Young Children's Responses to Maximum Performance Tasks: Preliminary Data and Recommendations

Réactions des jeunes enfants aux tâches de durée maximale d'exécution : données préliminaires et recommandations

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Abstract

The purpose of this study was to examine the ability of 4- to 6-year-old children with typical speech to perform certain maximum performance tasks, with a view to developing diagnostic criteria for identifying dyspraxia and dysarthria in this age group. Twenty children were asked to prolong [a], [mama], [f], [s], and [z] for as long as they could. They were also asked to repeat the syllables [pa], [ta], and [ka] and the trisyllabic sequence [pataka] as fast they could. The children's responses to the prolongation tasks were highly variable within and across children. Using traditional elicitation methods, these measurements do not appear to be good potential indicators of dysarthria or dyspraxia in this age group. In contrast, repetition rates were much more stable within and across children. All but one child repeated monosyllables at a rate of at least 3.4 syllables per second. Every child achieved a correct repetition of [pataka] at a rate of at least 3.4 syllables per second. Recommendations for interpreting young children's performance on these tasks are provided.

Abrégé

La présente étude porte sur des enfants de 4 à 6 ans dont la parole est typique et examine leur capacité à exécuter des tâches de durée maximale d'exécution dans le but d'élaborer des critères de diagnostic pour la dyspraxie et la dysarthrie chez ce groupe d'âge. Nous avons demandé à vingt enfants d'allonger les séquences [a], [mama], [f], [s] et [z] aussi longtemps qu'ils le pouvaient. Nous leur avons aussi demandé de répéter les syllabes [pa], [ta] et [ka] et la séquence trisyllabique [pataka] aussi rapidement que possible. Les réponses des enfants à la tâche de prolongation ont donné des résultats très variables pour chaque enfant et entre les enfants. À partir des méthodes habituelles de d'évocation, ces mesures ne semblent pas être de bons indicateurs de la dyspraxie ou de la dysarthrie chez ce groupe d'âge. En revanche, la fréquence de répétition était beaucoup plus stable. À l'exception d'un seul enfant, tous ont répété les monosyllabes a une fréquence d'au moins 3,4 syllabes la seconde. Chaque enfant a réussi à répéter correctement [pataka] a une fréquence d'au moins 3,4 syllabes la seconde. L'article formule des recommandations pour interpréter la performance des jeunes enfants à ces tâches.

Key Words: speech sound disorders, speech development, maximum performance tasks

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Speech-language pathologists are expected to conduct an oral-peripheral examination as a part of their standard assessment procedures, even when the client is a young child (e.g., see Bliele, 2002; Hodson, Sherz, & Strattman, 2002; Miccio, 2002; Tyler & Tolbert, 2002). Textbooks about speech sound disorders include specific instructions for conducting such an examination (Bauman-Waengler, 2004; Bernthal & Bankson, 2004; Creaghead, Newman, & Secord, 1989). Asking the child to prolong certain sounds for as long as possible and to repeat certain syllables as quickly as possible is a central part of this assessment procedure. These tasks are administered in order to identify problems with speech motor function that may contribute to the child's speech sound disorder.

Having administered the procedures, the challenge of interpreting the child's responses remains. Thoonen, Maassen, Wit, Gabreels, and Schreuder (1996) developed some criteria for diagnosing dysarthria and dyspraxia by integrating information about the child's responses to maximum performance tasks (MPTs), specifically maximum phonation and fricative durations and repetition rates for single syllables and the standard trisyllabic sequence [pataka]. These criteria 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 (the specific criteria are described later in this paper).

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 known 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, the performance of the children with developmental phonological disorders was intermediate between the dysarthric and dyspraxic groups and the normally developing control group.

Although the procedures described by Thoonen et al. (1996, 1999) appear to be very useful for the diagnosis of dyspraxia and dysarthria in school-aged children, these researchers concluded that the criteria that they described could not be validly applied to children younger than the age of 6 years. The purpose of the present study was to examine the normal range of performance on sound prolongation and syllable repetition tasks for a sample of 4- to 6-year-old children with typical speech development with a view to developing criteria that will be valid with younger children.

