

Oral-diadochokinetic rates for Hebrew-speaking school-age children: Real words vs. non-words repetition

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Abstract

Oral-diadochokinesis (DDK) tasks are a common tool for evaluating speech disorders. Usually, these tasks involve repetitions of non-words. It has been suggested that repeating real words can be more suitable for preschool children. But, the impact of using real words with elementary school children has not been studied yet. This study evaluated oral-DDK rates for Hebrew-speaking elementary school children using non-words and real words. The participants were 60 children, 9–11 years old, with normal speech and language development, who were asked to repeat “*pataka*” (non-word) and “*bodeket*” (Hebrew real word). Data replicate the advantage generally found for real word repetition with preschoolers. Children produced real words faster than non-words for all age groups, and repetition rates were higher for the older children. The findings suggest that adding real words to the standard oral-DDK task with elementary school children may provide a more comprehensive picture of oro-motor function.

Keywords: oral-diadochokinesis, oral-DDK, articulation rate, children, non-words

Introduction

Oral-diadochokinesis (DDK) is a common assessment tool widely used by speech-language pathologists (SLPs) in both research and clinical contexts. It measures how quickly an individual can accurately produce a rapid series of sounds. Accordingly, oral-DDK tasks are of importance in evaluating oro-motor skills of individuals (adults as well as children) with neuro-muscular and speech disorders (Bernthal, Bankson, & Flipsen, 2008; Kent, Kent, & Rosenbek, 1987; Williams & Stackhouse, 2000). The most frequently used measurement of oral-DDK is its rate. In other words, how quickly an individual is able to repeatedly produce strings of syllables. The oral-DDK stimuli that are most frequently used, and for which there are the largest amount of published data, are the monosyllables “pa”, “ta” and “ka” (referred also as Alternate Motion Rates) and

their combination into trisyllabic sequences, “pataka” (Sequential Motor Rates; Fletcher, 1972; Potter, 2005).

The segmental features of the stimuli have an impact on the oral-DDK rate (Shriberg & Kent, 1994), as different consonants have different temporal (durational) characteristics. Furthermore, it has been suggested that the linguistic nature of the stimuli can affect the production rate (Potter, 2005; Yaruss & Logan, 2002). Mainly, using a non-word sequence may impede the performance of young children, while using a real word might reflect more precisely their speaking abilities. The study focuses on the diagnostic implications of using real and non-word stimuli when evaluating the performance of school-age children with the oral-DDK task.

Oral-DDK tasks

Maximum rate of syllable production indicates the speed with which one can move the articulators (mainly, lips and tongue) in a non-word task. Thus, oral-DDK test can estimate spontaneous speech, but is not affected by linguistic (phonological) abilities (Tiffany, 1980). In fact, one of the underlying assumptions in the design of DDK tasks is that the observed level of performance is predominantly the result of neuromotor and not linguistic skills (Wilcox, Morris, Speaker, & Catts, 1996).

Typically, a SLP assesses non-word oral-DDK rate either by counting the number of syllables produced in a given time unit (10 s, count-by-time method) or by calculating the time required for the production of a specified number of syllables (time-by-count method; Fletcher, 1972; Kent et al., 1987). The second method requires fewer operations of the examiner (as he or she needs only to count the defined syllables’ number). A recent analysis of the literature (Icht & Ben-David, 2014) offered an oral-DDK rate norm for young to middle-age adult English speakers repeating the sequence “pataka” of 6.2 syllables/s. In their cross-cultural investigation of published data across five languages (see Table 2 on p. 33), the authors also found that socio-demographic factors, such as one’s spoken language, can affect oral-DDK rates. Icht and Ben-David concluded that providing normative data for speakers of different language (even dialects) is crucial for a correct clinical evaluation. There is also substantial evidence in the literature to show that demographic factors, such as age, affect oral-DDK rates (Canning & Rose, 1974; Fletcher, 1972). Specifically, normative rates are much slower for children than for adults, as will be discussed next.

Oral-DDK rates for children

The literature indicates a gradual increase in oral-DDK rates with age in typically developing children across different languages. For example, Blomquist (1950; 9-11 years), Canning and Rose (1974; 4:6–14:6 years), Fletcher (1972; 6–13 years), Mahler (2012; 4–9 years) and McCann and Wrench (2007; 5–7 years) reported this pattern in English; Modolo, Berretin-Felix, Genaro and Brasolotto (2011; 8–10 years), in Brazilian-Portuguese, and Prathanee, Thanaviratananich and Pongjanyakul (2003; 6–12 years) in Thai.

Overall, findings (with English-speaking children) show that preschool children can typically produce one trisyllabic sequence (“pataka”) per second, resulting in an oral-DDK rate of 3 syllables/s. By the age of six years, this value increases to 4.5 syllables/s (Robbins & Klee, 1987). Adult-like rates of production and temporal consistency are generally achieved by the age of 9–10 years (Canning & Rose, 1974) or even later (by age 15 years; Fletcher, 1972), depending upon the criteria used to indicate adult-like performance. However, there is a high variability in the results of studies examining the oral-DDK performance of children, as these studies have used

different methodologies. For example, some used the time-by-count method (Canning & Rose, 1974; Fletcher, 1972; St Louis & Ruscello, 1987; Williams & Stackhouse, 1998), while others generated the data by the count-by-time procedure (Cohen, Waters, & Hewlett, 1998; Henry, 1990; Potter, 2005; Robbins & Klee, 1987; Yaruss & Logan, 2002). Another difference is the sequence participants are asked to repeat. Typically, non-words are being used (nonsense syllables such as “papapa,” or “pataka”), but some studies have used repetitions of real words, usually “buttercup” and “patty cake” (Canning & Rose, 1974; Robbins & Klee, 1987).

