Obtaining and Interpreting Maximum Performance Tasks from Children: A Tutorial

Obtenir et interpréter des durées maximales d'exécution chez des enfants : un tutoriel

Susan Rvachew, Megan Hodge and Alyssa Ohberg

Abstract

The diagnosis of motor speech disorders in children can be aided by the use and interpretation of measures of maximum performance tasks. These tasks include measuring how long a vowel can be sustained or how fast syllables can be repeated. This tutorial provides a rationale for including these measures in assessment protocols for children with speech sound disorders. Software developed to motivate children to cooperate with these procedures and to expedite recording of sound prolongations and syllable repetitions is described. Procedures for obtaining maximum performance measures from digital sound file recordings are illustrated followed by a discussion of how these measures may aid in clinical diagnosis.

Abrégé

Le diagnostique d'un trouble moteur de la parole chez un enfant peut être facilité par l'utilisation et l'interprétation de tâches de durée maximale d'exécution. Ces tâches comprennent la mesure de la durée vocalique et de la rapidité de répétition des syllabes. Le présent tutoriel explique les raisons pour inclure ces tâches dans les protocoles d'évaluation pour les enfants atteints d'un trouble de parole. Le logiciel élaboré pour motiver ces derniers à collaborer lors de ces procédures et pour accélérer l'enregistrement du prolongement sonore et des répétitions de syllabes y est décrit. Les démarches pour obtenir des durées maximales d'exécution à partir d'un fichier sonore numérique y sont illustrées et sont suivies par une discussion sur la façon dont ces mesures peuvent aider à poser un diagnostic.

Key Words: Speech sound disorders, motor speech disorders, assessment, maximum performance tasks

Children with speech sound disorders form a heterogeneous group from a number of perspectives, including underlying etiological factors, the developmental course of the disorder, and the nature of the overt speech errors that are present at a given point in time (Shriberg, 1997). Most frequently the speech sound disorder is of unknown origin and has no obvious motoric basis, a subtype that will be referred to here as developmental phonological disorder. This subtype has also been referred to as speech sound disorder of unknown origin, non-specific speech delay, functional articulation disorder or functional phonological disorder in the literature cited in the following sections.

Other children's speech sound errors can be linked to motoric factors, with or without a known primary cause. Childhood apraxia of speech (also referred to as speech dyspraxia) is identified by a number of inclusionary characteristics including difficulties with sequencing articulatory movements, phonemes, and syllables; trial and error groping behaviours; and unusual and inconsistent error patterns for both consonants and vowels. Dysarthria may also be observed in children and manifests itself as more consistent error patterns resulting from slow and imprecise movements associated with an abnormal sensorimotor profile that typically includes weakness and tone abnormalities of the affected speech muscle groups.

One purpose of a speech-language assessment is to determine the extent to which motoric factors contribute to a child's difficulties with the acquisition of the sound system of the native language. Knowledge about whether or not the child's speech disorder has a motor component will help the clinician to choose the most appropriate

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treatment approach. Accurate diagnosis may also have ramifications for the child's access to treatment services because both public and private funders often favour the provision of services to children with an identifiable medical impairment.

Measures of maximum performance tasks (MPTs) such as how long a vowel can be sustained (maximum phonation duration; MPD) or how fast syllables can be repeated (maximum repetition rate; MRR) are well-established procedures used by speech-language pathologists when assessing older children and adults (Duffy, 1995; Kent, Kent, & Rosenbeck, 1987). More recently, Thoonen and colleagues (Thoonen, Maassen, Gabreels, & Schreuder, 1999; Thoonen, Maassen, Wit, Gabreels, & Schreuder, 1996) described the application of MPTs to assist clinicians in diagnosing the presence and nature of motor speech impairment in younger children (age 6 to 10 years). Published protocols for identifying and describing oral and speech praxis characteristics of children also include maximum syllable repetition rate measures as part of a battery of nonspeech and speech performance measures (e.g., Hickman, 1997). The classification system developed by Thoonen et al. is particularly appealing because it offers clinicians a systematic framework for integrating and interpreting measures from MPTs to assist in differential diagnosis of childhood speech disorders.

As with all assessment procedures, the ease and reliability with which measures of MPTs can be obtained and their validity and usefulness in differential diagnosis are key determinants to being adopted in clinical practice. This tutorial provides a rationale for including these measures in assessment protocols for young children with speech sound disorders. It summarizes the tasks and classification procedure developed by Thoonen et al. and how the measures obtained are interpreted to ascertain the presence and nature of motor speech impairment. Software that expedites recording of the MPTs recommended by Thoonen et al. is described and procedures for obtaining MPT measures from digital sound file recordings are illustrated for readers who may be unfamiliar with computer-assisted measurement.

Rationale

Accurate identification of speech motor limitations can be difficult, especially in the case of children who do not present with an obvious primary impairment such as cerebral palsy or traumatic brain injury. Campbell (2003) reported that second opinion assessments conducted at the Children's Hospital of Pittsburgh confirmed a prior diagnosis of childhood apraxia of speech (CAS) in only 17 percent of cases, suggesting a significant over-diagnosis of CAS among children with a severe and persistent speech sound disorder. On the other hand, Gibbon (1999) has suggested that a more subtle form of motoric involvement, termed 'undifferentiated lingual gestures', is frequently under-diagnosed among children who present with errors that appear to be phonological on the basis of perceptual analyses (in particular, velar fronting and/or backing and fricative gliding and/or stopping). Certain phonetic errors such as a lateral lisp may also reflect an inability to independently control the lateral margins of the tongue. Under-identification of motor speech limitations may harm individual clients if it prevents them from accessing services to which they are entitled or receiving the most appropriate form of treatment. Over-identification also has far-reaching implications, since threats to the credibility of our profession will have a negative impact on the funding of speech therapy services.

One reason for misdiagnosis may be an over-reliance on diagnostic checklists as a means of identifying motor speech disorders (Shriberg, Campbell, Karlsson, Brown, McSweeny, & Nadler , 2003). These lists have a kind of face validity because they describe the overt characteristics of the child's speech. Unfortunately they lack specificity because they fail to distinguish between fundamental characteristics of a motor speech disorder and the consequences of such a disorder. The linguistic consequences of dysarthria or dyspraxia are not clearly distinguishable from the linguistic consequences of a developmental phonological disorder. Unintelligibility and persistence of the speech problem are not specific to motor speech disorders and systematic error patterns are not specific to development phonological delay. Shriberg, Aram, and Kwiatkowski (1997) demonstrated that CAS could not be differentiated from a developmental phonological disorder on the basis of structural or phonological characteristics of the child's conversational speech (i.e., phonetic repertoire, syllable structure repertoire, percentage of consonants correct, intelligibility index, or phonological processes).

