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Oral-diadochokinetic rates among healthy Malaysian-Mandarin speakers: A cross linguistic comparison

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Abstract

Purpose: This study examined the effects of non-word versus real word, age, and gender on oral-DDK rates among healthy Malaysian-Mandarin speakers. Comparison between non-word of Malaysian-Mandarin and Hebrew speakers was examined.
Method: One-hundred and seventeen speakers (18–83 years old, 46% men) were audio-recorded while performing non-word (repetition of "pataka") and real-word oral-DDK tasks ("butter cake" and "怕他看 ([p^{h}a4t^{h}a1k^{h}an4])"). The number of syllables produced in 8 seconds was counted from the audio recording to derive the oral-DDK rates. A MANOVA was conducted to compare the rates between age groups (young = 18–40 years, $n = 56$; middle = 41–60 years, $n = 39$; older = 61–83 years, $n = 22$) and gender. In a second analysis, "pataka" results were compared between this study and previous findings with Hebrew speakers
Result: No gender effects were found. However, rates significantly decreased with age ($p < 0.001$). Repetition of real words was faster than that of non-words – English words (5.55 ± 1.19 syllables/s) > non-words (5.29 ± 1.23) > Mandarin words (4.91 ± 1.13). Malaysian-Mandarin speakers performed slower than Hebrew speakers on "pataka" task.
Conclusion: Aging has a large impact on oromotor functions, indicating that speech-language pathologists should consider using age-adjusted norms.

Keywords: *oral-DDK; adults; Mandarin speakers; non-word; real-word*

Introduction

Oral-diadochokinetic (DDK) rates or syllable sequence production rates within a certain period of time, are common practice among speech-language pathologists (SLP) to examine the clients' oromotor integrity (Icht & Ben-David, 2014). Oral-DDK (i.e. (maximum rate of syllable repetition /pa/, /ta/ or /ka/ or /pataka/) has been used to reveal neuromotor abnormalities such as dysarthria, ataxia, and childhood apraxia of speech in clinical settings (Kent, 2015). Application of oral-DDK should be done carefully, by comparing individual performance to a norm within the specific language. Age and language are known to affect oral-DDK rates in English and Hebrew speakers (Ben-David & Icht, 2017). Yet, such data are missing in Malaysian-Mandarin speakers, who usually converse in more than one language during daily life (i.e. Mandarin, English, Malay). Moreover, the effect of task (non-word versus real-word repetition) is unclear among Malaysian-Mandarin speakers. This is of immediate importance as the literature suggests that oral-DDK norms

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cannot be transferred from one language to the other (Icht & Ben-David, 2014).

Oral-DDK application in clinical setting

There is an ongoing debate on whether oral-DDK tasks reflect the real speech behaviour (see Kent, 2015; Maas, 2017). In fact, several researchers argue that non-speech and speech tasks use different underlying control mechanisms (Lowit, Marchetti, Corson, & Kuschmann, 2018; Staiger, Schölderle, Brendel, Bötzel, & Ziegler, 2017a, Staiger, Schölderle, Brendel, & Ziegler, 2017b; Ziegler, 2002). Specifically, Ziegler (2002) found that repeating a syllable at maximum rate and producing the same syllable within a sentence context are two different tasks, which could be affected differently by brain lesions. In another study, when participants (130 controls and 130 speakers with motor speech disorders) were asked to perform speech task (oral reading), speech like tasks (rapid syllable repetitions), and nonspeech tasks (rapid single articulator movements of the tongue/lips), results showed that movement rates obtained from these three tasks were significantly different (Staiger et al., 2017b). The findings reflect the major differences in task demands and underlying control mechanism, questioning the validity of using nonspeech tasks as a diagnostic index for speech (Staiger et al., 2017b).

The oral-DDK has been viewed as a window into disease process, that different neurological diseases yield different "signature patterns" in DDK tasks (Ackermann, Hertrich, & Hehr, 1995). Individuals with cerebellar disease shows highly variable repetition, while individuals with Parkinson's disease shows small and diminishing range of movement. If speech deficits in dysarthria reflect the neuropathological symptoms through the speech mechanism, and the oral-DDK shows "signature patterns" of different disease processes, then the oral-DDK could be used to map onto speech production characteristics (Darley, Aronson, & Brown, 1975; Duffy, 2005). In terms of neural control capabilities with neuron motor capabilities, both the orbicularis oris superior and inferior muscles have a ceiling frequency of approximately 6.1 Hz, corresponding to reported maximum oral-DDK rates in neurotypical adult speakers (Kent, Kent, & Rosenbek, 1987). We can speculate that oral-DDK rates reflect the performance of reciprocal articulatory muscle groups through a sensorimotor network involving the cerebral cortex and rate-control mediated by the cerebellum (Wildgruber, Ackermann, & Grodd, 2001). Measuring the oral-DDK rates has been suggested as an indicator of motor impairment, potentially revealing subtle impairments in orofacial motor control that precede breakdown in speech functions (Kent, 2015). The clinical value can be justified by findings in the reduced tongue strength measurement in Parkinson's disease (Solomon, Robin, & Luschei, 2000) and amyotrophic lateral sclerosis (Langmore & Lehman, 1994).