Together, these methodological differences make it difficult to establish unified performance norms. For example, oral-DDK rates for “pataka” sequence with preschool children (4–4:5 year-old), range from 3.63 syllables/s (Yaruss & Logan, 2002) to 4.95 syllables/s (Potter, 2005). Moreover, clinical research questions the compatibility of the task itself to young children (Canning & Rose, 1974). Particularly, Yaruss and Logan (2002) claim that some preschool age children have difficulties complying with the task’s instructions, while others fail to complete the oral-DDK task, as described in the following section.

The complexity of oral-DDK tasks for children

Oral-DDK tasks are frequently used to assess children, both in clinical and research settings. However, the common administration protocols might generate possible challenges specific to this population. These difficulties relate to the instructions given, to the task demands, to the modelling protocol and to the nature of the stimuli.

Instructions and task demands

The unnatural demands of maximum performance tasks can be challenging for young children (Wit, Maassen, Gabreëls, & Thoonen, 1993). In most studies, the experimenters instructed the child to produce sequences at a maximum rate by using phrases such as “as fast as possible”, “as quickly as possible” or “as fast as you can”. Some clinicians also stress accuracy, asking the children to repeat each syllable “as quickly as possible, without making a mistake” (Canning & Rose, 1974), or “as quickly and accurately as possible” (Yaruss & Logan, 2002). Cohen et al. (1998) suggest that children may respond to these instructions by increasing their loudness instead of their production rate. Williams and Stackhouse (2000) also observed that young children often became louder as they attempted to become faster. Another challenge relates to the demand to persist in repeating the syllable sequence. The instruction to “keep going until I tell you to stop” may direct children to remain alert for the stopping cue, instead of sustaining the repetition task at maximum speed (for a review on attentional demands, see Ben-David & Algom, 2009).

Modelling protocol

An inspection of the literature shows a high variability in the modelling protocol (how and when the experimenter demonstrates the task) used with children. In some studies, the experimenter provided a model only when the child did not follow the auditory instructions (Robbins & Klee, 1987). Others provided a model only before practice trials (Williams & Stackhouse, 1998), while some used a multi-step modelling process (Thoonen, Maassen, Gabreëls, & Schreuder, 1999; where the model was given on several occasions). This inconsistency in modelling protocols can contribute to the variance in the reported results.

The stimuli

As previously described, oral-DDK task is used to investigate an individual’s speech motor ability free from linguistic factors, as it involves repetition of nonsense syllables strings (non-words).

However, it is possible that the production of unfamiliar, nonsense, stimuli can be cumbersome for young children. For example, the commonly used trisyllabic sequence “pataka” can be too abstract for them (Canning & Rose, 1974). Indeed, Yaruss and Logan (2002) reported that 6 of the 15 participants they tested (mean age 46.5 months) were unable or unwilling to produce non-words (although Williams & Stackhouse, 2000, have failed to demonstrate this pattern within three- to five-years-old children). In addition, evaluating young (preschool) children, difficulties in correct production of one or more of the target phonemes may affect overall rate (and obviously, accuracy). For example, a typical phonological process of fronting may be reflected in a substitution of the target phoneme /k/ in /t/ (Pena-Brooks & Hegde, 2000). As these phonemes have different temporal features (Ladefoged & Johnson, 2014), fronting may affect the rate of repetition.

Summary

Overall, it seems that oral-DDK tasks can be quite challenging for young children (Cohen et al., 1998). A possible way to make this task more simple and accessible for children is the use of real words, as discussed next.

Evaluating children’s oral-DDK rates using real words

There is an ongoing debate regarding the use of non-words versus real words in oral-DDK tasks. Clearly, the inclusion of real words into a DDK test battery adds a linguistic dimension to the assessment (Wilcox et al., 1996). Some investigators recommend using only word stimuli for the assessment of children (Netsell, 2001) for the reasons detailed above. Others advise including both real and non-words (Canning & Rose, 1974; Robbins & Klee, 1987) to provide a more global vantage point. Accordingly, Williams and Stackhouse (1998) suggest that each stimulus involves different demands on a child’s neuro-motor and linguistic processing. Real word repetition assesses a child’s ability to access a stored motor program through linguistic cues. Whereas non-word repetition assesses the ability to access a new (or less familiar) motor program in the absence of linguistic cues (Tiffany, 1980).

Examining the real words used in oral-DDK tasks for English speakers, they appear to share the phonological characteristics of the commonly used trisyllabic nonsense sequences. For example, “pataka” is replaced by using the word “pattycake”. The target consonants of both stimuli are identical – all voiceless plosives that represent different places of articulation (lips, tongue tip and tongue dorsum). Yet, there are two differences between these stimuli: (a) the second vowel is different, (b) the prosodic structure of the final syllable – CVC in “pattycake”, but CV in “pataka”. Note that the real word stimulus carries an extra consonant, hence an additional temporal component. This difference may, in fact, slow down the repetition rate for real word versus the non-word stimulus. Comparing another real word “buttercup”, commonly used to replace the non-word “pataka”, two more differences arise: (c) the onset of the first syllable – the voiced bi-labial plosive /b/ rather than its counterpart voiceless /p/, and (d) the second syllable is of CVC structure (instead of CV in the non-word stimulus). Again, this may extend the duration of the real word relative to the non-word.