Maximum Performance Tasks

A more promising approach is to administer Maximum Performance Tasks (MPTs) to children. Thoonen, Maassen, Wit, Gabreels, and Schreuder (1996) explained that "although [MPTs] assess abilities that differ from normal speech production..., they provide information on motor speech abilities underlying dysarthria and [CAS] (e.g., articulatory coordination, breath control, speaking rate, speech fluency, articulatory accuracy and temporal variability)" (p. 312). These researchers demonstrated how Maximum Phonation Duration (MPD) and Maximum Repetition Rate (MRR) can be used to differentiate groups of children with spastic dysarthria, CAS, developmental phonological disorder, or normally developing speech. Their criteria for classification were derived from the responses of children aged 6 to 10 years of age, some with normally developing speech and some with clinically diagnosed dyspraxia or dysarthria. Briefly, children with dysarthria were found to produce short phonation durations and slow monosyllabic repetition rates; children with dyspraxia produced slow trisyllabic repetition rates and short fricative durations. Later, these criteria were cross-validated with new samples of school-aged children, this time including a sample of children with a developmental phonological disorder with no motoric component. It was shown that these tasks could be used to identify dysarthria with 89% sensitivity and 100% specificity. In other words, 89% of the children with clinically diagnosed dysarthria were identified as dysarthric on the basis of their responses on the MPTs (sensitivity). Furthermore, none of the children who were not dysarthric by clinical criteria were falsely identified as dysarthric on the basis of their responses to the MPTs (specificity). Dyspraxia was identified from MPT responses with 100% sensitivity and 91% specificity. Overall, diagnostic accuracy was excellent with 95% correct classification of 41 children as presenting with normally developing speech, developmental phonological delay, childhood apraxia of speech, or dysarthria. Of particular interest was the finding that children with a developmental phonological disorder performed these tasks in a qualitatively and quantitatively different manner from children with dysarthria or dyspraxia. Children with dyspraxia were often unable to produce a correct trisyllabic sequence. Children with a developmental phonological disorder were usually able to produce the sequence accurately but only after an unusual number of unsuccessful attempts. Overall their performance on these tasks was intermediate between the control group and the dysarthric and dyspraxic groups.

Kent, Kent, & Rosenbeck (1987) described some of the difficulties inherent to the clinical application and interpretation of MPTs which may explain why these techniques are not routinely applied, especially with young children. A primary issue with interpretation of MPT performance is the availability of good quality normative data. Kent et al. reviewed a number of studies that provided normative data for school-age children and young adults but noted that there was a lack of normative data for younger children and older adults. Subsequently, however, Robbins and Klee (1987) described the MRR and MPD performance of children aged 2;6 through 6;11 (with a sample of 10 children at each 6-month age interval). Williams and Stackhouse (2000) reported additional data regarding repetition performance for 3-, 4-, and 5-year-old children.

Reliability of the measures obtained from the child's performance of each task presents another challenge. Stability of the results across repeated trials can be poor. Individual performance is affected by the task instructions and the motivation of the child. Kent et al. (1987) suggested that standardized instructions and procedures would help reduce variability within and across children. In this report we describe a software tool that presents a standard protocol for clinicians to follow when administering MPTs to young children and recording their productions. Experience with the software indicates that it increases children's motivation to comply with the protocol. To date all of the preschool-aged children that we have tested with this tool have provided a complete set of responses for each of the maximum performance tasks.

Unstable performance levels across trials also leads to questions about the validity of these measures as implemented in a clinical setting. Kent et al. (1987) reported that it can take as many as 15 trials before a stable response is achieved, particularly when attempting to obtain maximum phonation duration. However, Potter, Kent, & Lazarus (2004) reported that in their investigation of typical performance on repetition tasks, the first attempt was most frequently the fastest and most accurate. Over 90% of the children who attempted and could perform the task gave their best performance within the first three trials. This is an encouraging finding because our experience has been that it is impractical to attempt more than three trials with a young child. Although instability across repeated trials is a potential threat to the validity of MPTs, Kent et al. concluded that "nonetheless, the test may still have clinical utility as a screening procedure if it is recognized that the object is to determine if the client can reach some minimal standard" (p. 369). This is the approach taken by Thoonen et al. (1999). They established the threshold values for Maximum Phonation Duration and Maximum Repetition Rates that can be used to diagnose dyspraxia or dysarthria in children aged 6 through 10 years of age.

Finally, some of the variability in results that is observed may result from the difficulty of obtaining an accurate measurement of MPD and MRR when administering the tasks 'live' with the use of a stop-watch. Kent et al. (1987) and Thoonen et al. (1996, 1999) recommended that responses be recorded and measures of the acoustic waveform be used whenever possible to obtain more precise measurements. The software described in this report makes it easy for the clinician to record the child's responses and retrieve them for measurement. Durations and repetition rates can then be accurately measured from these recordings using any available waveform editor. Procedures for measuring MPD and MRR from a waveform display are demonstrated in a later section.

A Protocol for Obtaining MPTs from Children

The protocol for obtaining MPTs described here was developed by Thoonen et al. (1996, 1999). This procedure involves the administration of nine tasks as follows: prolongation of [a] and [mama] to yield a maximum phonation duration (MPD), prolongation of [f], [s], and [z] to yield a maximum fricative duration (MFD), repetition of the single syllables [pa], [ta], and [ka] to yield a maximum repetition rate-monosyllabic (MRRmono), and repetition of the syllable sequence [pataka] to yield a maximum repetition rate-trisyllabic (MRRtri). Two additional outcome measures are derived from the child's performance during the trisyllabic repetitions task, specifically a score indicating whether the child achieved a correct trisyllabic sequence (Seq) and the number of attempts beyond the standard three trials required for the child to achieve a correct sequencing of [pataka] (Attempts). The instructions for administering these items and then combining results across the nine tasks to yield the six outcome measures are shown in Table 1.

Table 1

Instructions for administration of the maximum performance tasks, including Maximum Phonation Duration (MPD), Maximum Fricative Duration (MFD), Maximum Repetition Rate for Single Syllables (MRRmono), and Maximum Repetition Rate for Trisyllabic Sequences (MRRtri), adapted from Thoonen et al. (1996)