In fact, several studies have shown that temporal acoustic measures of oral-DDK rate effectively discriminate speakers with dysarthria from neurotypical adults. For example, an objective assessment of DDK performance by individuals with multiple sclerosis and Parkinson's disease (PD) revealed that performance of /pa/, /ta/ or /ka/ and /pataka/ are significantly slower when produced by an individual with multiple sclerosis due to increased syllable length and gap duration between syllables during oral-DDK tasks (Tjaden & Watling, 2003). Apart from slower repetition rates, faster rates and increase variability of syllable duration have been reported in the literature (Ackermann, Konczak, & Hertrich, 1997; Rusz, Hlavnička, Čmejla, & Růžička, 2015; Skodda, Flasskamp, & Schlegel, 2010). Maximum rate of syllable repetition and conversational speech rate were similar in individuals with severe dysarthria (Wang, Kent, Duffy, Thomas, & Weismer, 2004), suggesting some shared aspects of natural conversational speech and non-linguistic oral motor tasks. In addition, similarities between disturbance in the rate of syllable repetition was observed in connected speech in Parkinson's disease speakers (Skodda, Flasskamp, et al., 2010; Skodda, Grönheit, & Schlegel, 2010), suggesting that performance across two tasks reflected similar pathophysiology.

Rationale of using oral-DDK rates in clinical setting

Several reasons support to usage of oral-DDK rates as a complement to speech assessment procedures in clinical setting. First, oral-DDK has been used to assist SLPs in distinguishing different types of dysarthria. Hypokinetic dysarthria is characterised by normal maximum repetition rate with reduced amplitude of the articulatory movements (Ackermann et al., 1995), while ataxic dysarthria manifests a dysrhythmic maximum repetition rate (Brendel et al., 2015). Obtaining oral-DDK rates as an independent variable is a good method to reveal dissolution or breakdown in motor coordination in individuals with dysarthria as oral-DDK rates could be used to map the progression of disease and advancing severity of dysarthria over time (Kent, 2015). The oral-DDK has been used to reveal neurological abnormalities. For example, oral-DDK has been used as an index of motor control in various dysarthrias (Ackermann et al., 1995; Wang et al., 2004), including speech disturbances in ataxia (Sidtis, Ahn, Gomez, & Sidtis, 2011), and as part of a diagnostic protocol in childhood apraxia of speech (Murray, McCabe, Heard, & Ballard, 2015). The oral-DDK is frequently used for oral-motor assessment in clinical practice for screening and differential diagnosis of speech sound disorders and apraxia of speech (Maassen et al., 2020; Thoonen, Maassen, Wit, Gabreëls, & Schreuder, 1996; Wit, Maassen, Gabreels, & Thoonen, 1993). Another reason is that a repetitive speech pattern, as in oral-DDK task, are less variable and easier to judge within a short period of time (Knuijt, Kalf, Van Engelen, Geurts, & de Swart, 2019). With limited skillsets by SLPs who specialise in the management of adult speech disorders in Malaysia, the oral-DDK rate protocol (oral-DDK:MALMAN[1]) could be used by SLPs to augment traditional speech assessment procedures.

Motivation and engagement of using real-word

Syllables repetition has been the common practice when assessing oral-DDK. Differences in oral-DDK rates are possibly due to different neural processing schemes for real-word and non-word utterances (Stackhouse & Wells, 1993). One hypothesis explains that there are motor programmes stored for real-word repetition (generated by linguistic cues), that such programmes do not exist for non-words, resulting in faster production for real-word repetition. Hence, the absence of neuro-motor programme and linguistic information could slow down the production when producing non-word repetition (Williams & Stackhouse, 2000). This hypothesis suggests that different neuro-motor programmes activate for producing the same phonemes of real-word and non-word repetitions. The use of real-word stimuli involves accessing a stored motor programme, while non-word stimuli require the speaker to assemble a new motor programme (Williams & Stackhouse, 2000). Repetition of real-words involves the retrieval of the stored motor programme, which is part of the representation of the lexical items in our lexicon. As a result, the repetition of real-words is influenced by prior linguistic knowledge and may not rely solely on speech motor ability. For instance, one could hypothesise that the advantage in engagement for real-word repetition would be greater than the non-word repetition. By contrast, patients with apraxia of speech would perform differently from individuals with dysarthria. Due to coordination problems, those with apraxia of speech would be more likely to perform with more sound substitutions, regardless of the task. The second motivation to include real-word repetition is because non-familiar, abstract, and nonsense syllable-sequences repetition is challenging, as participants may be occupied by trying to understand the meaning of the non-word, therefore slowing down their performance (Icht & Ben-David, 2015).

