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Research Report

Oral-diadochokinetic rates for Hebrew-speaking healthy ageing population: non-word versus real-word repetition

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Abstract

Background: Oral-diadochokinesis (oral-DDK) tasks are extensively used in the evaluation of motor speech abilities. Currently, validated normative data for older adults (aged 65 years and older) are missing in Hebrew. The effect of task stimuli (non-word versus real-word repetition) is also non-clear in the population of older adult Hebrew speakers.
Aims: (1) To establish a norm for oral-DDK rate for older adult (aged 65 years and older) Hebrew speakers, and to investigate the possible effect of age and gender on performance rate; and (2) to examine the effects of stimuli (non-word versus real word) on oral-DDK rates.
Methods & Procedures: In experiment 1, 88 healthy older Hebrew speakers (60–95 years, 48 females and 40 males) were audio-recorded while performing an oral-DDK task (repetition of /pataka/), and repetition rates (syllables/s) were coded. In experiment 2, the effect of real-word repetition was evaluated. Sixty-eight older Hebrew speakers (aged 66–95 years, 43 females and 25 males) were asked to repeat '*pataka*' (non-word) and '*bodeket*' (Hebrew real word).
Outcomes & Results: Experiment 1: Oral-DDK performance for older adult Hebrew speakers was 5.07 syllables/s (SD = 1.16 syllables/s), across age groups and gender. Comparison of this data with Hebrew norms for younger adults (and equivalent data in English) shows the following gradient of oral-DDK rates: ages 15–45 > 65–74 > 75–86 years. Gender was not a significant factor in our data. Experiment 2: Repetition of real words was faster than that of non-words, by 13.5%.
Conclusions & Implications: The paper provides normative values for oral-DDK rates for older Hebrew speakers. The data show the large impact of ageing on oro-motor functions. The analysis further indicates that speech and language pathologists should consider separate norms for clients of 65–74 years and those of 75–86 years. Hebrew rates were found to be different from English norms for the oldest group, shedding light on the impact of language on these norms. Finally, the data support using a dual-protocol (real- and non-word repetition) with older adults to improve differential diagnosis of normal and pathological ageing in this task.

Keywords: oral-diadochokinesis (oral-DDK), ageing, Hebrew, oral-motor function, word repetition.

What this paper adds

What is already known on the subject?

Oral-DDK tasks are routinely used by speech and language pathologists evaluating motor speech disorders. Age and language are known to affect oral-DDK rates. Normative data for Hebrew speakers are available for school-age children and young adults, yet are missing for older adults.

What this paper adds

Oral-DDK rates for Hebrew-speaking older adults, aged 60–95 years, are provided. Rates for the oldest group (75–86-year-olds) were found to be different from English norms, shedding light on the impact of language on

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these norms. In the current study, age was found to slow performance rate, where 75–86-year-olds were slower than 65–74-year-olds, yet gender did not. The data also show faster rates using real-word relative to non-word stimuli. Finally, the data call for using a dual-protocol (real- and non-word repetition) with older adults to improve diagnosis. The study provides possible norms for oral-DDK rates in Hebrew for different age groups of older adults, with real- and non-word repetition, to be used in the clinic. The data suggest that a speech and language pathologist should generally consider using different norms for 65–74- and 75–86-year-old clients. Results highlight the importance of using different language specific norms for oral-DDK rates, specifically for older adults. Finally, findings suggest using a dual assessment procedure for older adults (regardless of language), which includes both real-word repetition and non-word repetition, to improve differential diagnosis of normal and pathological ageing in this task.

Introduction

Speech–language pathologists (SLPs) frequently use oral-diadochokinesis (oral-DDK) tasks as part of assessing speech disorders (Williams and Stackhouse 1998). Such tasks require rapidly repeated and coordinated movements of the articulators, and thus are an important measure of oro-motor skills (Fletcher 1972). In order to interpret clinical data accurately it is necessary to have knowledge of normative performance. These norms need to take into consideration factors such as age, gender and language/culture (Icht and Ben-David 2014). Examining the literature, validated norms for English speakers are available for children (Fletcher 1972), younger adults (Ptacek *et al.* 1966) and older adults (Pierce *et al.* 2013). However, normative data for other languages are mostly unavailable for clinicians.

Recently, a literature review by Icht and Ben-David (2014) noted the impact of language on oral-DDK performance, and suggested possible norms for Hebrew-speaking younger adults (Icht and Ben-David 2014) and for school-aged children (Icht and Ben-David 2015). The first goal of the present study was to suggest possible norms for older Hebrew speakers (65 years and older) using a sequential motion rate (SMR) task.