Task	Instructions
Maximum Phonation Duration (MPD)	
[a]	1. Produce a prolonged [a] for approximately 2 seconds on one breath in a monotonic manner with normal pitch. Ask the child to imitate your model. Repeat if necessary until the child is successful in imitating your model. 2. As above except model a prolongation of [a] for 4 to 5 seconds and then ask the child to imitate your model. 3. Ask the child to say [a] for as long as possible on one breath (with no model provided in this case). Repeat the instruction two more times, providing the child with a total of three opportunities to prolong [a] for as long as possible.
[mama]	Repeat steps 1, 2, and 3 above except that in this case, model a repetition of the syllables [mama...]. Again at step 3, give the child three opportunities to produce [mama...] for as long as possible on a single breath.
MPD	MPD is the mean of the longest prolongation of [a] and the longest prolongation of [mama...].
Maximum Fricative Duration (MFD)	
[f]	Repeat steps 1,2, and 3 as described for MPD, in this case modelling a prolonged production of [f]. Again at step 3, give the child three opportunities to prolong [f] for as long as possible on a single breath.
[s]	Repeat steps 1,2, and 3 as described above, in this case modelling a prolonged production of [s]. Again at step 3, give the child three opportunities to prolong [s] for as long as possible on a single breath.
[z]	Repeat steps 1,2, and 3 as described above, in this case modelling a prolonged production of [z]. Again at step 3, give the child three opportunities to prolong [z] for as long as possible on a single breath.
MFD	MFD is the mean of the longest prolongation of [f], the longest prolongation of [s] and the longest prolongation of [z].
Maximum Repetition Rate - Monosyllabic (MRRmono)	
[pa]	1. Ask the child to say [pa], and then [papapa], and then [papapapapa]. 2. Model the repetition of approximately 12 [pa] syllables on a single breath at a rate of about four syllables per second and ask the child to imitate your model. 3. Ask the child to repeat step 2 but this time as fast as possible. Stop recording when the child has produced 12 or more syllables. Provide the child with two additional opportunities to maximize the repetition rate.
[ta]	Repeat steps 1,2, and 3 as described above, in this case modelling repetition of the syllable [ta]. Again at step 3, give the child three opportunities to produce [ta] as fast as possible on a single breath.
[ka]	Repeat steps 1,2, and 3 as described above, in this case modelling repetition of the syllable [ka]. Again at step 3, give the child three opportunities to produce [ka] as fast as possible on a single breath.
MRRmono	For each trial the repetition rate is calculated as the number of syllables produced per second. MRRmono is the mean repetition rate for the fastest repetition of [pa], the fastest repetition of [ta], and the fastest repetition of [ka].

Table 1 continued on page 150

Table 1 (continued)

Instructions for administration of the maximum performance tasks, including Maximum Phonation Duration (MPD), Maximum Fricative Duration (MFD), Maximum Repetition Rate for Single Syllables (MRRmono), and Maximum Repetition Rate for Trisyllabic Sequences (MRRtri), adapted from Thoonen et al. (1996)

Task	Instructions
Maximum Repetition Rate - Trisyllabic (MRRtri)	
[pataka]	1. Ask the child to say [pataka] at a slow rate. Practice this syllable sequence, breaking it down into its component parts if necessary, until the child can produce a single correct sequence. 2. Produce the sequence twice [patakapataka] fluently and at a slow rate and ask the child to imitate. 3. Produce the sequence three times at a normal speaking rate and ask the child to imitate. 4. Produce the sequence four times at a rate of about four syllables per second and ask the child to imitate. 5. Model a repetition of the sequence, five times and as fast as possible. Ask the child to produce the sequence as fast as possible for as long as possible on a single breath. Give the child two additional trials to perform this task. If the child cannot produce the sequence accurately, repeat the steps and allow three additional attempts to produce a correct sequence as fast as possible and as long as possible on a single breath.
MRRtri	MRRtri is the number of syllables per second produced during the child's fastest attempt at repeating this sequence. The sequence must be produced correctly over 5 repetitions on a trial for it to be used to calculate the MMRtri.
Sequence	Score 1 if the child produces a correct repetition of the sequence. Score 0 if the child does not suceed in producing a correct sequence.
Attempts	This score is the number of additional attempts (beyond the first three) that are required for the child to achieve a correct repetition of the sequence.

Generic free or inexpensive software programs are available to record sound and display the waveforms of the recordings (e.g., GoldWave, Goldwave, Inc., 2005; PRAAT, Boersma & Weenink, 2005). Software packages are also available that count syllable peaks and perform an automatic count (e.g., Motor Speech Profile, KayPentax). The TOCS+™ MPT Recorder© ver. 1 (Hodge & Daniels, 2004) is freeware that was developed specifically to facilitate administration and measurement of MPTs with children, following the protocol of Thoonen et al. (1996). It turns any personal computer that has an operating system with Windows 98 or later into a digital audio recorder with a sampling rate of 48 kHz and a quantization size of 16 bits.

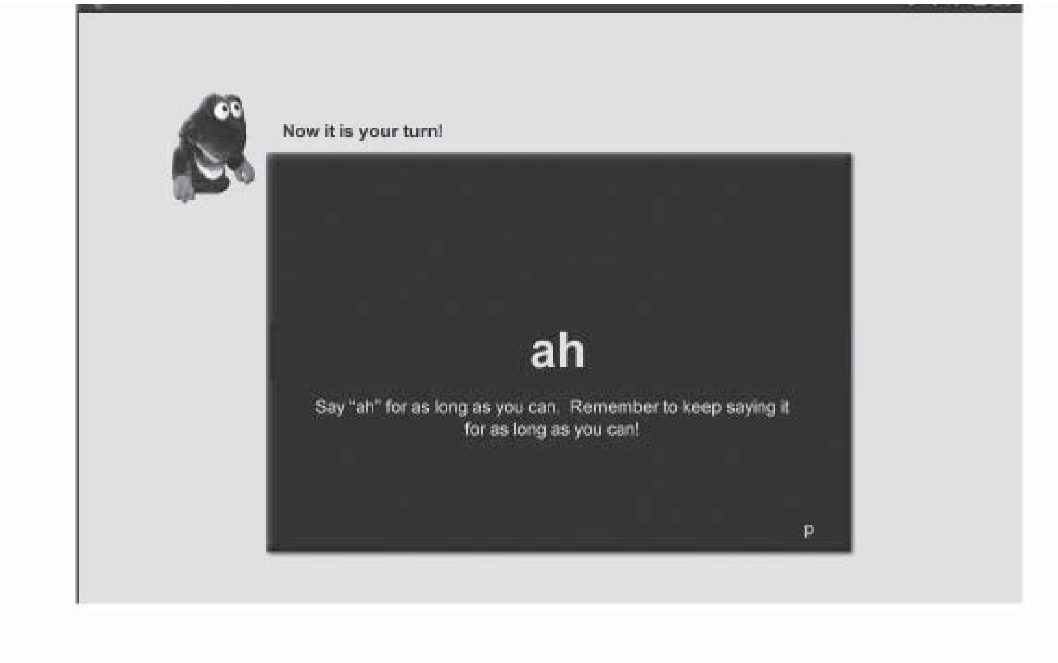
An inexpensive computer microphone is adequate for the durational measures to be obtained from the recordings of the child's responses to the MPTs. A head-mounted microphone is preferable if the child will tolerate this but a table microphone is a second option. The software sets a standard recording level at start-up that can be checked and modified within the software before administering the MPT protocol. It guides the user through administration of the MPD, MFD, and MRR tasks in succession. At the beginning of each task type (MPD, MFD, MRRmono, and MRRtri) a screen with instructions similar to those summarized in Table 1 is displayed to cue the examiner so that the same instructions are given each time. This is followed by successive screens for a practice trial followed by the required number of test trials for each MPT listed in Table 1. For each of these trials, a short tone and a small icon appear on the screen to signal to the child that it is time to start the task (see Figure 1). This ensures onset synchronization of the child's response and recording, reduces the likelihood of overlapping examiner and child speech, and avoids false starts and unnecessary repeat trials. Recordings of each trial are saved as a .wav file that is named by task and trial number and stored in the child's folder.