Method

Participants

The children were recruited from inner-city and suburban daycares and suburban kindergarten classrooms in the Montreal area. These preschool settings had English-French bilingual programs. Parents were asked to volunteer their children to participate in a comprehensive study of oral language and early literacy development, involving two to three assessment sessions, each lasting approximately 45 minutes. Only those aspects of the assessment procedures and the resulting data that are relevant to the children's maximum performance task will be described here.

A parent questionnaire was used to obtain information about the child's language background and developmental history and family socio-economic status. The Peabody Picture Vocabulary Test (PPVT; Dunn & Dunn, 1997) and the Goldman-Fristoe Test of Articulation-Second Edition (GFTA; Goldman & Fristoe, 2000) were used to screen for speech and language delay. Of the 29 children whose parents volunteered them to participate in this study, 23 were selected on the basis of the following criteria: proficient speakers of English; aged 4 to 6 years; receptive vocabulary and articulation skills within the normal range; no known developmental delays; no known sensory disorders such as hearing or visual impairment; no known primary medical or developmental conditions that might impact speech and language development.

For the first 5 children to be enrolled in the study, their responses on the MPTs were recorded using a digital minidisk player. These children either did not complete the entire test protocol or did so reluctantly and only with much coaxing and multiple visits to their daycares. Their responses will not be described in this report. At this point in the study, the TOCS+™ MPT Recorder© software was developed and then employed to record the children's performance, as described below. With the aid of this software, 20 additional children completed the test protocol without any extraordinary effort. Only the results recorded from these 20 children will be described in this report. An additional 4 children were recruited but did not complete the assessment due to scheduling problems.

This group of 20 children was comprised of 10 girls and 10 boys with a mean age of 69 months ($SD = 7.8$). All participants either had English as a native language or were judged to be proficient in English. English proficiency was determined by teacher report, examiner's impression, and receptive vocabulary skills as measured by the PPVT. All of the children's mothers had either college diplomas or university degrees with the exception of one mother whose highest level of education was secondary school completion. The children's mean percentile ranking on the GFTA was 37.60 ($SD = 17.92$), and their mean standard score on the PPVT was 104 ($SD = 12.22$). One child scored slightly below normal limits on the GFTA but his only

speech sound error (dental distortion of /s/ and /z/) was judged to be developmentally acceptable and thus this child was included as a participant.

Procedure

The standardized tests and the MPTs were administered by the third author (Alyssa Ohberg) during two separate test sessions. These sessions included tests relating to a different study of emergent literacy development and thus each session lasted approximately 45 minutes but the MPTs themselves required only 20 minutes on average.

Administering the MPTs. The child was asked to prolong the sounds [a], [mama], [f], [s], and [z] for as long as possible on a single expiration. The child was given one practice trial and three test trials for each of these tasks. Then the child was asked to repeat the syllables [pa], [ta], and [ka] and the syllable sequence [pataka], in each case as fast as possible on a single expiration. The child was given one practice trial and three test trials for each repetition task. For the trisyllabic sequence repetition task only, the child was allowed as many as three additional attempts, as necessary, to obtain an accurate repetition of the sequence.

The TOCS+™ MPT Recorder© software was used to administer the assessment protocol and record the child's responses. As described in detail elsewhere (Rvachew, Hodge, & Ohberg, 2005), this software facilitates the recording of the child's responses directly to digital .wav files using a computer. The software also ensures standardized administration of the protocol as the instructions are available to the child and clinician on a task-by-task basis. The software provides an auditory and visual prompt to the child to begin producing the desired response for each trial.