Most of the studies that examined children’s performance with these real words stimuli found faster oral-DDK rates compared to performance with the common nonsense stimuli (Canning & Rose, 1974; Robbins & Klee, 1987; Yaruss & Logan, 2002). It is notable that the facilitating impact of real word repetition was found to interact with the age of young children. Using real words appears to generate a clear benefit for children from the age of four years old, but no benefit for three-year-old children (Williams & Stackhouse, 1998). Williams and Stackhouse (2000) noted

that the distinction between real and non-word repetitions becomes clearer as the child reached school age. Finally, the advantage in performance with real words was questioned by Potter (2005), who found reversed results – higher oral-DDK rates for non-words than for one of the two real words she tested (“pattycake”) with preschool children (aged 3–5:5 years). This calls for further comparison of real and non-word oral-DDK tasks with school-age children, as conducted in our study presented next.

The present study

Oral-DDK tasks are widely used in evaluation procedures of children with speech and language disorders, such as stuttering, dysarthria and childhood apraxia of speech. However, the traditional non-word repetition oral-DDK rates may not give a reliable picture of the child’s speaking abilities. Given the possible difficulties young children can face with the task, using real word repetition could provide a meaningful supplement to this measure, gaining a more holistic look of the child’s oro-motor mechanism.

The main goal of this study was to test whether a real word advantage in oral-DDK task will be found with elementary school children (9, 10 and 11 years old). Performance in real word oral-DDK task was found to be faster for preschool children (aged 4–6 years old; Canning & Rose, 1974; Robbins & Klee, 1987; Yaruss & Logan, 2002). Hitherto, the performance of elementary school children (7–11 years old) has not been tested with real word repetition. It is not clear if the same speeded performance with real words will be found for 9 to 11 year olds, or whether age will eliminate the need to use both type of stimuli.

Our second goal was to test the increase in oral-DDK rate with age in Hebrew speaking elementary school children. Gradual maturation of speech production is reflected in improved motor coordination – increased speed and accuracy (consistency) of performance (Henry, 1990; Kent et al., 1987). This is evident primarily after the age of four years (Williams & Stackhouse, 1998). Indeed, the literature on preschool children indicates an increase in oral-DDK rates with age in typical development. With elementary school children, there are similar findings mainly for non-word repetition (with English speakers, Fletcher, 1972; Mahler, 2012). However, there is only scant evidence on real word repetition with this age group (Robbins & Klee, 1987). It is reasonable to assume that our data, with Hebrew speakers, will follow the same pattern. Yet, the limited data in the literature clearly merit replication.

The third goal of this study was to offer tools for oral-DDK testing in Hebrew with children. Examining the literature, no real word has been used in Hebrew, limiting oral-DDK testing to non-word sequences. This paper presents a pioneer examination of a real word (phonologically controlled) oral-DDK task in Hebrew, possibly providing a more diagnostic measure for speech production (and/or articulation rate) at a young age. Furthermore, as no performance norms for oral-DDK rates in Hebrew are available, our study aims to provide preliminary baseline data with Hebrew-speaking elementary school children. Finally, we suggest a dual evaluation protocol in Hebrew, using both real and non-words that can be used in clinical practice and research.

Method

Participants

Sixty children (30 males), unpaid volunteers, participated in this study. Of the 60 participants, 20 (10 males) were 9 years old (between 8.9 and 9.2 years old), 20 (10 males) were 10 years old

(between 9.9 and 10.3 years old) and the remaining 20 (10 males) were 11 years old (between 10.10 and 11.3 years old).

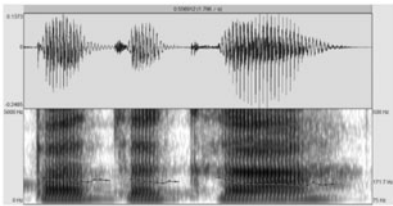
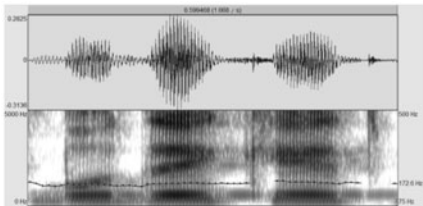
We note that typically developing children in this age group have already fully acquired the phonological systems (segmental and prosodic features) of their native language. This is a usual finding in Hebrew (the tested language in our study, see: Bat-El, 2009; Ben-David, 2001), in English (Dodd, Holm, Hua & Crosbie, 2003) and in other languages (e.g. Arabic: Amayreh & Dyson, 1998).

All participants were pupils from public elementary schools, visiting community centres in two medium sized cities in the centre of Israel, with a comparable socioeconomic status and cultural background (as reported by their parents). They were all native Hebrew speakers (none were bilinguals), whose parents (by filling a written questionnaire) reported no history of speech or hearing difficulties, neurological disease, abnormal oral structure/function and/ or phonetic (articulation) disorders. This study received prior approval from the local ethics committee and from the related community centres. Written informed consent was obtained from all of the participants' families and all children assented.