Measurement of MPD and MRR

Digital recordings of MPTs obtained using the TOCS+ MPT Recorder (or other software with recording capabilities) can be displayed as a waveform by a variety of software packages, such as those cited previously. In the examples that follow, Time-Frequency-Response version 2.1 (TFR; AVAAZ Innovations, Inc., 1999) was used to demonstrate the measurement of durations and repetition rates. The basic procedure is the same regardless of the specific software used to display the waveforms and measure the durations.

Measurement of MPD is the most straightforward. After loading the sound file into a waveform display window, visual inspection of the waveform and the partial playback feature of the software helps to identify the waveform that represents the production of the [a]. For example, in the waveform shown in Panel A of Figure 2, the prolonged [a] is preceded by some examiner speech and the client's inhalation, and there is a second inhalation

Figure 1



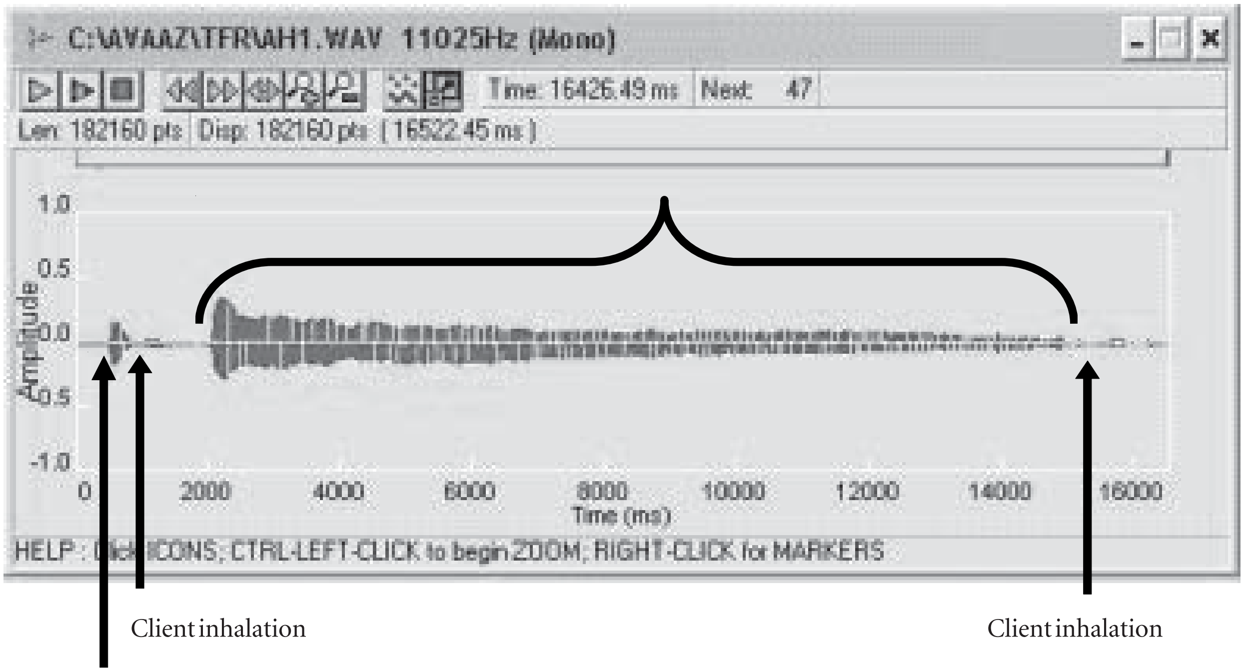
Now it is your turn!

ah

Say "ah" for as long as you can. Remember to keep saying it for as long as you can!

Figure 1: Instruction screen with visual prompt to the child to begin the practice trial for the first maximum performance task, from the TOCS+MPT Recorder Version 1 (altered to appear in black and white)

Figure 2 A.



C:\AVAAZ\TFR\AH1.WAV 11025Hz (Mono)

Time: 16426.49 ms Next: 47

Len: 182160 pts Disp: 182160 pts [16522.45 ms]

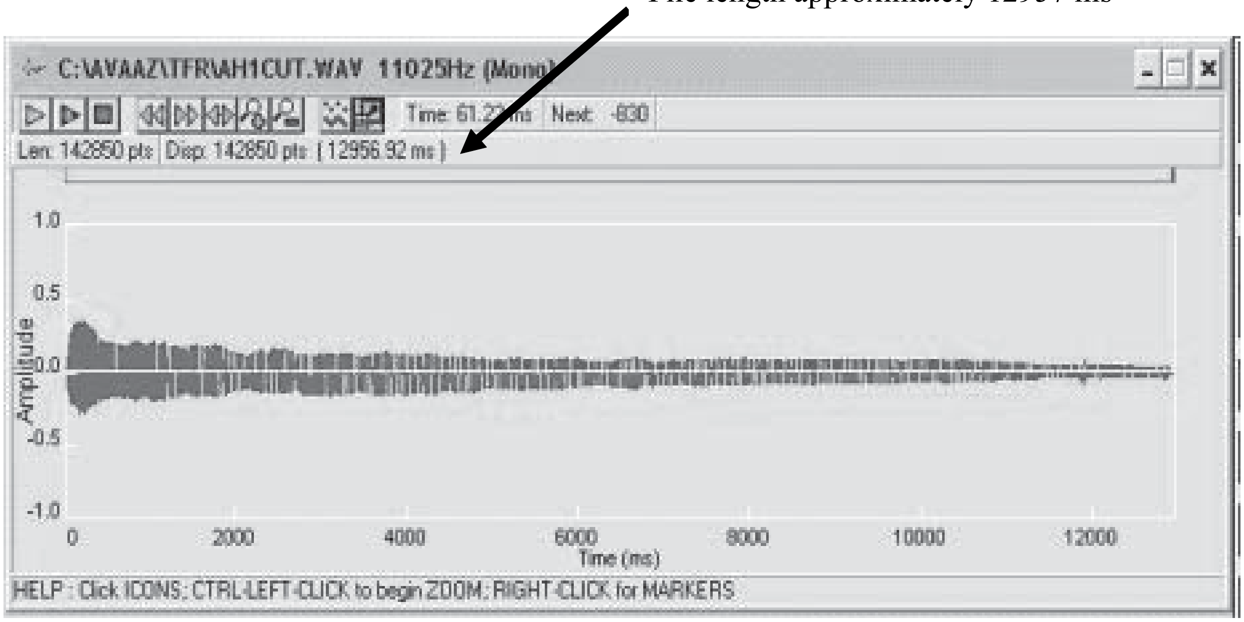
HELP : Click ICONS; CTRL-LEFT-CLICK to begin ZOOM; RIGHT-CLICK for MARKERS

Client inhalation

Client inhalation

Examiner Speech

Figure 2 B



File length approximately 12957 ms

Figure 2. Panel A shows the waveform of the recording of a prolonged ‘ah’ [a] marked by a bracket and surrounded by extraneous information in the file. Panel B shows the prolonged ‘ah’ cut from the first file as shown in A so that the extraneous information is removed. The duration of the file in milliseconds is indicated with an arrow.

that follows the [a] production. Waveform editors provide a 'click and drag' function for marking off the specific waveform of interest, in this case the waveform that is marked with a bracket. In Panel B of Figure 2 the duration of the [a] is shown as being 12,956.92 ms which, when divided by 1000, yields approximately 12.96 seconds. The procedure for measuring duration of [mama], [f], [s], and [z] is the same as that shown here for [a].