Measurement of durations and repetition rates. The time needed to measure all of the durations and repetition rates obtained from each child was 10 to 15 minutes. The waveform function of TFR (Avaaz Innovations, Inc.), a speech analysis program, was used to measure the durations of each prolongation of [a], [mama], [f], [s], and [z], using visual inspection of the waveform and the partial playback function to identify and mark the beginning and end of each prolonged sound, the duration of which was provided by the TFR software. For the repetition of single syllables, visual inspection of the waveform and the partial playback function was used to identify an uninterrupted sequence of 10 syllables produced on a single expiration, excluding the first and last syllable produced. The duration of this sequence of 10 syllables was provided by the software and then the examiner calculated the number of repetitions produced per second. For the trisyllable repetitions, the duration of 4 repetitions of [pataka] was measured and then the number of syllables produced per second was calculated.

Summary statistics. These measurements were then reduced to a number of summary statistics as follows: Maximum Phonation Duration (MPD) = the mean of the durations of the longest [a] and the longest [mama] prolongation; Maximum Fricative Duration (MFD) = the mean of the longest prolongation of [f], the longest prolongation of [s], and the longest prolongation of [z]; Maximum Repetition Rate for single syllables (MRRmono) = the average repetition rate for the fastest repetition of [pa], the fastest repetition of [ta], and the fastest repetition of [ka]; Maximum Repetition Rate for the trisyllabic sequence (MRRtri) = number of syllables per second produced during the fastest accurate repetition of the sequence [pataka]; Sequence = 1 if the child produced a correct repetition of the sequence and 0 if the child did not succeed in producing a correct sequence; Attempts = the number of additional attempts (beyond the first three) that were required for the child to achieve a correct repetition of the sequence.

Interpretation. First, the children's scores for each summary statistic were interpreted in relation to the criteria for identifying dyspraxia and dysarthria as described by Thoonen et al. (1999) for children aged 6 to 10 years of age. Then, scatter plots of the children's responses were examined to identify criteria that might be more appropriate to the younger children that were assessed for this study.

Results

Table 1 shows each participant's longest durations for each prolongation task, fastest repetition rate for each repetition task, and the final score for each of the summary statistics described above. Prolongation durations were highly variable across children, with MPD ranging from 4.25 to 13.94 and MFD ranging from 4.74 to 13.26 seconds. Repetition rates were less variable across children, with MRRmono ranging from 3.03 to 5.11 syllables per second and MRRtri ranging from 3.42 to 6.74 syllables per second. Table 2 shows that stability within subjects was also greater for repetition rates than for prolongations, although reliability across trials was more than adequate for every task except prolongation of [mama].

As described in the introduction, Thoonen et al. (1996, 1999) validated certain criteria for assigning dysarthria scores of 0, 1, or 2 and dyspraxia scores of 0, 1, or 2. Scores of 0 on either scale indicate an absence of the condition while scores of 2 indicate the presence of the condition in children aged 6 to 10 years of age. Thoonen et al.'s criteria are shown in Table 3. All 11 of the control group children with normally developing speech assessed by Thoonen et al. (1999) received dysarthria scores of 0. All but one of these children also received dyspraxia scores of 0. The one control participant who received a dyspraxia score of 2 received speech therapy at a later age after referral by the classroom teacher. We applied these same criteria to the younger children assessed in this study. The result is shown in Table 3 as the proportion of children meeting the criteria for each possible dysarthria or dyspraxia score.

Thoonen et al.'s (1999) criterion for ruling out dysarthria is MRRmono greater than 3.5 syllables per