Language differences on oral-DDK rate

In addition to cognitive demands, differences in language species may impact the oral-DDK rate performance. A population's general speech rate, phoneme frequency, syllabic and word structure may affect ease and accuracy of productions during rapid articulation (Icht & Ben-David, 2014; Maddieson, 2013). Using the same non-word stimuli "pataka," Icht and Ben-David (2014) revealed a significant difference in oral-DDK rate between speakers of four different native languages (Portuguese, Greek, Farsi, and American English). Such findings revealed that oral-DDK measure is sensitive to variations in language difference (Prathanee, Thanaviratananich, & Pongjanyaku, 2003). Several reasons contributed to such finding. First, speech rates differed between languages and dialects. When examining the speaking rate and/or articulation rate of typical adult speakers of different varieties of English, namely American English (Clopper & Smiljanic, 2011; Jacewicz, Fox, O'Neill, & Salmons, 2009), New Zealand English (Robb, Maclagan, & Chen, 2004), Australian English (Block & Killen, 1996), and British English (Tauroza & Allison, 1990), adult speakers of New Zealand English show the highest speaking rate, followed by speakers of British English and American English, and the speakers of Australian English showed the lowest speaking rate. Second, the tonal language (Mandarin) could contribute to oral-DDK rate differences. Mandarin is a commonly spoken tonal language used mainly by the Chinese population. Mandarin phonemically distinguishes tones; Tone 1 having high-level pitch, Tone 2 high-rising pitch, Tone 3 low-dipping pitch, and Tone 4 high-falling pitch (Chao, 1948; Jongman, Wang, Moore, & Sereno, 2006). These tones function to differentiate word meanings. Each of the tones has a consistent temporal difference, and the consistent temporal difference in all the Mandarin tones is also likely to give rise to the longer repetition rate (Jongman et al., 2006). Third, different phonemic frequency within a specific language can affect the accuracy of rapid articulation (i.e. common used phonemes produced faster and more accurately than less common ones) (Mousikou & Rastle, 2015).

Impact of aging and gender on oral-DDK

To improve differential diagnosis of speech in aging, it is important to understand the effect of normal aging on speech production. Literature of oral-DDK rates in healthy adults often reported a slowdown in oral-DDK rates as we age (Pierce, Cotton, & Perry, 2013). For example, young adults group (mean age 35.9 years) performed higher oral-DDK rates when compared to elderly adults (mean age 70.96 years old) (Padovani, Gielow, & Behlau, 2009). In addition, performance by younger (<40 years old) and geriatric adults (>65 years old) differed significantly in maximum vowel duration, maximum intensity, maximum intraoral pressure, and vital capacity during oral-DDK task (Ptacek, Sander, Maloney, & Jackson, 1966). Similar results were found in a recent study, whereby adults (>60 years old) showed a reduction in maximum repetition rate and maximum phonation volume, indicating that age is an important determinant in maximum speech performance (Knuijt et al., 2019). Such decrease in oral-DDK rates may be related to atrophy and degeneration of oral cavity muscles (Bennett, Van Lieshout, & Steele, 2007), or changes in the oral structures (GoozÉe, Stephenson, Murdoch, Darnell, & Lapointe, 2005). In addition, degeneration of the oral structures due to aging could result in thinner and less elastic of tongue muscles (Caruso, Mueller, & Shadden, 1995). Changes in respiratory system and stiffening of the thorax may also reduce lung volume capacity (Ramig et al., 2001) and result in increased effort in maintaining oral-DDK task as we age. Taken all together, these factors could contribute to slow down articulators' movements and hence a slower rate of oral-DDK for older adults. While aging slows down oral-DDK rate, studies on speech and articulation rates have not shown significant gender differences (Ben-David & Icht, 2017; Hartelius, Svensson, & Bubach, 1993; Lass & Sandusky, 1971).

Concerning the effect of age on oral-DDK rate, conflicting results have been reported in three different languages. Age-related changes in oral-DDK rates were found among four elder cohorts of Japanese speakers, including 65–69, 70–74, 75–79 and 80–88 years (Kikutani et al., 2009). Similar findings were reported in elderly Hebrew speakers who tend to reduce their oral-DDK rates (15–45, 65–74, 75–86 years) (Ben-David & Icht, 2017). Using a mirror as visual feedback, Ben-David and Icht (2018) found their younger cohort (aged 20–40 years old) performed faster oral-DDK rates (6.77 vs. 5.58 syllables/sec) than an older cohort (>65 years old).

Motivation and aims of this study

At present, protocols for assessing motor speech disorders (i.e. using oral-DDK rate) are limited among Malaysian SLPs, mainly due to the lack of normative data and clinical training. Thus, an additional motivation is to create a systematic oral-DDK administration protocol for SLPs to use when assessing speech motor production in their caseloads. In order to evaluate performance in oral-DDK accurately, it is important to gauge specific norms of a particular language. Given language affects articulation rates (Jacewicz et al., 2009), it is unclear whether an English-US norm can be generalised to other languages, rather a need exists to generate norms specific for the Malaysian population. When designing a clinical-friendly test, stimuli familiarity should be considered. Perhaps, the use of a real-word repetition task could motivate adults' performance, by generating an engaging context. Hence, we first examined the effects of non-word versus real-word, age, and gender on oral-DDK rates among healthy Malaysian-Mandarin speakers. Malaysian-Chinese, unlike Malay ethnicity in Malaysia, are able to speak in either Mandarin or English at home, and uses Malay or English while interacting with different ethnicities at school or community (Lim, 2018). This population, often are known as multilinguals (Chong, Cheoy, Mazlan, & Maamor, 2019; Lim & Lee, 2017). Second, we compared our non-word "pataka" oral-DDK performance rates with current available norms of speakers from other countries, as well as raw data comparison from the Hebrew speakers.