The second goal of the current study was to measure whether Hebrew-speaking older adults benefit from using a real word in the oral-DDK task. Testing children, several researchers recommended using real-word repetition to simplify the task. Indeed, for English- and Hebrew-speaking children, real-word repetition was generally found to be faster than non-word repetition (Williams and Stackhouse 1998, Icht and Ben-David 2015). Using real-word rather than non-word repetition might be relevant for testing older adults as well. Specifically, framing tasks in an engaging relevant context has been found to improve performance of older adults (Carstensen and Mikels 2005).

Oral-diadochokinesis (oral-DDK) tasks

Oral-DDK is a clinical tool widely used by SLPs in order to assess the articulatory system and oro-motor functions (Williams and Stackhouse 1998). In a typical oral-DDK task, an individual is required to repeat accurately and rapidly a specific syllable (e.g., 'pa,' 'ta,' or 'ka')—alternate motion rates (AMR)—or multiple syllables (a syllable sequence, e.g. 'pataka')—SMR. The most common measurement is the oral-DDK *rate*, which refers to the number of precise productions of syllables an individual produces/s (Kent *et al.* 1987). Oral-DDK tasks are quick and simple to administer, and they do not involve the use of expensive equipment or invasive clinical procedures. Despite their simplicity, they provide important clinical information on oral-motor abilities of patients across the life span. This task can also flag possible neurological disorders and can be used to evaluate the presence and severity of neurological impairments (e.g., in traumatic brain injury; Wang *et al.* 2004). These advantages have made the task a popular tool, both in SLP clinics (as part of many evaluation protocols) and in research.

Clearly, oral-DDK tasks involve adequate function of the articulators (tongue, lips), as well as ample muscle control and coordination (Fletcher 1972). These factors are known to change with ageing, possibly slowing down performance, as discussed in the following section.

Impact of ageing on oral and vocal anatomy and physiology

Healthy ageing is associated with slowed speed for large and fine motor movements. With ageing, muscle mass and strength decline, and movements gradually become less coordinated (Haywood and Getchell 2014). As oral-DDK gauges a coordinated motor function, these age-related changes may explain a slowdown in performance.

Specifically, the normal ageing process induces many changes within the oral organs that can affect the ability of the articulators to move rapidly and accurately. These changes include atrophy of oral cavity muscles (which become thinner and less elastic), degeneration of the underlying connective tissue and of the surface epithelium (Caruso *et al.* 1995). These may affect the organs' ability to move smoothly without becoming easily fatigued. The tongue, for example, is composed of skeletal muscles that are affected by atrophy and sarcopenia (a decrease in the size and number of muscle fibres) in ageing, resulting in reduced muscle strength (Bennett *et al.* 2007). A degeneration of glands in the mouth mucosa has been reported with ageing as well. Such glandular changes may cause drying of the epithelium, which in turn may increase stiffness of the structures and negatively affect the elasticity of the organs (Linville 2004). This loss of elasticity in the oral tissues may affect the rate at which the organs move. Altogether, these age-related changes can adversely affect oral-DDK rates, as they may slow the articulators.

Another change during normal ageing is related to voice quality. Age-related atrophy of the intrinsic laryngeal muscles, accompanied with degeneration of the vocal folds, may lead to vocal tremor. Increased hoarseness (related to reduce lung volume capacities) has also been reported as a characteristic of older adults' voice (Linville 2004). These factors may result in increased effort maintaining an oral-DDK task. In addition, an older person may frequently feel a need to clear her or his throat while performing the task (due to the dryness of the vocal folds epithelium), which may affect the overall rate as well.

After presenting the effect of ageing on oral and vocal anatomy and physiology, the next section briefly describes findings regarding the performance of older adults in oral-DDK tasks.

Oral-DDK in older adults

The share of older adults in the total population is constantly growing, and is expected to grow further during the coming decades (UN Population Division 2013). This global demographic shift entails profound consequences for health- and other aged-care services planning. As people age, normal changes occur across all body systems, affecting their function. Moreover, chronic and degenerative diseases are more common at older ages. As older adults usually require more healthcare and more specialized services, the attention of health professionals to this population is merited (World Health Organization (WHO) 2011).

Consequently, in order to evaluate performance in oral-DDK tasks accurately, it is important to gauge specific norms for older adults. Yet, normative data regarding performance rates among older adults are scarce, and many of the studies focus on pathological ageing (e.g., Parkinson's disease), rather than on healthy ageing. For example, a recent literature review by Pierce *et al.* (2013) found only seven published studies on healthy ageing (see their discussion on p. 258). Most of these studies found that oral-DDK rate decreases with ageing.