Table 1

Maximum Performance Task results obtained from 4-, 5-, and 6-year-old children

P#	Age	GFTA	[a]	[mama]	MPD	[f]	[s]	[z]	MFD	[pa]	[ta]	[ka]	MRR	MRR	Seq	Attempts
	(months)												mono	tri		
27	49	84	9.73	9.75	9.74	3.65	15.13	11.48	10.1	3.79	3.89	3.6	3.76	3.98	1	1
25	56	50	14.8	8.48	11.6	7.96	4.96	6.73	6.55	4.65	4.59	4.1	4.45	4.67	1	0
28	59	73	7.71	6.46	7.09	11.22	12.4	11.88	11.8	4.27	3.88	3.56	3.90	3.99	1	0
29	65	30	13.49	8.7	11.1	11.92	11.83	13.35	12.4	4.19	4.16	3.78	4.04	3.95	1	0
6	66	30	9.52	9.17	9.35	4.86	5.28	7.23	5.79	5.28	4.76	5.29	5.11	6.74	1	1
24	66	37	12.12	10.87	11.5	17.8	6.47	13.83	12.7	5.13	4.83	4.45	4.80	6.08	1	0
26	66	32	6.22	11.62	8.95	7.65	7.3	7.73	7.56	4.33	4.12	3.86	4.10	4.18	1	0
7	68	30	8.35	12.35	10.4	5.03	7.88	16.97	9.96	4.05	4.24	3.97	4.09	4.78	1	0
12	68	37	6.57	8.37	7.47	10.1	4.46	9.31	7.96	4.48	4.3	3.76	4.18	3.72	1	0
11	69	27	7.9	11.14	9.52	8.5	7.98	10.78	9.09	5.2	4.92	4.51	4.88	4.24	1	0
9	71	20	15.93	11.95	13.9	6.85	7.79	8.12	7.59	4.57	4.82	4.01	4.47	3.64	1	0
10	71	27	4.29	4.21	4.25	3.48	5.28	5.47	4.74	3.04	2.97	3.09	3.03	3.42	1	3
19	72	48	4.16	8.23	6.2	2.39	8.41	8.01	6.27	4.65	4.53	4.16	4.45	3.99	1	0
21	72	22	12.02	10.88	11.5	8.42	6.68	8.48	7.86	4.56	3.46	4.55	4.19	3.77	1	1
22	72	22	8.55	6.91	7.73	6.08	6.19	8.53	6.93	4.93	4.93	4.57	4.81	3.82	1	3
13	74	52	6.15	5.96	6.06	5.86	6.68	8.11	6.88	4.89	5.06	4.39	4.78	4.59	1	0
15	75	31	10.91	9.17	10	13.62	12.8	13.36	13.3	4.76	4.23	3.85	4.28	3.49	1	0
20	77	14	5.44	5.74	5.59	10.6	13.09	9.58	11.1	4.79	4.81	3.77	4.46	5.05	1	1
17	79	56	7.56	7.17	7.37	3.11	9.04	11.18	7.78	4.7	4.73	4.59	4.67	4.74	1	0
23	83	30	10.11	8.14	9.13	6.53	6.11	11.51	8.05	4.97	5.65	4.5	5.04	4.77	1	1
M	68.90	37.60	9.08	8.76	8.92	7.78	8.29	10.08	8.72	4.56	4.44	4.12	4.37	4.38	1.00	0.55
SD	7.85	17.92	3.34	2.26	2.44	3.90	3.11	2.86	2.47	0.53	0.61	0.49	0.49	0.85	0.00	0.94
Min	49.00	14.00	4.16	4.21	4.25	2.39	4.46	5.47	4.74	3.04	2.97	3.09	3.03	3.42	1.00	0.00
Max	83.00	84.00	15.93	12.35	13.94	17.80	15.13	16.97	13.26	5.28	5.65	5.29	5.11	6.74	1.00	3.00

Note: GFTA scores expressed as percentile ranks. Longest of 3 trials is shown for [a], [mama], [f], [s], and [z]. Fastest of 3 trials is shown for [pa], [ta], and [ka] repetitions.

Table 2

Within subject stability represented as the intraclass correlation coefficient (ICC) for each task across 3 trials.