Method

Participants included 117 Malaysian-Mandarin speakers (54 men [46%]; age: $M \pm SD = 43.4 \pm 17.9$ years, range 18–83 years). All participants had no history of speech and language difficulty, neurological disorders, or hearing impairment, and all reported Mandarin as the dominant language (≥60% usage) for daily conversation. Ethics approval for this study was obtained from the National University of Malaysia's Research Ethics Committee Board and written informed consent was obtained from each participant.

Stimuli

Participants completed oral-DDK tasks each of which involved a non-word or real-word: a non-word trisyllabic syllable sequence "pataka," an English word "butter cake," or a Mandarin short phrase "怕他看" ([p^ha4t^{h}a1k^{h}an4]) that means "afraid to let him/her see." This phrase was selected because of the consonant placement of the words that is similar to the non-word stimulus as well as the familiarity with the target population (Icht & Ben-David, 2017). The English word "buttercake" rather than "buttercup" was used in this study because this is a food commonly seen in the community.

Data collection procedure

Participants were seated in a quiet room during data collection. Each participant completed a short practice session (~3 minutes) before a speech recording thereby familiarising her/him with the task. During the data collection, participants were instructed to take a deep breath and repeat the presented stimulus accurately and as fast as they can within one breath at their normal speaking loudness level. Stimuli were presented using a cue card (Appendix A) and randomised across participants. Participants were cued to stop speech production after 8 seconds. Participants were asked to repeat each stimuli once. In the condition where there was error on the first trial, participants were asked to repeat the stimulus again. Only two trials per stimulus was allowed. Participants who were not able to produce the stimulus accurately at the second trials will be excluded. All speech production was audio recorded using the Zoom R16 recorder (Zoom North America, New York) connected to a microphone (CM-2000 Custom dynamic microphone, Kyoritsu, Japan) and a laptop (Asus A456U). The microphone was placed 15 cm away from participant's mouth. The data collection session took approximately 15 minutes to complete. Approximately 57% of the participants (primarily elderly) were not able to visit the lab due to transportation issues (i.e. not able to drive, afraid of heavy traffic, or no transportation). In such cases, a SONY recorder (ICD-UX560F) was used for data collection by a research assistant at their home in a quiet room.

Data analysis

Speech recordings were analysed using Audacity® 2.1.3 (Audacity® 2.1.3, 1999–2017) (Carnegie Mellon University, Pittsburgh) to count the number of syllables produced in 8 seconds. All the trisyllables and words that were not completed within the 8-second period were excluded. The DDK rate was calculated using the count-by-time scale, as shown in Equation (1) (Fletcher, 1972). Both intra- and inter-rater reliabilities (i.e. point-to-point agreement to the nearest millisecond) were excellent with 100% and 96.15%, respectively, when evaluated by random sampling of 20% of the data.

$$Oral - DDK\ Rate = \frac{total\ number\ of\ trisyllables}{8\ seconds} \times 3 \quad (1)$$

Multivariate analysis of variance (MANOVA) was conducted to investigate the effects of age (Younger: 18–40 years, Middle: 41–60 years, Older: ≥61 years) and gender (women, men) on the DDK rates for three oral tasks (non-word, English real word, Mandarin real word). When an effect was significant in multivariate and/or univariate tests at 0.05 alpha level, marginal group means were pairwise compared at a Bonferroni-corrected alpha level.

In a secondary analysis, repeated measures analysis of covariance (RM-ANCOVA) was performed to compare the DDK rates between the non-word, English, and Mandarin tasks while controlling for age and gender. If necessary, post-hoc pairwise comparisons of marginal means were conducted at a Bonferroni-corrected alpha level.

To compare our non-word "pataka" oral-DDK rates with current available norms of speakers from other countries, we summarised the oral-DDK rates observed in previous studies based on their reported means and standard deviations and conducted a *t*-test (Ben-David & Icht, 2017; Icht & Ben-David, 2014; Lass & Sandusky, 1971; Ptacek et al., 1966; Topbas, 2010). In addition, raw data comparison from the Hebrew speakers (Ben-David & Icht, 2017; Icht & Ben-David, 2014, and unpublished data) and our "pataka" oral-DDK rates was conducted using analysis of covariance (ANCOVA).

Result

Table I presents a detailed report on the data obtained. The multivariate test result was not significant for gender, Wilk's $\lambda = 0.04$, F (3, 109) = 1.35, p = .263, partial η^2 = .036, indicating no difference in the DDK rates for three different tasks as a whole between men and women. Nevertheless, the result of univariate test showed that when the stimulus was a Mandarin real word ("怕他看"), men ($M = 5.19$, $SD = 1.00$ syllables/s) had a significantly higher DDK rate compared to women ($M = 4.67$, $SD = 1.19$), F (1, 111) = 4.00, $p < .05$, partial η^2 = .035.