In a fine-tune analysis comparing rates for different age groups of older adults, the impact of age on oral-DDK rates seems more complex. On the one hand, Pierce *et al.* (2013) found no changes in oral-DDK rates (neither for AMR nor for SMR tasks) comparing two groups of older adults, aged 65–74 and 75–86 years. The authors suggested that, apart from a decrease in rate from younger to older adulthood (> 65 years), additional slowing might occur mainly after 85 years of age. On the other hand, Kikutani *et al.* (2009) reported age-related changes in oral-DDK rates when comparing four older age groups (65–69, 70–74, 75–79 and 80–88 years). The difference between the two studies might be related to the different age ranges of the samples, or to the cultural differences between the two: English speakers (Australia; Pierce *et al.* 2013) and Japanese speakers (Kikutani *et al.* 2009). These inconsistent findings call for a fresh examination of oral-DDK rates across different cultures and different age groups of older adults.

Cross-cultural differences

Reviewing studies that provided oral-DDK data in different languages (English, Portuguese, Greek and Farsi), Icht and Ben-David (2014) demonstrated that the oral-DDK measure is sensitive to variations in language (and potentially culture). This finding may result from several reasons. First, speech rate varies between languages (and even dialects), which, in turn, may affect oral-DDK rates. For instance, Jacewicz *et al.* (2009) found faster articulation rates for northern US English speakers (Wisconsin) than for southern speakers (North Carolina). Second, there is high variation in segmental speech structures between languages. The frequency of phonemes, as well as their features (e.g., place of articulation), varies across languages (Maddieson 2013). For instance, the fricative [x] is common in Hebrew, Farsi, Arabic and Dutch, but absent from the consonant inventory of English. The different frequency within a specific language can affect the ease and accuracy of their rapid articulation (common phonemes may be produced faster and more accurately than less common ones). Finally, languages also differ in non-segmental features, such as syllable and word structure. For example, the frequency of trisyllabic words is higher in Spanish than in French (Lleó and Demuth 1999). Since usually SMR tasks include strings of three syllables (e.g., /pataka/), the spoken language may alter oral-DDK scores.

Taken together, these factors may have a direct effect on the rapid and accurate production of an oral-DDK task. Indeed, oral-DDK measure was found to be sensitive to variations in language (and potentially culture, Icht and Ben-David 2014). These findings led to the conclusion that one universal oral-DDK norm (e.g., US English norm) cannot be used across languages and cultures. Consequently, setting language-specific oral-DDK norms is of high clinical importance. As aforementioned, oral-DDK norms for older adults are available for English speakers. Yet, such data are missing for older Hebrew speakers. The current study aims to fill this gap, examining performance for different age groups of this population.

Motivation and engagement of older adults

Framing tests in an engaging and relevant context boosts performance. As a person perceives the task as more relevant and/or more important (Rozell and Gardner 2000), performance of the task increases. Task demands and the level of exertion and endurance also influence personal engagement. Ideally, activities should demand concentration, be interesting and challenging, yet not exceed one's skill level. Engagement carries unique importance when testing older adults. Social, intellectual and emotional engagement were found to positively influence older adults' performance, on a wide range of tasks (Park *et al.* 2007). In recent years, there is a call to adapt tasks (e.g., instructions and stimuli) for older adults to better reflect their actual abilities.

Task and stimuli familiarity should also be considered when designing a senior-friendly test. Older adults are more focused on relevant/concrete than on abstract tasks (Carstensen and Mikels 2005). Conversely, younger adult participants, mostly undergraduates, are highly trained in performing unengaging abstract tasks that require quick and accurate responses. In fact, they were admitted to the university based on achievement of these skills, for example as tested in a Scholastic Assessment Test (SAT), or its equivalents. Apparently, older adults are less practiced in these types of tasks. In sum, when an SLP evaluates an older client, she/he should consider both personal (engagement) and task characteristics (the stimuli).

Turning to the oral-DDK task, most studies consist of repeating non-word stimuli: either a single syllable, such as /pa-pa-pa/, or a meaningless syllable string, such as /pataka/ (Fletcher 1972). Indeed, non-meaningful stimuli are often preferred in DDK studies, as the primary purpose of such tasks is to measure neuromotor rather than linguistic skill (Tiffany 1980). This aspect can, by itself, hamper older adults' performance. Older adults might perceive such tasks as abstract, irrelevant, strange and unengaging. Consequently, their performance will not correctly reflect their actual oromotor abilities. For example, as early as the mid-1960s, Ptacek *et al.* (1966) reported difficulty in eliciting maximum performance from older participants due to 'problems of motivation and comprehension of the tasks' (p. 258). The authors noted that their participants might have had the potential to produce faster rates than those recorded (for similar findings with children, see Icht and Ben-David 2015).