Apparatus and materials

Oral-DDK task was performed twice, once using a non-word and once using a real word. For non-word, we used the trisyllabic sequence ‘‘pataka’’, as it is a widely used sequence, for which normative data for adults is available in Hebrew (Icht & Ben-David, 2014). For real word (that, hitherto, has not been used in Hebrew), we chose the word ‘‘bodeket’’ (the female rendition of the noun *examiner* or the verb *inspecting* in Hebrew). It is a familiar Hebrew word (Frost & Plaut, 2005) that shares phonological features with ‘‘pataka’’, the non-word stimulus (Table 1) and also with ‘‘buttercup’’ and ‘‘pattycake’’, the real words used in evaluating oral-DDK with English-speaking children. It is notable that this word does not carry an emotional valence (on the effects of emotional valence, see Ben-David, Cahjut & Algom, 2012; Ben-David, van Lieshout & Leszcz,

Table 1. The phonological characteristics of the real Hebrew word ‘‘bodeket’’ and the non-word ‘‘pataka’’.

| | /pa.ta.ka./ | /bo./dɔ.kɛt./ |
|--------------------|---|--|
| Segmental features | | |
| Target consonants | /p, t, k/ – all voiceless plosives | /t, k/ – voiceless plosive /b, d/ –voiced plosives |
| | Places of articulation: lips, tongue tip and tongue dorsum | |
| Target vowels | /a/ | /o, ə/ |
| Prosodic features | | |
| Syllable structure | cv.cv.cv | cv.cv.cvc |
| Stress | --- | Penultimate |
| Spectral analysis |  |  |

Spectral analysis was conducted using PRAAT software (V. 5383 for windows), with a digital recording of the first author (a native Hebrew speaking female with an Israeli accent) with a sampling rate of 44 100 Hz.

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2011). Count-by-time oral-DDK rates were audio-recorded for each participant, using a Sony ICD-PX312 digital recorder placed on a table, 25 cm from the participant's mouth.

Procedure

The participants were tested individually in a quiet room at the local community centre. Before arrival, parents were informed on the study, signed a consent form and filled out the questionnaire. Upon arrival, each participant received a short explanation regarding the oral-DDK task. First, the task (real or non-word repetition) was demonstrated once to each participant by a research assistant (SLP student), and the participant was allowed to practice the task for one minute. Next, the participant was asked to repeat the stimulus, as fast and accurate as he/she can ("now, please repeat these syllables once again, as quickly as possible, without making a mistake, until I will signal you to stop"; for detailed administration protocols, see Potter, 2005) for 10 s, using a count-by-time method. For half the participants, the non-word "pataka" was presented as the first task and the real word "bodeket" as the second, and for the other half, this order was reversed. Following the practice phase, each participant performed each task (real and non-word repetition) once. The whole session lasted no more than 10 min.

Data analysis

Oral-DDK rate (syllables/s) was calculated by multiplying the total number of trisyllables ("pataka" or "bodeket") produced by each participant in 10 s, by 0.3. In case that a trisyllable was only partially completed by the time 10 s elapsed, it was excluded. Counting was performed manually from the digital recordings by two trained SLP students. When the two did not agree on a specific sample, it was recounted by both until a consensus was reached. The order of the tasks (real and non-word repetition) was not found to have a significant impact on the data ($F < 0.5$) and will not be analyzed further.

Results

Figure 1 presents average oral-DDK rates and standard errors (syllables/s) for trisyllabic real word and non-word repetition for the three tested groups of children. In a careful examination of Figure 1, two clear results are evident. First, across the three examined ages, children produced real words faster than non-words (mean number of syllables per second for real words: $M = 5.2$ syllables/s, $SE = 0.17$; and for non-words: $M = 4.55$ syllables/s, $SE = 0.26$). Second, Oral-DDK rates appear to increase moving from 9 to 11 years of age for both the real word task ($M = 4.85$ syllables/s, $SE = 0.13$ vs. $M = 5.61$ syllables/s, $SE = 0.17$, for 9 and 11 years old, respectively) and the non-word task ($M = 4.08$ syllables/s, $SE = 0.23$ vs. $M = 5.12$ syllables/s, $SE = 0.15$, for 9 and 11 years old, respectively).

Statistical analysis supports these conclusions using a repeated measures ANOVA with age (9, 10 and 11 years old) and gender (boys, girls) as a between participants variable, and type of stimuli (non-word, real word) as a within participants variable. Analysis revealed a significant main effect for age ($F(2,54) = 9.16$, $p < 0.001$, $\eta_p^2 = 0.25$), where rates increased with age, and a main effect for the type of stimulus ($F(1,54) = 15.47$, $p < 0.001$, $\eta_p^2 = 0.22$), with faster overall performance for real word repetition. No significant interaction of the two was found ($F < 1$), indicating that all age-groups have benefitted similarly from using a real word (see detailed data in Table 2). Examining gender, we found no main effect ($F < 1$) with similar averages for boys and girls. We note a marginally significant trend for an interaction of gender and type of stimulus ($F(1,54) = 3.58$, $p = 0.06$), as girls benefitted more from using a real word than boys did (a benefit of .97 syllables/s,