Task	ICC
Prolong [a]	.71
Prolong [mama]	.47
Prolong [f]	.88
Prolong [s]	.81
Prolong [z]	.84
Repeat [pa]	.91
Repeat [ta]	.94
Repeat [ka]	.83
Repeat [pataka]	.93

Note: All *ICCs* are significantly different from 0 with the *p* values being equal to or less than .001 in each case, except the *ICC* =.47 in which case *p* =.047.

second while a MRRmono less than 3 syllables per second leads directly to a diagnosis of dysarthria. These criteria seem to be appropriate even with these younger normally developing children. All but one of the normally developing 4- to 6-year olds enrolled in this study achieved a MRRmono greater than 3.5 syllables per second and no child produced a MRRmono of less than 3 syllables per second. However, monosyllable repetition rates between 3 and 3.5, when accompanied by MPD of less than 7.5 seconds, also lead to a diagnosis of dysarthria when applying the Thoonen et al. (1999) criteria. The one child whose MRRmono was in the borderline range between 3.0 and 3.5 produced a very short MPD and thus received a dysarthria score of 2. However, inspection of the scatterplot shown in Figure 1 reveals that 35% of these young children failed to achieve a MPD that exceeded 7.5. Therefore, these data confirm previous reports that maximum phonation durations are difficult to obtain from children younger than age 6 years (Kent et al., 1987; Thoonen et al., 1996; 1999). However, the expectation that children should achieve a MRRmono that is greater than 3.4 seems appropriate even for these very young children.

Table 3

Proportion of Twenty 4- to 6-year old children meeting the criteria established by Thoonen et al. (1999) for assigning dysarthria and dyspraxia scores to 6- to 10-year-old children

Score	Classification	Criteria	Proportion of Children
Dysarthria Scores			
0	Not dysarthric	MRRmono > 3.5	.95
1	Undefined	MRRmono 3.0 <> 3.5 and MPD > 7.5	.00
2	Dysarthric	MRRmono < 3.0, or MRRmono 3.0 <> 3.5 and MPD < 7.5	.05
Dyspraxia Scores			
0	Not dyspraxic	MRRtri > 4.4 syllables/second	.40
1	Undefined	MRRtr 3.4 <> 4.4 syllables/second and MFD > 11 seconds, or MRRtr 3.4 <> 4.4 syllables/second and additional attempts < 3	.15
2	Dyspraxic	MRRtri < 3.4 syllables/second, or unable to produce a correct sequence, or fails to meet criteria for scores 0 or 1	.45

Figure 1

Maximum repetition rate for monosyllables (MRRmono) plotted against maximum phonation duration (MPD) for each child.