There are different processing skills involved in the production of real- and non-word repetition (the psycholinguistic assessment framework; Stackhouse and Wells 1997). Real-word repetition involves prior linguistic knowledge, by matching auditory output to a familiar item (and a stored motor programme) in the lexicon. Possibly, using a real-word stimulus may facilitate older adults' performance, generating an engaging context, improving motivation to perform and revealing their full potential. One of most notable cognitive skills improved with ageing (and not just preserved) is vocabulary (Ben-David *et al.* 2015). Thus, using real words may somewhat alleviate the stress associated with the oral-DDK task. In contrast, non-word repetition requires production of a novel motor programme, and, therefore, not dependent on prior phonological and other linguistic information. In sum, comparing performance at these two different levels, non- and real-word repetition, might lead to a more sensitive diagnosis of speech difficulties, especially when testing older adults.

Present study

The effect of age-related anatomical and physiological changes on healthy older adults' speech is not fully clear, neither is the contribution of spoken language. If healthy ageing does not affect speech, then speech disorders in older people are likely the result of an a-typical ageing process. However, if healthy ageing is marked by changes in speech production, speech disorders ensue. In order to improve differential diagnosis of speech and language pathologies in ageing, it is of clinical importance to understand the effect of normal ageing on speech production. Specifically, should a decrease in oral-DDK rates in ageing flag a pathology, or is it merely an expected outcome of ageing? Should one expect changes in oral-DDK rated between 70- and 80-year-olds? Can SLPs use English older speakers' norms for older speakers of other languages?

The present study presents new findings on older Hebrew speakers, currently missing from the literature, and compares them with the literature on older English speakers (experiment 1). These can serve as preliminary normative data to be used with older Hebrew-speaking clients. Experiment 2 compares older adults' oral-DDK performance using real-word ('bodeket') repetition, with the traditional non-word ('pataka') repetition, in an attempt to form a more senior-friendly procedure. As the current study's goal was to allow for a comparison with a real-word repetition, we opted to use the SMR task. As stressed by Tiffany (1980), /pataka/ and a real-word equivalent enables approaching the form of natural speech articulation, without its sense (non-word repetition) and with its linguistic characteristics (real-word repetition).

Experiment 1: Normative data

The goal of this experiment was to examine oral-DDK rates in Hebrew-speaker older adults, establishing a representative normative dataset that can be used by SLPs. The experiment also evaluated the possible impact of gender and age on oral-DDK rates in this population.

Method

Participants

Ninety-two healthy Hebrew-speaking older adults volunteered to participate in the study. Four participants were not able to complete the task because of difficulties in understanding the instructions, and their data were removed from analysis. The final sample included 88 participants, 48 females and 40 males (age range 60–95 years, mean age, $M = 73.7$, standard deviation, $SD = 8.8$ years). See table 1 for the distribution of age and gender.

Participants' education reflects averages for older adults in Israel, 25% reported 6–9 years of education, 30% reported 10–12 years of education and 45% reported more than 12 years of education (Brodsky *et al.* 2007). The majority of these participants (83%) were non-native Hebrew speakers, coming from a variety of linguistic backgrounds (e.g., Northern Africa, Europe and Middle East), who immigrated to Israel as young children and have been using Hebrew as their main language for at least 55 years. This ratio well represents the Israeli population, as latest surveys indicate that over 80% of Israelis over 65 years are non-native Hebrew speakers (Brodsky *et al.* 2007). The distribution of linguistic background was similar across the four older adult age groups, and it will not be further discussed.

Participants were recruited from four different independent-living retirement homes, and two community centres, all located in the centre of Israel. Following Ptacek *et al.* (1966), participants were excluded if they reported (in an interview conducted by SLP students) one or more of the following diagnoses: (1) severe hearing losses; (2) respiratory diseases (e.g., bronchial asthma, respiratory infection); (3) neurological disorders that may affect the speech mechanisms; and (4) structural or functional abnormalities of the oral mechanism. None of the participants was edentulous (had a total absence of teeth), as all wore replacement prostheses (either partial or complete dentures) that allowed standard speech production, as evaluated by a research assistant (RA, an SLP student). The study was approved by the local ethics committee.

Apparatus, procedure and analysis

The participants were tested individually in a quiet room, either in their own apartments (independent-living retirement homes) or in the community centres they frequented. The RA was present at the room throughout the experimental session. In the beginning of the session, each participant read and signed an informed consent form and was interviewed by the RA to evaluate exclusion criteria. The oral-DDK task was demonstrated to each participant by the RA, and he or she was given the chance to practise the task for 1 min. Next, each participant was asked to repeat the trisyllable /pataka/, rapidly and accurately as possible, for 10 s. Following previous studies, which showed that oral-DDK tasks have high test–retest reliability, a single trial of each task was generally recorded (e.g., Pierce *et al.* 2013). The complete session lasted no more than 20 min. Participants' oral-DDK productions were digitally audio-recorded using a Sony ICD-PX312 digital recorder. The recorder was placed on a table, about 15 cm from the participant's mouth.