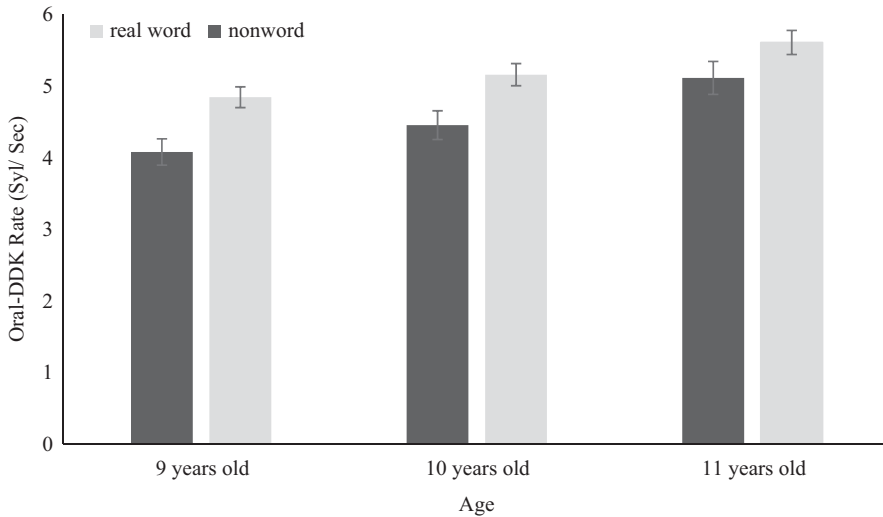


Figure 1. Oral-DDK rates (Means and SEs, Syl/s) for real and non-word repetition across the different ages (gauged by the count-by-time method).

Table 2. Oral-DDK mean rates (Syl/s) and SEs (in parenthesis) for real and non-word repetition across the different ages.

| Age (years) | Oral-DDK rates (Syl/s) | | Percent increase |
|----------------|------------------------|-------------|---------------------|
| | Non-word | Real word | |
| 9 | 4.08 (0.22) | 4.85 (0.13) | 18.8 |
| 10 | 4.46 (0.33) | 5.16 (0.15) | 15.8 |
| 11 | 5.12 (0.14) | 5.61 (0.17) | 9.7 |
| Average | 4.55 (0.15) | 5.21 (0.10) | 14.4 |

$SE = 0.3$ vs. 0.34 syllables/s, $SE = 0.26$ for girls and boys, respectively). However, the effect size for the interaction was minute, $\eta_p^2 = 0.06$. No other significant interactions were found.

To examine the development-related differences more closely, three post-hoc paired comparisons of: (i) 9 and 10 year olds, (ii) 10 and 11 year olds and (iii) 9 and 11 year olds (Bonferroni corrected) were conducted. Significant effects for age were observed only in the two latter comparisons ($F(1,36) = 6.3$, $p = 0.02$, $\eta_p^2 = 0.15$; $F(1,36) = 21.71$, $p < 0.001$, $\eta_p^2 = 0.38$). This suggests that the performance of nine and ten year olds was not significantly different from each other ($F(1,36) = 2.44$, $p > 0.1$), but both of these groups performed with slower oral-DDK rates than 11 year olds.

Discussion

The oral-DDK task is a basic and quick tool for the assessment of oro-motor functions. It is part and parcel of a standard SLP's test-battery for children. In fact, poor performance on oral-DDK tasks has become the most common criterion for identifying and selecting participants for studies of developmental dyspraxia (McCabe, Rosenthal & McLeod, 1998). The most common protocol

for this task involves the repetition of a non-word trisyllable sequence. However, it has been suggested that preschool children may have difficulties with this non-word sequence. As a possible solution, real word repetition was suggested as a more accurate test for functional oro-motor and speech abilities with preschool children. In this study, we have shown that this advantage goes beyond preschool years and extends to elementary school as well. We compared oral-DDK rates for real word and non-word repetition among 60 children, 9 to 11 years old. We note that typically, speech (phonological) abilities have already been mastered in this age range, thus any difference between the two stimuli may not be attributed to segmental and prosodic acquisition.

Real words vs. non-words

This study is the first to provide a comparison of real word and non-word repetition in an oral-DDK task with school-age children. We found a 14% advantage for real word repetition (averaging across the three ages tested, see Table 2 for detailed data). This advantage is notable especially as the real word tested in our study has a longer prosodic structure than the non-word (the final syllable is of a CVC structure in the former and a CV in the latter). This result is comparable to previous findings with preschool children (Canning & Rose, 1974; Robbins & Klee, 1987; Yaruss & Logan, 2002; but see, Williams & Stackhouse, 2000). It appears that non-words present a challenge even for 11-year-old speakers.

Several hypotheses have been offered to explain the advantage for real word repetition. First, most likely there are motor programs stored for real word repetition (generated by linguistic cues), but such programs do not exist for non-words. The hypothesis stipulates that the neural loop for producing a word once is similar to that used for repeating it over and over again. However, when repeating non-words, the absence of neuro-motor programs and other linguistic information can impair praxis and slowdown production (Williams & Stackhouse, 2000). In other words, different neuro-motor programs may be activated for producing the same phonemes in the context of a real word and in the context of a non-word. Second, the abstract, non-familiar, nature of nonsense syllable-sequences is challenging for young children (for the reasons described in detail in the outset of this study). For example, young children may be occupied by trying to figure out the meaning of the non-word, slowing down their performance.

We recommend using a dual assessment procedure for elementary school children, including repetition of both real word and non-word stimuli. Such protocol may be significant in the differential diagnosis of children's speech difficulties. Moreover, the difference in performance between the two conditions can be informative for the clinician. In this respect, when contrasting oral-DDK rates of real words against non-words with young children, it is important to choose a real word that typically exists in the expressive lexicon of the relevant age-group (Williams & Stackhouse, 1998).