Measurement of MRRmono is accomplished by loading the sound file into the wave form display window and marking off 10 consecutive repetitions of the syllable, as shown in Figure 3. As described in Table 1, all 10 syllables should be produced on a single breath. These 10 syllables should not include the first syllable after an inspiration or the last syllable before an inspiration. In Panel B of Figure 3 the selected 10 syllables are isolated from the rest of the file. The total duration of the selected portion is shown as approximately 1835 ms. When using Thoonen et al.'s protocol for interpreting the results it is necessary to calculate the number of syllables produced per second. This value is obtained by converting the time value to seconds and dividing the 10 repetitions by the total time in seconds yielding 10/1.835 = 5.45 syllables per second in this case.

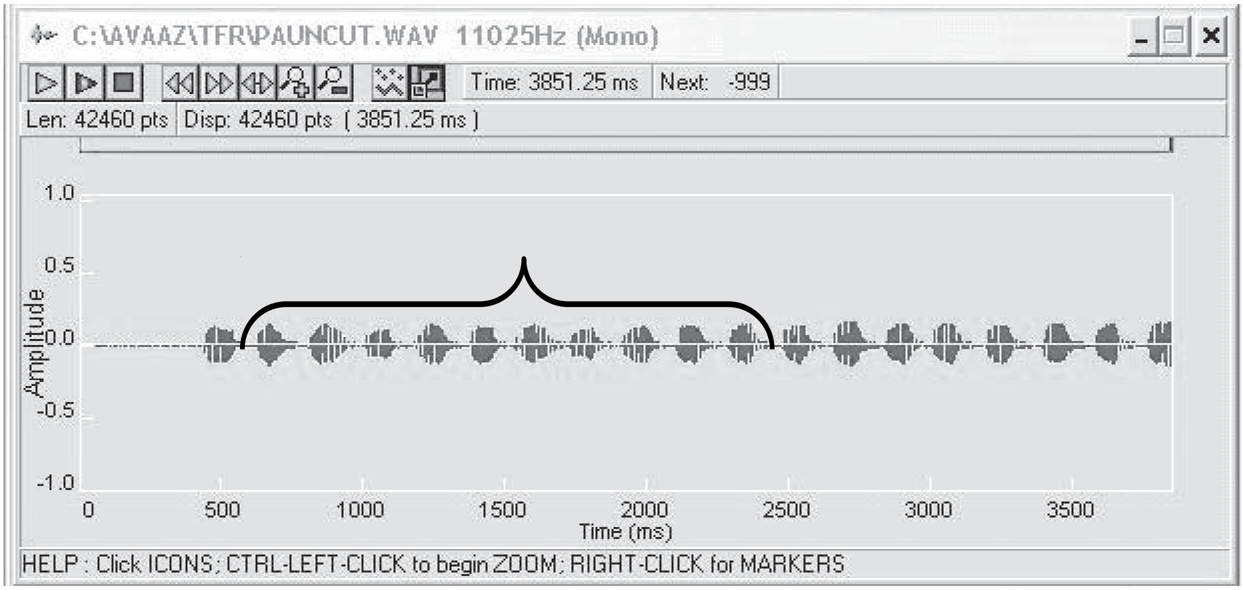
The procedure for determining MRRtri is the same as that for determining MRRmono except that 4 consecutive repetitions of the sequence [pataka] (i.e., 12 syllables) are marked off. The number of syllables per second is calculated as described previously for MRRmono . For the example shown in Figure 4, the total time taken to produce 4 repetitions of the sequence [pataka] was 1580 ms. This results in a rate of 7.59 syllables per second (12 syllables/ 1.58 seconds).

Alternative Calculation Procedures

The procedures described in the previous section for measuring MRRmono and MRRtri are specific to the Thoonen et al. (1999) protocol. The way in which repetition rates are calculated and represented depends upon the norms that will be used to interpret the child's performance. Some norms for single syllable repetition rates are presented as the time taken to produce a specified number of repetitions (e.g., Fletcher, 1972). When using Fletcher's time-by-count norms the examiner simply marks the required number of repetitions and notes the time taken to produce those repetitions. Some norms for the interpretation of trisyllable repetition rates, such as those published by Robbins and Klee (1987), are based on the number of repetitions of the entire sequence, (e.g., in the example in Figure 4, four repetitions of the sequence in 1.58 seconds yields a rate of 2.53 repetitions of [pataka] per second).

An important point about the measurement of MRRtri described by Thoonen et al. (1999) is that it requires a repetition of correctly articulated sequences. Some younger children may be unable to correctly articulate the [ka] phoneme in which case they might repeat [patata], a response that should not be scored using Thoonen et al.'s procedure. Williams and Stackhouse (2000) reported repetition performance for three-syllable words and nonsense words in which accuracy, rate, and consistency measures were derived independently. Therefore, their

Figure 3 A



C:\AVAAZ\TFR\PAUNCUT.WAV 11025Hz (Mono)