The DDK rates were significantly different between three age groups across different tasks as a whole (Wilk's $\lambda = 0.59$, F (6, 218) = 10.83, $p < .001$, partial η^2 = .230); as well as for each of the non-word (F (2, 111) = 25.23, $p < .001$, partial η^2 = .313), English (F (2, 111) = 29.99, $p < .001$, partial η^2 = .351), and Mandarin (F (2, 111) = 31.69, $p < .05$, partial η^2 = .363) tasks. Post-hoc pairwise comparisons indicated that Younger group produced the most number of syllables followed by Middle and

Table I. Comparison of oral-diadochokinetic (DDK) rates between tasks. Younger ($n = 56$, 28 women), Middle ($n = 39$, 19 women), Older ($n = 22$, 16 women).

				Gender effect		Age effect		Gender × Age interaction	
Tasks	Age group	*M* (*SD*)	95% CI	*p Value*	ES[a]	*p* Value	ES[a]	*p* Value	ES[1]
Nonword "pataka"	Younger (18-40)	5.86 (0.81)	5.64–6.07	0.114	.022	<.001	.313	.737	.005
	Middle (41-60)	5.30 (1.03)	4.97–5.64						
	Older (61-83)	3.82 (1.23)	3.28–4.37						
English "buttercake"	Younger (18-40)	6.16 (0.73)	5.97–6.36	0.186	.016	<.001	.351	.331	.020
	Middle (41-60)	5.51 (0.85)	5.24–5.79						
	Older (61-83)	4.08 (1.38)	3.47–4.69						
Mandarin 怕他看 ([p^ha4t^ha1k^han4])	Younger (18-40)	5.53 (0.79)	5.32–5.74	0.048	.035	<.001	.363	.543	.011
	Middle (41-60)	4.78 (0.77)	4.53–5.03						
	Older (61-83)	3.57 (1.21)	3.03–4.10						

[a]Partial eta squared: .01 = small, .06 = moderate, .14 = large.

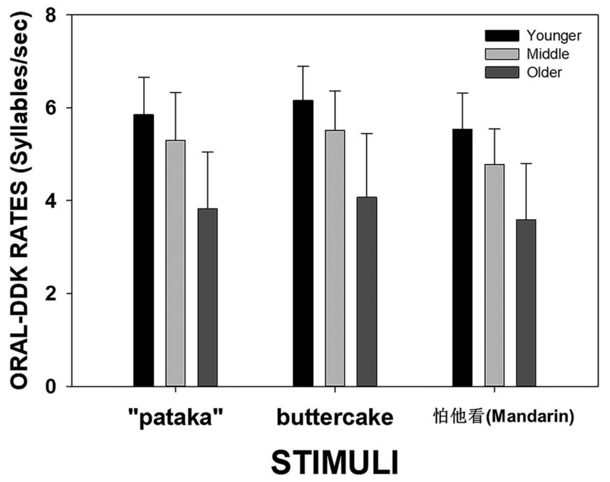

Figure 1. Means and standard deviations of Oral-DDK rates (syllables/s) for non-word, English, and Mandarin stimuli across Younger, Middle, and Older age groups.

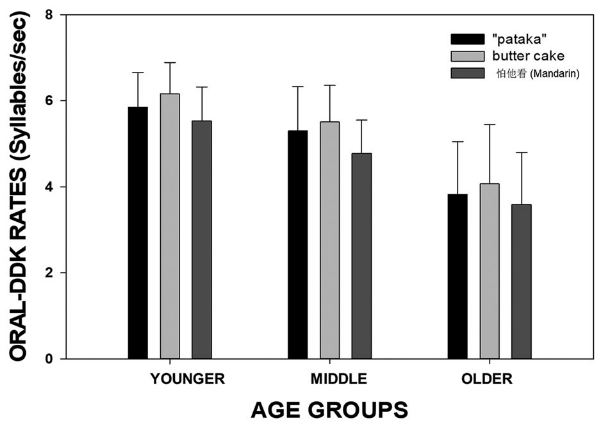

Figure 2. Means and standard deviations of Oral-DDK rates (syllables/s) for non-word, English, and Mandarin stimuli.

Older groups in each task. The number of syllables produced was significantly different between each pair of those three age groups (all corrected $p < .05$; see Figure 1). However, the interaction between age and gender was not significant, Wilk's $\lambda = 0.94$, F (6, 218) = 1.22, $p = .298$, partial $\eta^2 = .032$.

After controlling for gender and age, participants produced more syllables during the English task ($M = 5.55$, $SD = 1.19$) than the non-word ($M = 5.29$, $SD = 1.23$) and Mandarin ($M = 4.91$, $SD = 1.13$) tasks, Wilk's $\lambda = 0.58$, F (2, 110) = 39.54, $p < .001$, partial $\eta^2 = .467$. Post-hoc pairwise comparisons showed that the number of syllables produced significantly differed between each pair of those three tasks (all corrected $p < .001$; see Figure 2).