Demographics

Development-related effects

Our data show an increase in oral-DDK rates as the age of children changes from 9 to 11 years old. Specifically, we found no significant difference in performance between 9 and 10 year olds. But, the performance of 11 year olds was significantly better than that of nine and ten year olds combined, both in real word repetition (by 12%) and non-word repetition (by 19.9%). Examining Figure 1 once more, the impact of age and stimulus type appear to be additive. Namely, the real word advantage for 11 year olds was not significantly different than that of nine year olds. Upon a closer inspection, it is noteworthy that this real word advantage was more stable in the eleven year

old group (standard deviations of 0.17 syllables/s for the difference between real and non-word repetition rates) than for our younger participants (0.8 syllables/s, Levene's test, $L(1,58) = 7.83$, $p < 0.001$). This last evidence is consistent with the pattern of maturation of the oro-motor systems in this age range (Robbins & Klee, 1987).

Gender effect

Gender was not found to be a contributing factor to oral-DDK performance in our sample of elementary-school Hebrew speakers. This result echoes findings in the literature, as no gender-effects were found in former studies examining oral-DDK in children (Fletcher, 1972; Modolo et al., 2011).

Order effects

The order of the tasks (real word and non-word repetition) was not found to have a significant impact on the data. However, we note the following interesting trend. When the real word task was administered first, the real word advantage was nominally larger than when the non-word task was first administered ($F(1,40) = 3.37$, $p = 0.075$). In other words, it appears that children's performance may not be stable across the evaluation session. Perhaps, this may be attributed to fatigue, or even boredom, with this simple repetitive task. For these reasons, many assessment tools for children have been adapted to include age appropriate stimuli and protocols (e.g., see the children adapted version of Wisconsin Card Sorting Test, Chelune & Baer, 1986). Accordingly, while we recommend using a dual administration protocol, a careful selection of the tasks' order might be advisable.

Language context

Hebrew

To our knowledge, this article is the first available paediatric data for oral-DDK rates with Hebrew speakers. Our results can provide comparative data for clinicians exploring alterations in motor speech with Hebrew-speaking children. Moreover, this study is the first to offer (and to test) a Hebrew word for the assessment of real word oral-DDK rates. We carefully chose the common Hebrew word "bodeket", which shares the main phonological features (segmental and prosodic) with the non-word common sequence "pataka" (Table 1). Our experience in this study (as well as clinical observations made by the first author) shows that this word can serve as an appropriate stimulus for the oral-DDK task with young children.

Cross-language comparison

Table 3 offers a comparison of non-word oral-DDK data for school-age children across four languages (for the method of collecting and analyzing data across studies, see Ben-David, Nguyen, & van Lieshout, 2011; Ben-David & Schneider, 2009; Ben-David, Tewari, Shakuf, & van Lieshout, 2014). Careful inspection of Table 3 reveals that the Hebrew data collected in this study is well within the range of published data on other languages. This adds validity to our Hebrew sample. Not surprisingly, the Table reflects the high variability between the languages (nine year olds: $F(3,116) = 8.82$, $p < 0.001$, $\eta_p^2 = 0.2$; 10 years olds: $F(3,115) = 8.84$, $p < 0.001$, $\eta_p^2 = 0.2$).

The cross-language variability in oral-DDK rates was also reported in a recent analysis of adult performance (Icht & Ben David, 2014). In that analysis, data was collected from 10 different oral-DDK studies with adults speaking English, Portuguese, Greek, Farsi and Hebrew. The rates were found to differ significantly between languages. The authors suggested that cultural characteristics

Table 3. Oral-DDK mean rates (Syl/s) for 8–11 years old children, with the non-word sequence ‘‘pataka,’’ across languages.

| Study | Language | Age in years | | | |
|-------------------------|----------------------|--------------|-------------|-------------|-------------|
| | | 8 | 9 | 10 | 11 |
| Fletcher (1972) | English | 3.61 (0.87) | 3.89 (1.01) | 4.23 (.89) | 4.62 (1.06) |
| Prathanee et al. (2003) | Thai | 4.30 (0.78) | 4.66 (1.34) | 4.98 (1.12) | 5.34 (1.65) |
| Modolo et al. (2011) | Brazilian–Portuguese | 4.65 (0.95) | 5.10 (0.60) | 5.46 (0.65) | – |
| Present study | Hebrew | – | 4.08 (0.99) | 4.46 (1.47) | 5.12 (0.63) |

Standard deviations are presented in parenthesis.

of the populations, in addition to differences in the phonological systems (as well as other prosodic features) of the tested languages may engender this variance in rates. Alternatively, differences between studies may be related to methodological inconsistencies between laboratories (e.g. administration protocols).

This study stresses the need for validating clinical tools across languages before one ‘‘imports’’ a test or a norm (see a discussion in Greenfield, 1997). Applying cultural sensitivity to clinical assessment tools is called for in other fields of speech-language disorders, as well (e.g. in the field of voice disorders, the Voice Handicap Index questionnaire was translated to Swedish, Dutch, German, French, Hebrew, Arabic, see: Amir et al., 2006; Malki, Mesallam, Farahat, Bukhari & Murry, 2010; Ohlsson & Dotevall, 2009). When adapting the oral-DDK task to a different language and culture, one must note the frequency of usage of spoken words, the common phonemes and syllabic structures in a language, as well as consider constructing a cultural-sensitive protocol.