Oral-DDK count-by-time rate (syllables/s) was calculated by multiplying the total number of trisyllables produced by each participant in 10 s by 0.3. If a trisyllable sequence was only partially completed by the time 10 s elapsed, it was excluded. In case a participant did not produce the repetitions accurately (as judged by the RA), or if he or she were unable to produce 10 s of correct repetitions, their data were excluded from the analysis. Two SLP students listened separately to the digital recordings and performed manual counting of the syllables. When the two did not agree on a specific sample, it was recounted by an experienced SLP.

Results

As a first step, a regression analysis of oral-DDK rates was performed on all 88 participants, using age and gender as predictors. Gender was not found to have a significant contribution to the regression model [$F(1,85) = 1.5$, n.s.], so the final model, $r = .581$ [$F(1,86) = 43.8$, $p < .001$], includes only age as a contributing variable. In other words, as age increased, oral-DDK rates decreased.

The next step focused on two main age groups of older adults, 65–74 and 75–86 years (41 and 30 participants, respectively). These groups were selected to allow for a later comparison with English norms for older adults set by Pierce *et al.* (2013). In a univariate analysis of variance (ANOVA) with gender and age group as between participant factors, gender did not have a significant effect ($F < 1$), but age group did [$F(1,67) = 39.22$, $p < .001$, $\eta_p^2 = .37$]. The following average rates were obtained for older Hebrew

Table 1. Oral-DDK rates (syllables/s), by age group

Age range (years)	Number of participants (number of females)	Oral DDK rate (syllables/s)			
		Mean	SD	Minimum	Maximum
60–64	9 (7)	6.13	1.10	4.2	7.5
65–74	41 (17)	5.60	0.74	3.9	7.2
75–86	30 (21)	4.20	1.06	2.1	6.3
87–95	8 (3)	4.40	0.95	3.3	6.0
Average	88 (48)	5.07	1.16	2.1	7.5

speakers: 5.60 syllables/s (SD = .74 syllables/s) for the group of 65–74 years, and 4.20 syllables/s (SD = 1.06 syllables/s) for the group of 75–86 years. These averages may serve for clinical use by SLPs, considering a conservative confidence interval for the group of 65–74 years (with 1 SD around the mean) of 4.86–6.34 syllables/s, and for the 75–86 group (again, with 1 SD around the mean) of 3.14–5.26 syllables/s.

Figure 1 presents a visual comparison of the averages collected for Hebrew-speaking older adults to the English averages reported by Pierce (averaging across gender). For the 65–74 groups, language was not found to alter the results significantly [$t(79) = 1.69$, $p = .095$]. Yet, for the 75–86 groups, the effect of language was significant [$t(64) = 5.09$, $p < .001$], with slower performance for the Hebrew-speaking group. Note, Pierce *et al.* did not report a significant decrease of oral-DDK rates moving from the 65–74 to the older 75–86 group, whereas in the current data, age group was found to significantly slow down performance.

In order to provide a broader view of oral-DDK abilities and the impact of spoken language across the life span, figure 1 presents the current data alongside data from a previous study by the current authors (Icht and Ben-David 2014), which compared Hebrew and English speaking younger and middle-aged adults, aged 15–45 years. Interestingly, the latter study failed to find a significant difference between Hebrew and English speakers in that age range. A follow-up analysis tested whether the groups of 15–45 years performed faster than did the groups of 65–74 years and/or 75–86 years, for Hebrew and English speakers separately. For Hebrew speakers, the average for the 15–45 group was found to be significantly different from that of the 65–74 group [$t(154) = 5.42$, $p < .001$], and obviously significantly different from that of the 75–86 group [$t(143) = 12.30$, $p < .001$]. Thus, the data describe a gradient of oral-DDK rates in Hebrew speakers: 15–45 > 65–74 > 75–86 group. For English speakers, the rates of the 15–45 group (Icht and Ben-David 2014) were marginally faster than those of the 65–74 group (Pierce *et al.* 2013) [$t(179) = 1.58$, $p = .0.57$ single-tailed], and significantly different (faster) from those of the 75–86 English group [$t(175) = 3.73$, $p < .001$].

Experiment 2: Real word versus non-word repetition

The goal of experiment 2 was to compare oral-DDK rates between real- and non-word stimuli with Hebrew-speaking older adults. These data were compared with a former similar analysis conducted with school-aged children (Icht and Ben-David 2015).

Method

Participants

A group of 71 older adults taken from the same participant pool of experiment 1 (following the same inclusion and exclusion criteria) volunteered to participate in this experiment. Three participants were not able to complete the task because of difficulties in understanding the instructions, and their data were removed from analysis. The final sample included 68 participants (43 females and 25 males, age range 66–95 years, $M = 77.9$, SD = 7.1 years).