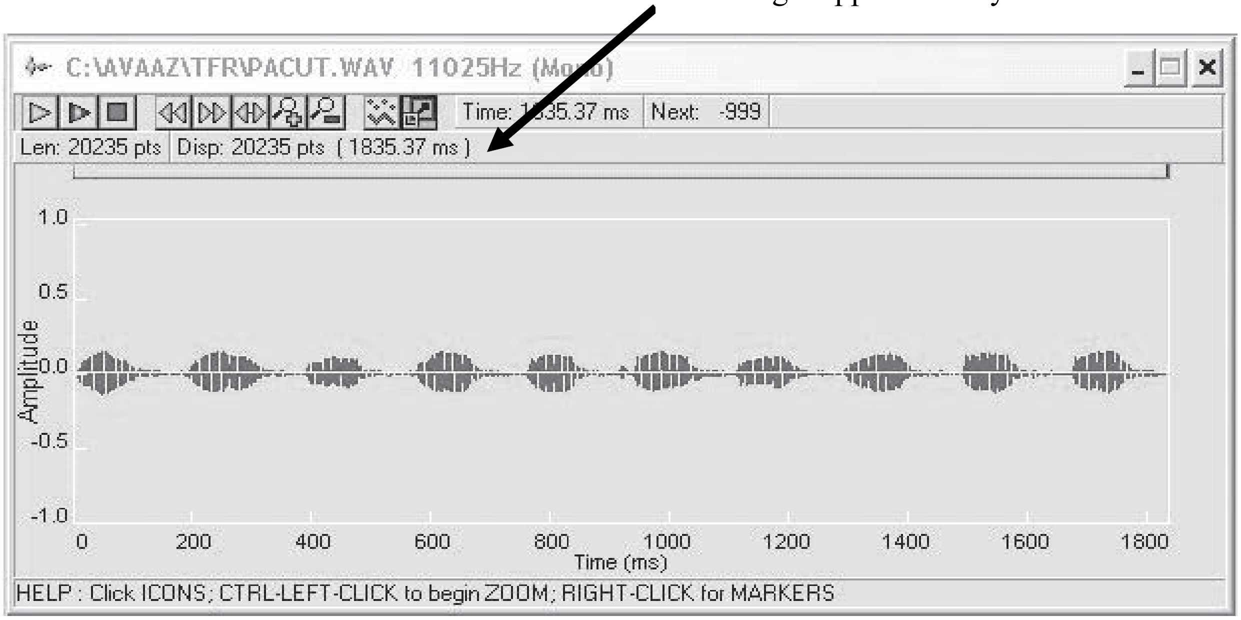
Time: 3851.25 ms | Next: -999

Len: 42460 pts | Disp: 42460 pts (3851.25 ms)

HELP : Click ICONS; CTRL-LEFT-CLICK to begin ZOOM; RIGHT-CLICK for MARKERS

Figure 3 B

File length approximately 1835 ms



C:\AVAAZ\TFR\PACUT.WAV 11025Hz (Mono)

Time: 1835.37 ms | Next: -999

Len: 20235 pts | Disp: 20235 pts (1835.37 ms)

HELP : Click ICONS; CTRL-LEFT-CLICK to begin ZOOM; RIGHT-CLICK for MARKERS

Figure 3. Panel A shows the client's repetitions of the syllable 'pa' from the first syllable until the time when recording was stopped. The duration of the 10 repetitions that are marked by the bracket is measured by cutting these repetitions from the file as shown in Panel B. The duration of the 10 repetitions shown in the cut file is indicated with an arrow.

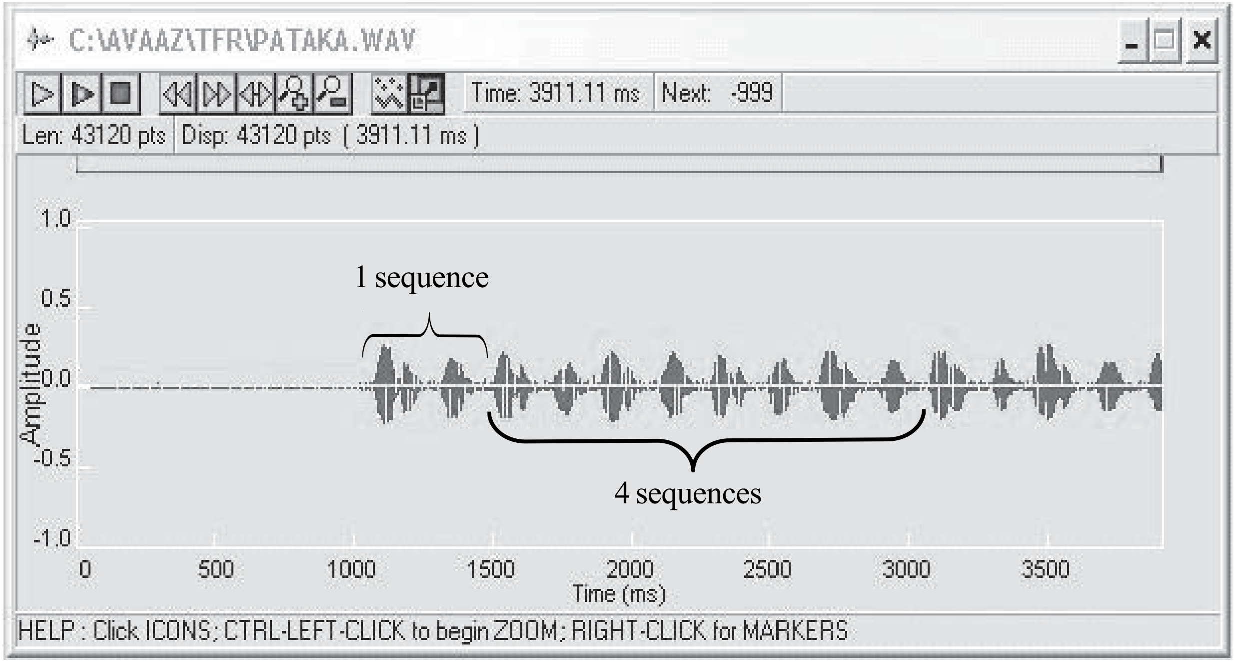
paper provides a normative reference for the repetition rate, regardless of accuracy, for 3- to 5-year-old children. They found that even 3-year-olds produced repetition rates no slower than three syllables per second. They suggested that the ability to repeat a consistent [patata] sequence at a rate of at least three syllables per second would not be reason for concern with this age group. However, inconsistent and inaccurate repetitions of the sequence would be cause for concern.

Differential Diagnosis

Thoonen et al. (1999) developed a flow chart for differential diagnosis of dysarthria and dyspraxia, based on MPT data that they obtained from children aged 6 through 10 years. The application of these criteria are described here. Figure 5 illustrates the results of this interpretative process for a hypothetical 7-year-old child.