Limitations

It is notable that our study was limited in its scope, as we focused on testing the oral-DDK rate – a measure that can be easily assessed in SLP clinics. Clearly, there are other measures that can be gauged in an oral-DDK task. It may be interesting to compare the frequency of articulation errors or speech disfluencies between real and non-word repetitions. Evaluating physiological factors (e.g. tongue strength) or adding an acoustical analysis of the participants’ vocal productions (for example, calculating the degree of the rate variation indicating the ability to maintain a constant vocalization rate) can also be informative. We also note that, in order to generate a baseline for performance, all of our participants were characterized as typically developed children. Future evaluation of the dual protocol with special population can provide indicative clinical information on this test. Finally, as listed in Table 1, the real word used in our study naturally does not share the exact same phonological structure with the non-word. This by itself may have an impact on performance. However, the differences are minute and similar in scope to those found with the commonly used English real words for oral-DDK testing (‘‘buttercup’’ and ‘‘pattycake’’).

Conclusions

This study investigated the performance of school-age (typically developing) children on a pair of oral-DDK tasks commonly used in clinical practice, real word and non-word repetition. Our results show that real word repetition was significantly faster than non-word. A developmental pattern was documented, as performance rates were faster for 11 year olds than for 9 or 10 year olds. We suggest a dual oral-DDK protocol (including real words and non-words) for the

assessment of oro-motor deficits in elementary school children. A dual-protocol allows for the comparison of neuromotor skills (non-word repetition) with linguistic skills (real word repetition). This approach can provide diagnostically relevant data, improving SLPs' evaluation and intervention processes (Caruso & Strand, 1999; Thoonen et al., 1999).

This study was the first to suggest an appropriate Hebrew real word that can be used in oral-DDK tasks. Our results can serve as a preliminary baseline for the performance rates of normally developed elementary school Hebrew speaking children. From a clinical perspective, this type of data is essential for the correct interpretation of performance, allowing appropriately targeted intervention programs. This study calls for further investigation of the impact of real word versus non-word repetition on oral-DDK performance, across ages and languages. Specifically, future studies can determine the efficiency and the implications of using a dual (non-word and real word) oral-DDK protocol.

Declaration of interest

The authors report no conflict of interest.

References

- Amayreh, M. M., & Dyson, A. T. (1998). The acquisition of Arabic consonants. *Journal of Speech, Language, and Hearing Research, 41*, 642–653.
- Amir, O., Ashkenazi, O., Leibovitz, T., Michael, O., Tavor, Y., & Wolf, M. (2006). Applying the Voice Handicap Index (VHI) to dysphonic and nondysphonic Hebrew speakers. *Journal of Voice, 20*, 318–324.
- Bat-El, O. (2009). Harmonic domains and synchronization in typically and atypically developing Hebrew-speaking children. *Language Sciences, 31*, 117–135.
- Ben-David, A. (2001). *Language acquisition and phonological theory: Universal and variable processes across children and languages* (Unpublished Doctoral Dissertation). Tel-Aviv University, Tel-Aviv, Israel.
- Ben-David, B. M., & Algom, D. (2009). Species of redundancy in visual target detection. *Journal of Experimental Psychology: Human Perception and Performance, 35*, 958–976.
- Ben-David, B. M., Chajut, E., & Algom, D. (2012). The pale shades of emotion: A signal detection theory analysis of the emotional Stroop task. *Psychology, 3*, 537–541.
- Ben-David, B. M., Nguyen, L. L. T., & van Lieshout P. H. H. M. (2011). Stroop effects in persons with traumatic brain injury: Selective attention, speed of processing or color-vision? *Journal of the International Neuropsychological Society, 17*, 354–363.
- Ben-David, B. M., & Schneider, B. A. (2009). A sensory origin for aging effects in the color-word Stroop task: An analysis of studies. *Aging, Neuropsychology, and Cognition, 16*, 505–534.
- Ben-David, B. M., Tewari, A., Shakuf, V., & van Lieshout, P. H. H. M. (2014). Stroop effects in Alzheimer's disease: Selective attention, speed of processing or color-naming? A meta-analysis. *Journal of Alzheimer's Disease, 38*, 923–938.
- Ben-David, B. M., Van Lieshout, P. H. H. M., & Leszcz, T. (2011). A resource of validated affective and neutral sentences to assess identification of emotion in spoken language after a brain injury. *Brain Injury, 25*, 206–220.
- Bernthal, J. E., Bankson, N. W., & Flipsen, P. (2008). *Articulation and phonological disorders* (6th Edition). Boston, MA: Allyn & Bacon Pub.
- Blomquist, B. L. (1950). Diadochokinetic movements of nine-, ten-, and eleven-year-old children. *Journal of Speech Disorders, 15*, 159–164.
- Canning, B. A., & Rose, M. F. (1974). Clinical measurement of the speed of tongue and lip movements in British children with normal speech. *British Journal of Disorders of Communication, 9*, 45–50.
- Caruso, A. J., & Strand, E. A. (Eds.). (1999). *Clinical management of motor speech disorders in children*. New York: Theime.
- Chelune, G. J., & Baer R. A. (1986). Developmental norms for the Wisconsin Card Sorting Test. *Journal of Clinical and Experimental Neuropsychology, 8*, 219–228.
- Cohen, W., Waters, D., & Hewlett, N. (1998). DDK rates in the pediatric clinic: A methodological minefield. *International Journal of Language & Communication Disorders, 33*, 428–433.