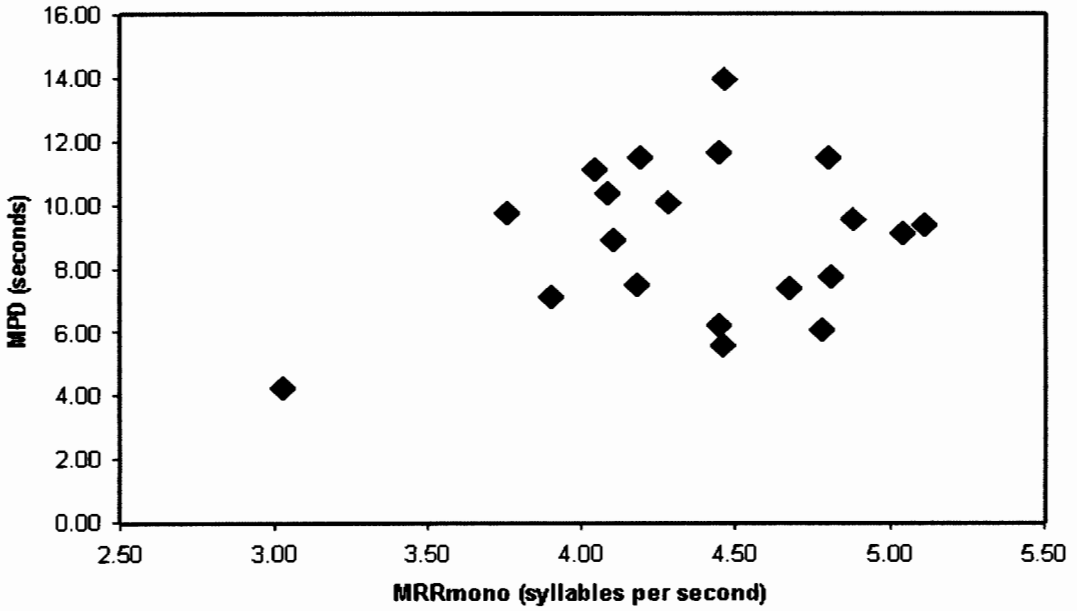
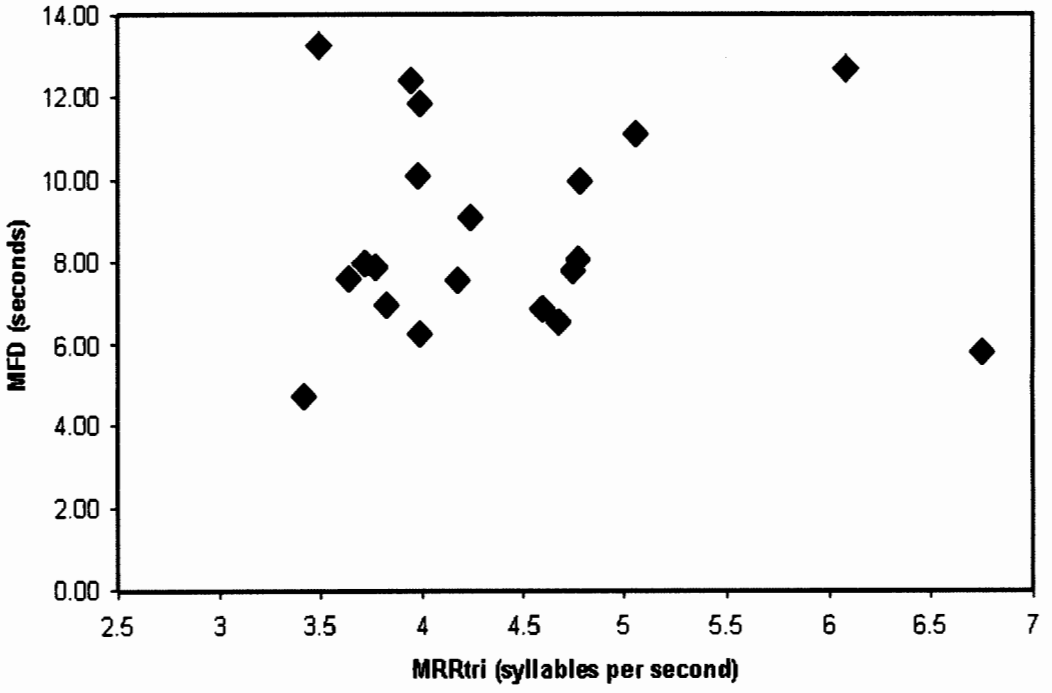


Figure 2

Maximum repetition rate for trisyllables (MRRtri) plotted against maximum fricative duration (MFD) for each child.



Thoonen et al.'s (1999) criterion for ruling out dyspraxia is MRRtri greater than 4.4 syllables per second. As shown in Table 3, only 40% of this sample of normally developing 4- to 6-year-olds met this criterion. Thoonen et al.'s most straightforward criteria for diagnosing dyspraxia are MRRtri less than 3.4 or a failure to produce any correct repetition of [pataka] within 6 trials. Every child enrolled in this study produced a correct sequence and no child produced it a rate slower than 3.4 syllables per second. However, inspection of the scatterplot in Figure 2 reveals that 60% of the children produced a MRRtri that was within the borderline range from 3.4 to 4.4. Nine of these children with borderline MRRtri results were assigned a dyspraxia score of 2 because they required three additional attempts (2 children) and/or their MFD was less than 11 seconds (9 children). However, considering the total group, only 4 children achieved a MFD that was greater than 11 seconds, as shown in Figure 2. With respect to the dyspraxia scores, these younger children are clearly not achieving the minimum expectations for older children with respect to MRRtri or MFD.