The process begins with the assignment of a dysarthria score of 0, 1, or 2, where 0 indicates that the child is not

Figure 4 A



C:\AVAAZ\TFR\PATAKA.WAV

Time: 3911.11 ms Next: -999

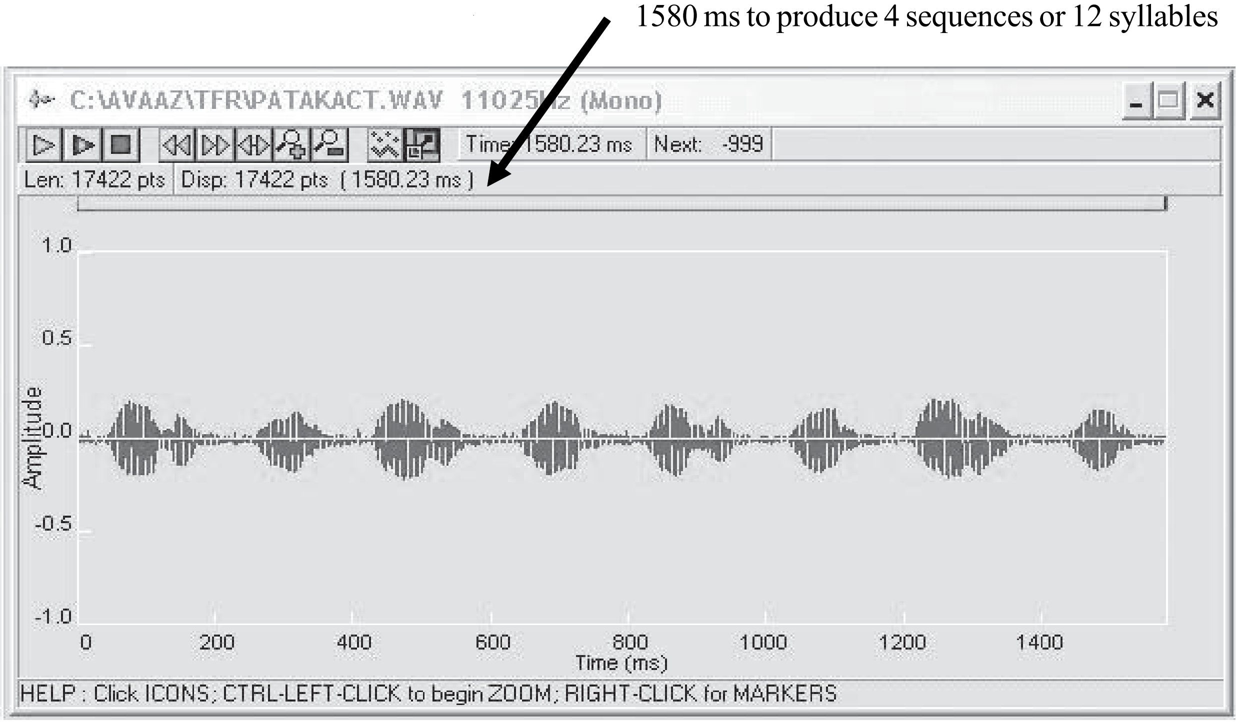
Len: 43120 pts Disp: 43120 pts (3911.11 ms)

HELP : Click ICONS; CTRL-LEFT-CLICK to begin ZOOM; RIGHT-CLICK for MARKERS

1 sequence

4 sequences

Figure 4 B



1580 ms to produce 4 sequences or 12 syllables

C:\AVAAZ\TFR\PATAKACT.WAV 11025Hz (Mono)

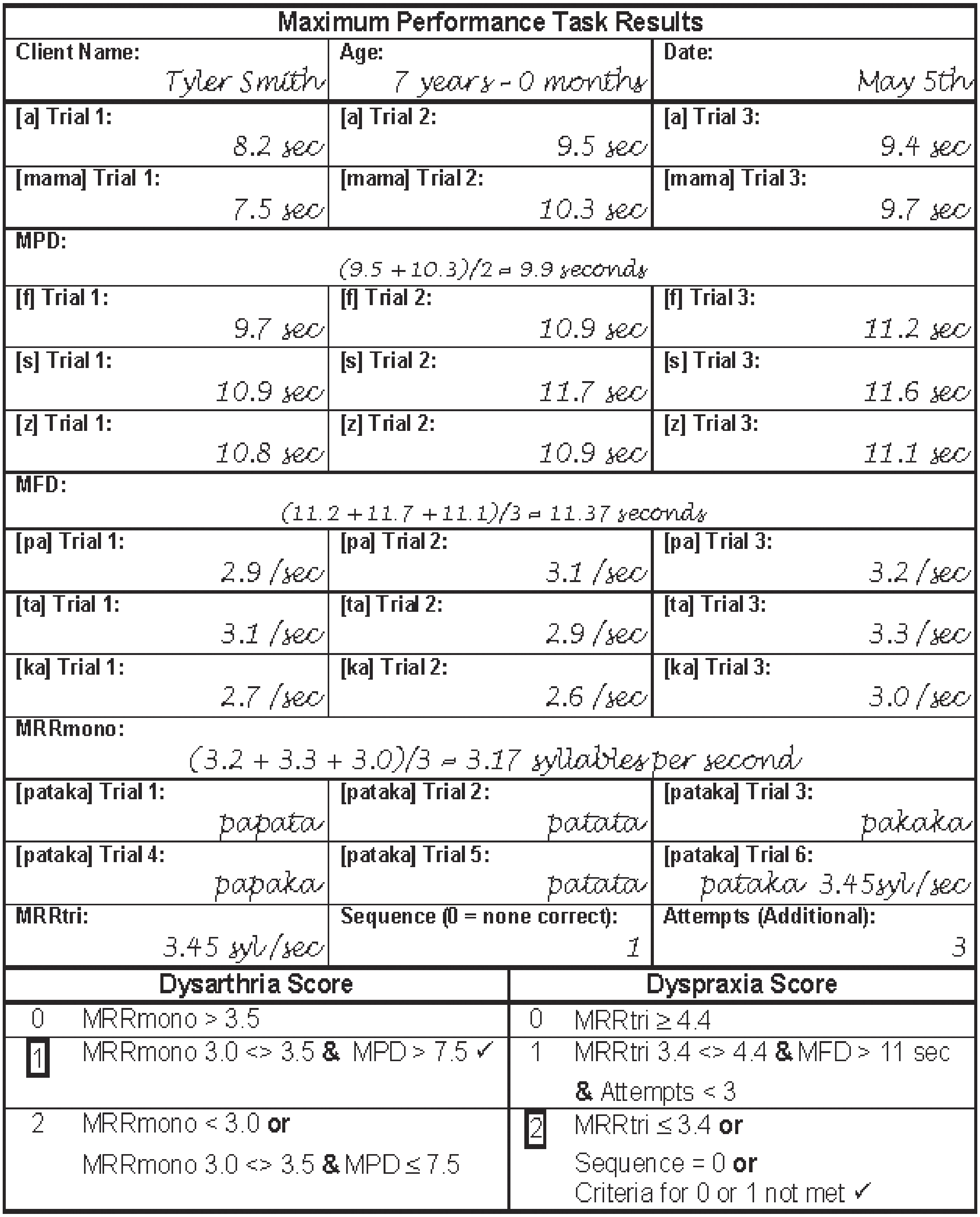
Time: 1580.23 ms Next: -999

Len: 17422 pts Disp: 17422 pts (1580.23 ms)

HELP : Click ICONS; CTRL-LEFT-CLICK to begin ZOOM; RIGHT-CLICK for MARKERS

Figure 4. Panel A shows the client's repetition of the sequence 'pataka' from the first syllable until the time when recording was stopped. The brackets indicate the first sequence, which is excluded, and the next 4 sequences that are cut to form the display shown in Panel B. The time taken to produce 12 syllables comprising these 4 sequences is marked with an arrow.