The "pataka" oral-DDK rates observed in previous studies are summarised in Table II. In general, the DDK rate for the non-word condition in the present study was slightly lower than what has been reported in those previous studies, t (520) = 7.37, $p < .001$. However, when the middle age group was compared against the English norm, Malaysian-Mandarin speakers showed a significantly lower oral-DDK performance rate on non-word repetition t (442) = 4.67, $p < .001$. Another comparison using the raw data from the Hebrew speakers (Ben-David & Icht, 2017; Icht & Ben-David, 2014, and unpublished data) showed that when participants' age and gender were controlled, the "pataka" oral-DDK rate (marginal $M = 5.02$, $SE = 0.09$) was significantly lower in the present study compared to the rate in these two recent studies (marginal $M = 5.72$, $SE = 0.06$), F (1, 356) = 36.94, $p < .001$, partial $\eta^2 = .106$).

Discussion

Non-word vs. real-word differences in oral-DDK

This study assessed the differences in oral-DDK rate using non-word and real-words (Mandarin vs. English) stimuli. Findings revealed that not only is Mandarin real-word repetition slower than that of non-word productions, but participant DDK performance varied significantly as a function of native language. For example, English words yielded the fastest oral-DDK rate followed by non-word and Mandarin stimuli. To increase task engagement, we used real-word to gauge the oral-DDK performance of our Malaysian-Mandarin speakers. English yielded fastest performance than non-word (5.55 English syllable/5.29 non-word syllable = 4.91% advantage), followed by non-word performance to Mandarin stimuli (5.29 non-word syllables/4.91 Mandarin syllable = 7.7% advantage). Previous studies on oral-DDK rate found that real-word repetition is faster than non-word repetition in pre-school and school-age children (Icht & Ben-David, 2015; Williams & Stackhouse, 2000), as well as in the healthy ageing population (Icht & Ben-David, 2017). In Hebrew studies, children (14.5% advantage) and older adults performed faster (13.5%) when repeating real word in Hebrew ("bodeket", means the female rendition of the noun *examiner* or the verb *inspecting*) than non-word "pataka" (Ben-David & Icht, 2017; Icht & Ben-David, 2015). These findings suggest that repetition of real-words may involve retrieval of a learned motor ability that is stored along with the lexicon (Icht & Ben-David, 2014; Williams & Stackhouse, 2000). For that reason, the repetition of real-words is relatively easier oral-DDK task, resulting in faster speech production rate when compared to non-words.

However, the findings of our current study suggest that this notion may not hold true for the repetition of real-words of all languages. For example, the DDK rate for Mandarin stimulus are slower than that of non-word stimuli. It is worth noting that the Hebrew word used in the Icht and Ben-David (2014, 2017) studies have the same syllable structure (CV-CV-CVC) as the Mandarin word of the present study. Despite the similarities in the selected stimuli (syllable structures, meaningfulness, and resemblance in the placement of articulators during production: bilabial, alveolar, velar and alveolar placement), the effect

Table II. Data extracted from the literature, in comparison to the current study.

Study	No. of Participants	Age range & *M* (in years)	Oral-DDK rate ("pataka")	
			M	*SD*
Ben-David and Icht (2017)	88 (48 women)	60–95, 73.70	5.07	1.16
Icht et al. (2013)	10 (5 men)	20–43, 31.80	6.15	1.03
Icht and Ben-David (2014)	105 (53 men)	20–45, 31	6.37	0.80
Lass and Sandusky (1971)	40 (20 men)	19–28, 21	6.30	0.36
Ptacek et al. (1966)	62 (31 men)	18–39[a]	6.05	0.88
Topbas (2010)	24 (12 men)	20–29, 22.80	6.55	0.94
Pierce, Cotton & Perry (2013)	76 (31 men)	65–86, 73.90	5.70-6.10[b]	0.69-1.67[b]
Weighted average of English	405 (200 men)	52.50[c]	6.06[c]	0.91[c]
Our finding	117 (63 women)	18-83, 43.44	5.29	1.23

Note. Oral-DDK rate is given as syllables/second.
[a]Mean is not available in the study. [b] –>Mean and SD are not available in the study; instead, range is reported in this table. [c]When mean was not available in a study, median from the study was used to calculate a weighted average.

of real-words is not the same as Hebrew DDK rates. Our findings suggest that the usage of real-word in oral-DDK tasks may not generalise to higher DDK rates among all languages, which could be related to differences in language features between stimuli.