Stimuli

Two types of stimuli were used: (1) for the *non-word* condition, the trisyllable /pataka/, replicating experiment 1; and (2) for the *real-word* condition, the familiar Hebrew word ‘bodeket’ (the female rendition of the noun *examiner* or the verb *inspecting*). This word was used in a previous study (Icht and Ben-David 2015) with 60 Hebrew-speaking children, and was found to serve as an appropriate stimulus for the oral-DDK task. The word stimulus was chosen as it shares the main phonological features (segmental and prosodic) with the non-word /pataka/.

Apparatus, procedure and analysis

These were identical to that of experiment 1, with the exception that the oral-DDK task was performed twice. For a random half of the participants, the non-word condition was performed before the real-word condition, and for the other half, this order was reversed. The whole session lasted no more than 25 min.

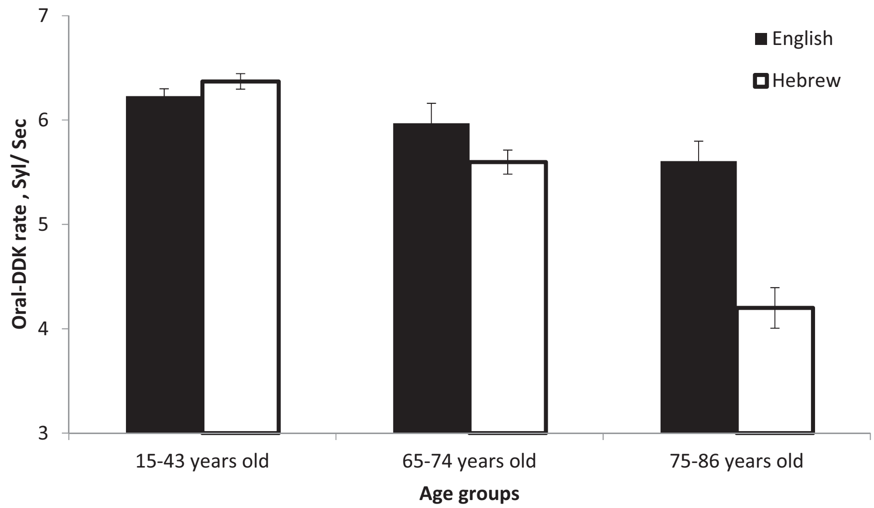

Figure 1. Average oral-DDK rates (syllables/s) and standard errors for Hebrew and English speakers for the tested groups of older adults (Hebrew: current data, English: Pierce *et al.* 2013) and for groups of younger adults. Source: Icht and Ben-David 2014).

Results

As a first step, echoing the analysis of experiment 1, regression analyses were conducted separately for real- and non-word repetition, using age as a predictor. Age was found to be a significant contributing factor for both tasks (real word: $r = .575$, $F(1,66) = 32.6$, $p < .001$; non-word: $r = .5$, $F(1,66) = 22.3$, $p < .001$). This pattern of results resonates with experiment 1, as age increased, oral-DDK rates decreased, even when asked to repeat real words.

The next step focused on our two main age groups of older adults, 65–74 and 75–86 years (23 and 39 participants, respectively) matching English norms for older adults set by Pierce *et al.* (2013). Gender and condition-order were not found to have a significant impact on performance, nor did they significantly interact with the effect of condition ($F < 1.4$, $p > .2$ for all), and these factors will not be further discussed. A repeated-measures ANOVA was conducted, with condition (real- versus non-word) as a within participant factor and age group as a between-participant factor. Averaged performance, across both conditions, was found to be affected by the age group ($F(1,60) = 31.1$, $p < .001$, $\eta_p^2 = .34$), with overall faster rates for the 66–74-year-old group. A significant main effect was also noted for the condition, as, on average, participants produced more real words in a second than non-words ($M = 5.09$, SD = 1.04 syllables/s, and $M = 4.51$, SD = 1.02 syllables/s, for real- and non-word repetition, respectively, $F(1,60) = 23.1$, $p < .001$, $\eta_p^2 = .28$). However, importantly, the effect of condition did not interact with the effect of age group ($F = .05$). That is, the size and direction of the improvement in performance by presenting real words was not different across the age groups.

Figure 2 depicts average oral-DDK rates and standard errors (syllables/s) for real- and non-word conditions with two groups of Hebrew speakers: older adults (current data, divided across the two age subgroup) and children (Icht and Ben-David 2015). Examining Figure 2, it appears that across age groups the same pattern can be observed, real words were produced faster than non-words.