- Dodd, B., Holm, A., Hua, Z., & Crosbie, S. (2003). Phonological development: A normative study of British English-speaking children. *Clinical Linguistics and Phonetics*, 17, 617–643.
- Fletcher, S.G. (1972). Time-by-count measurement of DDK syllable rate. *Journal of Speech and Hearing Research*, 15, 763–770.
- Frost, R., & Plaut, D. C. (2005). The word-frequency database for printed Hebrew. Retrieved 3 June 2013, from: <http://word-freq.mscc.huji.ac.il/index.htm>.
- Greenfield, P. M. (1997). You can't take it with you: Why ability assessments don't cross cultures. *American Psychologist*, 52, 1115–1124.
- Henry, C. (1990). The development of oral diadochokinesia and non-linguistic rhythmic skills in normal and speech-disordered young children. *Clinical Linguistics & Phonetics*, 4, 121–137.
- Icht, M., & Ben-David, B. M. (2014). Oral-diadochokinesis rates across languages: English and Hebrew norms. *Journal of Communication Disorders*, 48, 27–37.
- Kent, R. D., Kent, J., & Rosenbek, J. (1987). Maximal performance tests of speech production. *Journal of Speech and Hearing Disorders*, 52, 367–387.
- Ladefoged, P., & Johnson, K. (2014). *A course in phonetics* (7th Ed.). Stamford, CT: Cengage Learning.
- Malki, K. H., Mesallam, T. A., Farahat, M., Bukhari, M., & Murry, T. (2010). Validation and cultural modification of Arabic voice handicap index. *European Archives of Oto-Rhino-Laryngology*, 267, 1743–1751.
- Mahler, B. (2012). *Comparing motor speech skills of children with high functioning autism versus those of typically developing children using diadochokinetic tasks* (Unpublished Thesis). The Ohio State University, Columbus, OH.
- McCann, J., & Wrench, A. A. (2007). A new EPG protocol for assessing DDK accuracy scores in children: A Down s syndrome study. In Trouvain, J. & Barry, W.J. (Eds), *16th International Congress of Phonetic Sciences*. Saarbrücken, Germany: Saarland University.
- McCann, J., & Wrench, A. A. (2007). A new EPG protocol for assessing DDK accuracy scores in children: A Down's syndrome study. *Proceedings of the 16th International Congress of the ICPhS* (pp. 1985–1988).
- Modolo, D. J., Berretin-Felix, G., Genaro, K. F., & Brasolotto, A. G. (2011). Oral and vocal fold diadochokinesis in children. *Folia Phoniatrica et Logopedica*, 63, 1–8.
- Netsell, R. (2001). Speech aeromechanics and the dysarthrias: Implications for children with traumatic brain injury. *Journal of Head Trauma Rehabilitation*, 16, 415–425.
- Ohlsson, A. C., & Dotevall, H. (2009). Voice handicap index in Swedish. *Logopedics Phoniatrics Vocology*, 34, 60–66.
- Pena-Brooks, A., & Hegde, M. N. (2000). *Assessment and treatment of articulation and phonological disorders in children*. Austin, TX: PRO-ED, Inc.
- Potter, N. L. (2005). *Oral/speech and manual motor development in preschool children* (Unpublished PhD dissertation), University of Wisconsin-Madison, Madison, WI.
- Prathanee, B., Thanaviratnanich, S., & Pongjanyakul, A. (2003). Oral diadochokinetic rates for normal Thai Children. *International Journal of Language and Communication Disorders*, 38, 417–428.
- Robbins, J., & Klee, T. (1987). Clinical assessment of oropharyngeal motor development in young children. *Journal of Speech and Hearing Disorders*, 53, 271–277.
- Shriberg, L. D., & Kent, R. D. (1994). *Clinical phonetics* (2nd Edition). New York: Wiley.
- St Louis, K.O., & Ruscello, D. M. (1987). *Oral speech mechanism screening examination – Revised (OSMSE-R)*. Texas: PRO-ED.
- Thoonen, G., Maassen, B., Gabreels, F., & Schreuder, R. (1999). Validity of maximum performance tasks to diagnose motor speech disorders in children. *Clinical Linguistics & Phonetics*, 13, 1–23.
- Tiffany, W. R. (1980). The effects of syllable structure on diadochokinetic and reading rates. *Journal of Speech & Hearing Research*, 23, 894–908.
- Wilcox, K. A., Morris, S. R., Speaker, K. D. & Catts, H. W. (1996). The effect of syllable shape on articulatory rate and stability. In T. W. Powell (Ed.) *Pathologies of Speech and Language: Contributions of clinical phonetics and linguistics* (pp. 163–166). New Orleans, SLA: I.C.P.L.A.
- Williams, P., & Stackhouse, J. (1998). Diadochokinetic skills: Normal and atypical performance in children aged 3–5 years. *International Journal of Language and Communication Disorders*, 33, 481–486.
- Williams, P., & Stackhouse, J. (2000). Rate, accuracy and consistency: Diadochokinetic performance of young, normally developing children. *Clinical Linguistics & Phonetics*, 14, 267–293.
- Wit, J., Maassen, B., Gabreels, F. J. M., & Thoonen, G. (1993). Maximum performance tests in children with developmental spastic dysarthria. *Journal of Speech, Language, and Hearing Research*, 36, 452–459.
- Yaruss, J. S., & Logan, K. (2002). Evaluating rate, accuracy, and fluency of young children's diadochokinetic productions: A preliminary investigation. *Journal of Fluency Disorders*, 27, 65–86.