Discussion

The first conclusion to be drawn is that 4- to 6-year-old children can participate in maximum performance tasks. When using the *TOCS+™ MPT Recorder© ver. 1*, complete data was obtained from 20 young children within a reasonable time period and without undue effort on the part of the examiner to engage the child in the procedures.

The second conclusion, not surprisingly, is that the criteria for diagnosing dysarthria and dyspraxia in children older than 6 years cannot be validly applied to children younger than 6 years. However, it does appear that the criteria could be adjusted to yield valid diagnoses with younger children.

With respect to the diagnosis of dysarthria, these children achieved repetition rates for monosyllables that were very similar to those obtained from older children. Specifically, all but one child's MRRmono was greater than 3.4 and no child produced a MRRmono that was less than 3 syllables per second. These findings are consistent with other normative studies of syllable repetition rates (Robbins, 1987; Williams & Stackhouse, 2000). However, maximum phonation durations were considerably shorter than those obtained by Thoonen et al. (1996; 1999) for older children. The use of the MPD to adjudicate the one borderline MRRmono resulted in this young normally developing child receiving a dysarthria classification. One possible solution would be to modify the criteria and the procedure so that MPD is not obtained from children younger than 6 years or used in the diagnosis of motor speech disorders with this population. The criteria could be adjusted to involve only MRRmono as follows: Assign a dysarthria score of 0 (not dysarthric) if MRRmono is greater than 3.4; assign a dysarthria score of 1 (undefined) if MRRmono is between 3.0 and 3.4; assign a dysarthria score of 2 (dysarthric) if the MRRmono is less than 3.0 syllables per second. These criteria would result in 95% 'not dysarthric' and 5% 'undefined' diagnoses for the normally developing children described in this report.

With respect to the diagnosis of childhood apraxia of speech, only 40% of our younger sample met the expectation for older children of a trisyllabic rate greater than 4.4 syllables per second, yielding an unambiguous classification of 'not dyspraxic'. However, no child produced a MRRtri less than 3.4 and every child achieved a correct repetition of the sequence [pataka] and thus no children received an unambiguous 'dyspraxic' classification. The use of the MFD to make a decision about children achieving a MRRtri between 3.4 and 4.4 was clearly inappropriate since the range of MFD scores was great and only one-fifth of the sample was able to prolong a fricative for longer than 11 seconds. Again, the criteria could be adjusted so that only the MRRtri is taken into account, as follows: Assign dyspraxia score of 0 (not dyspraxic) if MRRtri is greater than 3.4 seconds; assign dyspraxia score of 1 (undefined) if MRRtri is between 3.0 and 3.4; assign dyspraxia score of 2 (dyspraxic) if MRRtri is less than 3 syllables per second. These criteria would result in 100% 'not dyspraxic' diagnoses for the normally developing children described in this report.

More research is required to cross-validate these recommended criteria with a different and larger sample of 4-to 6-year-old children. Validation of these criteria with children who have clinical diagnoses of dysarthria, childhood apraxia of speech, and phonological disorder of unknown origin is also required.

Further research to develop a procedure to obtain valid maximum phonation and maximum fricative durations from young children would also be valuable. It seems unlikely that normally developing preschoolers are physically unable to sustain a vowel or fricative for longer than 4 seconds. However, they do sometimes have difficulty understanding the instruction to do so. They also seem to require more time to learn to *consciously* control the coordination of respiration and speech production. They may not be sufficiently motivated to sustain a single sound for periods longer than 4 or 5 seconds. The availability of software to provide visual real-time feedback to children about the prolongation performance may help them to learn this task more quickly and motivate them to achieve the goal of sustaining a vowel or fricative for at least the criterion duration.

In the meantime, the practice of asking children to quickly repeat monosyllables and trisyllabic sequences is a valuable part of the assessment and diagnostic process for children with suspected speech sound disorders. Even children as young as four can be expected to repeat monosyllables and trisyllables accurately and at rates exceeding 3 syllables per second.

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