General discussion

Oral-DDK is an essential part of assessing speech disorders in younger and older adults in different cultures. However, without normative data, specific for age group and language, evaluation and diagnosis may be inaccurate and possibly misleading. Icht and Ben-David (2014) showed that spoken language can have a large impact on oral-DDK rates. Consequently, the (commonly available) English norms should not be taken as appropriate for all other languages. In the current study, the first goal was to suggest normative data for oral-DDK rates with older Hebrew speakers, currently missing from the literature. The results show that age has an impact on performance, across the life span. Specifically, older adults had slower rates than younger adults (comparing the data with the available data from the literature). Even within the older group, participants aged 65–74 years had faster rates than participants aged 75 years and above. In the latter group, one may also note a clear impact of language, with faster performance for English speakers over Hebrew ones. The second goal was to adjust the oral-DDK task to older participants/clients. To increase task engagement in this population, real-word repetition was used to gauge oral-DDK rates. As expected, older adults

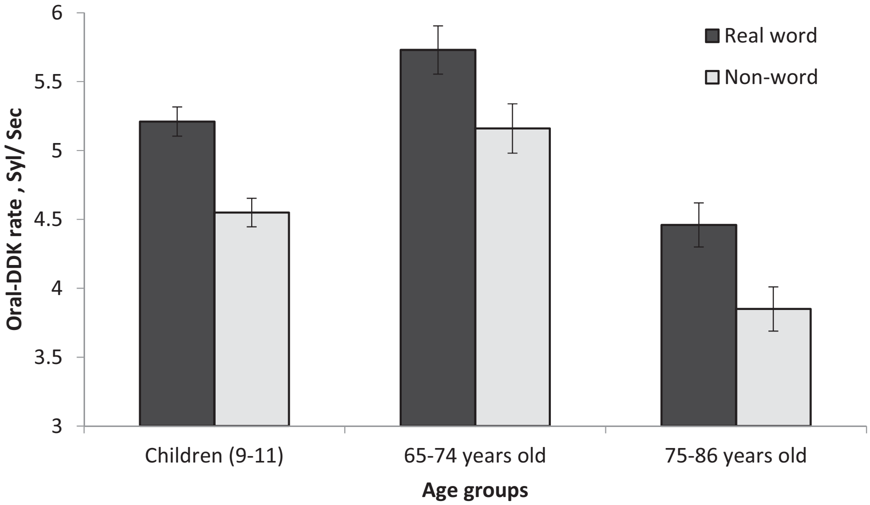

Figure 2. Average oral-DDK rates (syllables/s) and standard errors for real- and non-word repetition, for three groups of Hebrew speakers: two groups of older adults from the current study (65–74 and 75–86 years) and a group of children (9–11 years). Source: Icht and Ben-David (2015).

were found to benefit from a real-word over a non-word repetition.

Age-related slowing in oral-DDK rates

The literature indicates that ageing generally slows down articulatory movements and speech rates (Padovani *et al.* 2009). This slowdown is attributed to several age-related changes within the respiratory, laryngeal and oral structures (Caruso *et al.* 1995, Linville 2004), negatively affecting the motor functions of the tongue, lips, cheeks, and mandible. Along with these quantitative changes, qualitative changes also occur. Ryan and Burk (1974) described five characteristics of speech that were most highly correlated with judgements of (old) age: voice tremor, air loss, laryngeal tension, imprecise consonants and slow articulation rate. These factors may be directly related to speech production in general, and specifically, to the performance on oral-DDK tasks. Indeed, older adults' oral-DDK rates are typically slower relative to younger adults (for a review, see Pierce *et al.* 2013).

Providing normative data regarding the performance of different age-subgroups of older adults, speakers of different languages, is crucial, given their increasing share of the population worldwide. Yet, there are but a few published reports of oral-DDK rates in healthy older speakers (namely, those over 65 years), and most of them involve English speakers (e.g., Amerman and Parnell 1982, Pierce *et al.* 2013, Ptacek *et al.* 1966). As language was found to affect oral-DDK rates (Icht and Ben-David 2014), the first goal of this study was to provide a set of normative data for older Hebrew speakers, which may be highly useful in clinical practice.

In the sample of 88 older Hebrew speakers aged 60–95 years, age was found to correlate significantly with rates, explaining more than 25% of the variance. This is of interest, as experiment 1 did not compare younger and older participants, but rather participants usually grouped together as a single age group ('older adults'). Further analysis suggested faster norms for 65–74- than for 75–86-year-olds (all Hebrew speakers). Comparing these data with the data of Hebrew-speaking younger adults (Icht and Ben-David 2014) shows a clear age-related gradient of oral-DDK rates where, 15–45 > 65–74 > 75–86-year-olds. Note, data for English speakers show an increase from adulthood to older age, yet no difference was found between groups of 65–74 and 75–86 years (Pierce *et al.* 2013). This discrepancy might result from the language used, or from cultural differences in the makeup the older population sampled. Indeed, data for Japanese participants (Kikutani *et al.* 2009) indicate such a difference. Our results call for future studies in different cultures.