Language differences in oral-DDK

Consistent with Icht and Ben-David (2014), oral-DDK performance (non-word stimuli) appears to be influenced by the spoken language of the individuals. Icht and Ben-David (2014) extracted secondary data of oral-DDK rate (with non-word stimulus "pataka") of participants from four different language backgrounds, namely Portuguese, Greek, Farsi, and English. Statistical analysis of the oral-DDK rate of these four groups revealed a significant difference between the mean of the English speaking population and the means of Portuguese, Greek, and Farsi. These findings support the notion that spoken language affects oral-DDK rate. In the current study, the Mandarin stimulus has a distinctive feature (aspiration) that sets it apart from the English stimuli. In the current study, all three voiceless consonants in the Mandarin stimulus are aspirated ([p^ha4t^ha1k^han4]), while initial consonant of/b/in "buttercake" is voiced. The slower oral-DDK rate of Mandarin stimuli could be attributed to its aspirated consonants as syllables with an aspirated consonant are significantly longer than a syllable with an unaspirated consonant (Xu & Xu, 2003; Feng, 1985), when we compared between Mandarin and English stimuli. In Mandarin, consonant aspiration affects the fundamental frequency (F0) of the following vowel. The onset F0 of a tone is higher following unaspirated consonants than following aspirated consonant (Xu & Xu, 2003). Placement and manner in consonants in the stimuli could affect the oral-DDK rate. Syllables with a nasal in final position have a longer syllable duration, which can contribute to the slower rate of DDK for the Mandarin stimulus (Wang, 1994).

Age and gender effect on oral-DDK rates

The results of the present study are consistent with previous findings which have shown that gender has no measurable impact on the performance of oral-DDK rates (Ben-David & Icht, 2017; Hartelius et al., 1993; Lass & Sandusky, 1971). On the other hand, age is a significant factor that affects the oral-DDK performance, regardless of the stimulus type (non-word or real-word). Specifically, older adults manifest slower rates compared to younger and middle-aged adults. As such, we recommend that SLPs should refer to age-appropriate normative data for Malaysian-Mandarin speakers. For example, based on our results, a non-word oral-DDK rate of 4.2 syllables/s, should flag for further clinical speech assessment for age 18-40 years, but may reflect healthy aging process for 61-83 year olds. Older adults speak approximately 20-30% slower than younger adults (Ramig, 1983; Smith, Wasowicz, & Preston, 1987). Age-related changes in speech production rate are attributed to changes in anatomy and physiology of the oral structures, and reduced lung capacity (Bennett et al., 2007; GoozÉe et al., 2005; Ramig et al., 2001). Oral cavity muscles change (becomes thinner and less elastic), surface epithelium undergoes degeneration (Caruso et al., 1995), and reduced muscle strength of tongue (Bennett et al., 2007) can adversely affect oral-DDK rates. Reduction in muscle strength is accompanied by a decline in muscle mass, and resulting movements become less coordinated with advancing age (Haywood & Getchell, 2014). Since oral-DDK task measures the oral motor coordination, age-related changes in respiratory, laryngeal and oral structure (Caruso et al., 1995; Linville, 2004) may explain a slowdown in their oral-DDK performance. Given that dysarthria frequently occurs in elderly, such effects may manifest in oral-DDK performance. For this reason, future studies should obtain a DDK normative data among the elderly population for clinical usage.

Our data showed a greater difference in rates among older speakers compared to young and middle-age speakers, with SD = 1.27 syllables/s when combined the non-word and real-word stimuli. Also, for our older speakers, a greater range was found within their group, with some older speakers performing much slower, whereas the range of speakers' performance didn't differ much from each other in the young or middle-aged groups. Similar trends were observed in the Australia “pataka” data, with 1.41-1.67 syllables/s for older adults (Pierce et al., 2013). Increased variability was noticed on our English stimuli, with SD = 1.38 syllables/s. The relatively high variability reported in the present study may be due to sample size or language. However, when examining literature, our sample size is moderate compared to previous studies ($N = 20$ in Amerman & Parnell, 1982; $N = 23$ in Padovani et al., 2009; $N = 76$ in Pierce et al., 2013).

Comparison of “pataka” with Hebrew norm

Our results, with similar faster production of real-word of those Hebrew studies, support the benefits of using real-word for clinical use. We recommend to use a dual oral-DDK procedure (non-word and real-word) in clinical setting to improve differential diagnosis of normal and pathological aging in this task (oral-DDK: MALMAN). A combination of both real-word repetition and non-word repetition could enrich the profile of oral-motor abilities of patients (Icht & Ben-David, 2015). For example, oral-DDK task has shown high accuracy in differentiating children with apraxia of speech from other paediatric speech disorders (Murray et al., 2015). One hypothesis stipulates that the neural loop for producing a word once is similar to that used for repeating it over and over again. This is because there are motor programmes stored for real-word, generally generated by linguistic cues. However, such programmes do not exist for non-word (Williams & Stackhouse, 2000). That says, real-word repetition assesses one’s stored motor programme through linguistic cues, while non-word repetition assesses the ability to access a new or less familiar motor programme without linguistic cues (Tiffany, 1980). Non-word sequences are abstract and non-familiar to children, causing participants to try to figure out the meaning of the non-word, resulting in slowing down their performance (Icht & Ben-David, 2014). Real-word repetition is more relevant and less demanding for the elderly population with real-word repetition rates significantly higher than non-word repetitions (Icht & Ben-David, 2017). In light of these findings, we postulate that assessing non-word abstract forms could measure performance of neuromotor skills, whereas assessing real-word repetition would measure performance of linguistic skills.