Figure 5



Maximum Performance Task Results

Client Name: Tyler Smith	Age: 7 years - 0 months	Date: May 5th
[a] Trial 1: 8.2 sec	[a] Trial 2: 9.5 sec	[a] Trial 3: 9.4 sec
[mama] Trial 1: 7.5 sec	[mama] Trial 2: 10.3 sec	[mama] Trial 3: 9.7 sec
MPD: (9.5 + 10.3)/2 = 9.9 seconds		
[f] Trial 1: 9.7 sec	[f] Trial 2: 10.9 sec	[f] Trial 3: 11.2 sec
[s] Trial 1: 10.9 sec	[s] Trial 2: 11.7 sec	[s] Trial 3: 11.6 sec
[z] Trial 1: 10.8 sec	[z] Trial 2: 10.9 sec	[z] Trial 3: 11.1 sec
MFD: (11.2 + 11.7 + 11.1)/3 = 11.37 seconds		
[pa] Trial 1: 2.9 /sec	[pa] Trial 2: 3.1 /sec	[pa] Trial 3: 3.2 /sec
[ta] Trial 1: 3.1 /sec	[ta] Trial 2: 2.9 /sec	[ta] Trial 3: 3.3 /sec
[ka] Trial 1: 2.7 /sec	[ka] Trial 2: 2.6 /sec	[ka] Trial 3: 3.0 /sec
MRRmono: (3.2 + 3.3 + 3.0)/3 = 3.17 syllables per second		
[pataka] Trial 1: papata	[pataka] Trial 2: patata	[pataka] Trial 3: pakaka
[pataka] Trial 4: papaka	[pataka] Trial 5: patata	[pataka] Trial 6: pataka 3.45syl/sec
MRRtri: 3.45 syl/sec	Sequence (0 = none correct): 1	Attempts (Additional): 3

Dysarthria Score		Dyspraxia Score	
0	MRRmono > 3.5	0	MRRtri ≥ 4.4
[✓ 1]	MRRmono 3.0 <> 3.5 **&** MPD > 7.5 ✓	1	MRRtri 3.4 <> 4.4 **&** MFD > 11 sec **&** Attempts < 3
2	MRRmono < 3.0 **or** MRRmono 3.0 <> 3.5 **&** MPD ≤ 7.5	[✓ 2]	MRRtri ≤ 3.4 **or** Sequence = 0 **or** Criteria for 0 or 1 not met ✓

Figure 5. Example of calculation of Maximum Phonation Duration (MPD), Maximum Fricative Duration (MFD), Maximum Repetition Rate for monosyllables (MRRmono), Maximum Repetion Rate for trisyllabic sequences (MRRtri), Attempts, and Sequence. Interpretation of these data to yield a diagnosis is shown at the bottom of the chart.

dysarthric and a 2 indicates that the child is primarily dysarthric. MRRmono is the primary diagnostic marker for dysarthria. A score of 0 is assigned if MMRmono is greater than 3.5 syllables per second. A score of 2 is assigned if the MRRmono is less than 3 syllables per second. If the child's MRRmono is between 3 and 3.5, the MPD is examined: if the MPD is less than 7.5 seconds, a score of 2 is assigned; if the MPD is more than 7.5, a score of 1 is assigned.

Next, a dyspraxia score of 0, 1, or 2 is assigned, where 0 indicates that the child is not dyspraxic and a score of 2 indicates that the child is dyspraxic. MRRtri and Attempts are the primary diagnostic markers for CAS. A score of 0 is assigned if the child produces a correct trisyllabic sequence at a rate of at least 4.4 syllables per second without requiring more than 2 additional attempts. If the child cannot produce a correct sequence or the MRRtri for a correct sequence is less than 3.4 syllables per second a score of 2 is assigned. If the MRRtri is between 3.4 and 4.4 syllables per second, a score of 1 is assigned as long as the MFD is appropriate at more than 11 seconds and the child did not require more than 2 additional attempts to achieve a correct sequence. If the MRRtri is between 3.4 and 4.4 syllables per second *and* more than 2 additional attempts were needed to achieve a correct sequence a score of 2 is assigned. A score of 2 is also assigned if MRRtri is between 3.4 and 4.4 syllables per second *and* MFD is 11 seconds or less.

Note that a diagnosis of 'primarily dysarthria' would be concluded if the child received dysarthria and dyspraxia scores of 2. Children with dysarthria are likely to produce very slow repetition rates for both monosyllables and trisyllabic sequences. Children with CAS are likely to produce repetition rates that are slower for trisyllabic sequences than for monosyllables (Thoonen et al., 1999).

The hypothetical child profiled in Figure 5 received a dysarthria score of 1 and a dyspraxia score of 2, justifying a clinical diagnosis of CAS. His MRRmono was not slow enough to justify a diagnosis of dysarthria. His MRRtri was somewhat slow at 3.45 syllables per second, and he did not achieve a correct repetition of the sequence until the sixth trial. Thus the combination of Attempts = 3 and MRRtri between 3.4 and 4.4 led to a dysarthria score of 2, resulting in a diagnosis of childhood apraxia of speech.

Summary and Conclusions

A number of normative data sets are available to aid in the interpretation of a child's ability to prolong sounds and repeat syllables (e.g., Kent et al., 1987; Robbins & Klee, 1987; Thoonen et al., 1996, 1999; Williams & Stackhouse, 2000). For children with specific phonological errors such as velar fronting, the diagnostic accuracy of the procedure can be improved by considering accuracy and consistency of production of a trisyllabic sequence as described by Williams and Stackhouse (2000). Thoonen et al. have provided a framework for using MPTs to assist in differential diagnosis of speech dyspraxia or dysarthria in pediatric clients. Technological advances such as the *TOCS+™ MPT Recorder©* ver. 1 (Hodge & Daniels, 2004) and readily available waveform editors facilitate reliable administration and recording of children's responses and accurate measurement of maximum durations and maximum repetition rates.

The publication of new normative data and the availability of audio recording and editing software have eliminated significant impediments to the use of maximum performance tasks with children. It is our hope that the application of these procedures will result in reliable and valid normative data from younger children and become a routine part of the speech-language assessment protocol for all children with suspected or confirmed speech disorders and delays.

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Address correspondence to Dr. Susan Rvachew, School of Communication Sciences and Disorders, McGill University, 1266 Pine Avenue West, Montréal, Québec H3G 1A8. Development of the *TOCS+™ MPT Recorder© ver. 1* was supported by a grant from the Canadian Language and Literacy Research Network (www.cllrnet.ca) and uses the *Universal Sound Server©* software developed for the TOCS+ Project (www.Tocs.plus.ualberta.ca) at the University of Alberta by Tim Young. Readers interested in using the *TOCS+™ MPT Recorder©* can contact Megan Hodge (megan.hodge@ualberta.ca) to obtain a copy of the software.

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