The current analysis suggests that an SLP should generally consider using different norms for 65–74- and 75–86-year-old clients, and especially with Hebrew speakers. For example, based on the suggested norms in the current study, an oral-DDK rate of 4.0 syllables/s, which should flag further clinical investigation for Hebrew-speaking adults aged 74 years and younger, may reflect healthy ageing processes for 75–86-year-olds. This notion is now commonplace in the literature on older adults, given the gradual changes that occur in ageing in motoric speed (Haywood and Getchell 2014) and sensory acuity (Ben-David and Schneider 2009).

Individual differences among older adults

The current data were characterized by a relatively high variability of performance for older adults, with

SD = 1.16 syllables/s. In comparison, the SD of oral-DDK rates for Hebrew-speaking younger adults (Icht and Ben-David 2014) was much smaller, 0.8 syllables/s. A highly similar trend is observed in English data, with an SD of approximately 1.17–1.3 syllables/s for older adults (Pierce *et al.* 2013, Ptacek *et al.* 1966) and 0.82 syllables/s for younger adults (Icht and Ben-David 2014). Note, the current sample size (88 and 68 participants for experiments 1 and 2, respectively) is not smaller (and may even be higher) than those reported in the pertinent literature (e.g., 20, 23, 63 and 76 older participants in Amerman and Parnell 1982, Padovani *et al.* 2009, Ptacek *et al.* 1966, and Pierce *et al.* 2013, respectively). Thus, the relatively high variance reported in the current study appears not to relate to the sample size or language, but rather reflects an age-related trend, with increased variance in oral and laryngeal mechanisms and functions in ageing (Linville 2004). More generally, there is wide evidence for an age-related increase in variance on a variety of tasks, e.g., visual attention (Ben-David *et al.* 2014a) and eye movements (Ben-David *et al.* 2011).

Effect of language on oral-DDK rates: English versus Hebrew

This study may also offer insight into the effect of spoken language on oral-DDK rates in older age. A comparison of the current results with the English norms provided by Pierce *et al.* (2013) shows that the effect of language interacts with age. For the 65–74-year-old group, similar rates for English and Hebrew speakers were obtained. Notably, the same trend was observed with younger adults in a previous study (Icht and Ben-David 2014). However, the data for the 75–86-year-olds indicated slower performance for Hebrew over English speakers. That is, the effect of language was only observed for the older group tested. This finding calls for future studies to establish language-sensitive norms for the oral-DDK task, especially in older age.

Evaluating oral-DDK performance with real-word stimuli

The second goal was to test the effect of using a real word on the performance of older adults. Real-word stimuli yielded faster performance than non-word (by 13.5%) with our older adult sample of Hebrew speakers. These data echo our previous finding with Hebrew-speaking children (14.5% advantage), providing further support for the novel Hebrew real word suggested for clinical use. One can assume that the current findings might not be limited to Hebrew speakers. Thus, it is recommended to use a dual assessment procedure for older adults (regardless of language), which includes both real-word repetition and non-word repetition. We may recommend taking the difference of 14% in performance between the two tasks (noted above) as a first estimate of a gauge of healthy performance in these populations.

Using this protocol may assist in the differential diagnosis of normal and pathological ageing processes, and of different speech disorders. The dual assessment procedure enriches the profile for oral-motor abilities based on oral-DDK tasks. Specifically, real- and non-word oral-DDK rates may be differentially affected by different pathologies (see Ziegler 2002 on differences comparing sentence production and non-word oral-DDK rates across patient populations). For example, with dementia patients, one may hypothesize that the advantage in engagement for real-word (over non-word) repetition will be even larger than in healthy ageing adults (Ben-David *et al.* 2014b). On the other hand, since the motor disorder underlying dysarthria is not specific to speech production, it may result in decreased performance rate (e.g., prolonged durations) for both non- and real-word repetition. The pattern may be different for apraxia of speech, characterized with problems in coordinating individual articulators to achieve a speech motor task goal. One may expect that in this population, more sound substitutions and prosodic abnormalities will occur, regardless the task.

Caveats and future directions

One must acknowledge that the current study was limited in its scope, focusing on oral-DDK rate, as it is a measure that can be easily assessed in SLP clinics. Note, in order to generate a baseline for performance, all participants were characterized as healthy older adults. Future evaluation of the dual protocol with special populations can provide indicative clinical information on this test. Finally, the dual protocol should be tested in other languages and cultures to validate the advantage of real-word (over non-word) repetition in older age.

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