times (in seconds) that represent the time required for 10 repetitions of the trisyllable /pataka/ (a total of 30 syllables), with an average of 7.91 s (for preschool girls, see Table 2). To convert it to a count-by-time scale, Equation 1 can be used: 30 (= 10 repetitions tested × 3 syllables per string) divided by 7.91 s (seconds per 10 strings). This results in an estimate of 3.79 syllables/s (a count-by-time measure).

The transformation of standard deviations is less straightforward. We propose Equation 2, which serves to maintain the same coefficient of variance across measures. Note that a similar method has been adopted for SMR (Icht & Ben-David, 2014) and for the Stroop task (Ben-David, Nguyen, & Van Lieshout, 2011; Ben-David & Schneider, 2009).

$$Estimate\text{-}of\text{-}SD_{count\text{-}by\text{-}time} = \frac{M_{count\text{-}by\text{-}time} \times SD_{time\text{-}by\text{-}count}}{M_{time\text{-}by\text{-}count}}. \quad (2)$$

For example, taking the same data set discussed above (Zamani et al., 2016), the reported standard deviation was 0.87 (seconds/10 strings). To convert it to a count-by-time scale, Equation 2 can be used. The new calculated count-by-time mean (3.79) multiplied by the original coefficient of variance—that is, the original standard deviation (0.87) divided by the original mean (7.91). In other words, 3.79 × 0.109 = 0.416 (syllables/s).

Finally, one should note that these two methods differ in task demands as well. The count-by-time method presents a time constraint that can be stressful, especially for clinical populations (cf. Lindsay & Jacoby, 1994) and impair performance accuracy (for a comparable effect in the emotional Stroop task, see Ben-David et al., 2012). However, this additional stress was found to improve performance for people with speech disorders (e.g., people who stutter; Peters, Hulstijn, & Starkweather, 1989). When choosing which method to use for testing clients, the SLP should take this variable into account as well.

Conclusion

The purpose of this article is to introduce some principles that can assist in the administration of the SMR task, improving its sensitivity. Specifically, the following recommendations may be incorporated into the SMR protocol: (a) carefully choosing the SMR stimuli to match the client: nonwords, real words (some appropriate real words in several languages are suggested), or a dual protocol, with both real words and nonwords, to provide a multidimensional picture of oro-motor abilities; (b) allowing a client a single practice round prior to actual testing; (c) avoiding the use of mirror feedback during the task administration; and (d) comparing the performance rate to language-specific norms. In addition, performance rate normative data for Hebrew-speaking clients (children and younger and older adults) are reported, which may be used by SLPs. Finally, a pair of equations is offered, enabling an easy transformation of data (averages and SDs) from time-based (seconds) scores to rate-based (syllables/s) scores.

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