Meanwhile, psychometric evaluation of the Computer Articulation Instrument (CAI, consisting of picture naming, non-word imitation, word and non-word repetition and maximum repetition rate) of 1524 typically developing Dutch-speaking children (aged between 2;0–7;0) has showed a reliable and valid instruction for assessment of typical and delayed speech development (van Haaften, Diepeveen, Terband, et al., 2019). A follow-up study reported that children of speech sound disorders have showed a different speech profile when compared with normative Dutch-speaking children. Specifically, bi- and trisyllabic oral-DDK performance are most sensitive for diagnosing speech sound disorders, rather than using the word and nonword repetition tasks (van Haaften, Diepeveen, Terband, et al., 2019). Similar results of poor production of bi- and trisyllabic sequences were a specific characteristics of apraxia of speech (Thoonen et al., 1996; Wit et al., 1993). Although emerging clinical data have shown that bi-trisyllabic speech production is sensitive to differentiate between children with speech sounds disorders and apraxia of speech, these data were limited to particular disorders and may not apply to all types of development or acquired speech disorders. Hence, we continue to recommend a dual-protocol as it allows for the comparison of neuromotor skills (with non-word) with linguistics skills (real-word) and aligned with Levelt’s psycholinguistic model to assess different speech tasks covering phonological and speech motor skills speech processes.

Our findings also highlight the importance of testing the native language of the speakers (in our case, Mandarin) during speech assessment. A comparison of the present findings with the English norms shows that Malaysian-Mandarin speakers consistently produced syllables repetition at a slower rate, regardless of the non-word or real-word stimuli. While it’s impossible for us to directly compare the Mandarin norm with other languages (Farsi, Greece, Hebrew), the mean of non-word repetition oral-DDK rate was lower than the Western’s “pataka” norm. In fact, direct comparison of the Hebrew speakers on “pataka” repetition yielded a significant difference between two populations. This suggests that the same norms, established for English speakers, is not appropriate for use with Malaysian-Mandarin speakers.

Caveats and future directions

One of the limitations of this study is that the participants involved are not evenly distributed across different demographic factors: participants’ age is skewed to the young age adult group. When we compared the middle age group to the English norm, Malaysian-Mandarin speakers still showed a lower oral-DDK performance rate on non-word repetition. Such findings may also be due to instructional differences. We instructed participants to produce the oral-DDK within one breath without encouraging or pushing them further to reach their maximum performance. We would expect our participants to perform at a faster rate if our research assistant provides a faster model or continue to encourage participants to reach a higher rate during training phase. This is the first report to examine oral-DDK production in Malaysian-Mandarin speakers, using a real word oral-DDK task in Mandarin. To facilitate accurate comparison between clinics, we also suggest an administration protocol for the oral-DDK tasks in Malaysian-Mandarin speakers (oral-DDK:

MALMAN) that was used to reach the findings in this paper (Supplementary material).

The oral-DDK task provides important information on oromotor status and is applicable in Malaysia, a country that has limited advanced motor speech assessment equipment and limited numbers of SLPs (∼300, with 1 SLP serving 100,000 residents, Chu, Khoong, Mohamad Ismail, Altaher, & Rogayah, 2019; Malaysian Association of Speech-Language & Hearing, 2018). The oral-DDK task reflects neuromotor maturation and integration of the orofacial structures, such as tongue and lips (Mason, Helmick, Unger, Gattozzi, & Murphy, 1977; Wang et al., 2004). Clinically, it has been used to evaluate the presence and severity of neurological impairments. Inaccurate or an abnormal oral-DDK performance might indicate central nervous system or peripheral nervous system disorders. For instances, slower oral-DDK was reported in individuals with traumatic brain injury (Wang et al., 2004), spinocerebellar ataxia (Schalling, Hammarberg, & Hartelius, 2007), Parkinson's disease and Friedreich's ataxia (Ackermann et al., 1995). When comparing oral-DDK and conversational speech rate in individuals with dysarthria, it was found that DDK syllable rate was similar to conversational syllable rate, suggesting that DDK task could capture some shared aspect of conversational speech (Wang et al., 2004). This means that slowness in conversation speech rate could be due of speech motor control limitation rather than cognitive or linguistic limitations. In addition, the oral-DDK protocol allows for systematic and relatively language independent assessment of articulation abilities, which could be important when assessing bilingual speakers (Icht & Ben-David, 2014). One unique aspect of this study is that we did not simply compare languages differences (Mandarin, English, Hebrew) of oral-DDK rate across participants, but that our participants are multilinguals. That is to say, any differences with other studies could be due to linguistic or cultural differences. Malaysia is a country with speakers of multiple languages (Mohd Ibrahim, Lim, Yazmin, & Lim, 2020). Establishing normative data of different languages will enable SLPs to select the most appropriate reference data set based on the language mastery of these multilingual patients. For example, reference to the Mandarin and English norm is the most appropriate for a patient who is fluent in both Mandarin and English. Application of the oral-DDK task should be done by comparing individuals' performance to a language-specific norm.

Note

1. Define as Oral-DDK: Malaysian Mandarin speakers

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Declaration of interest

The authors report no conflicts of interest.

Supplemental material

A short video is uploaded on the website to show clinicians how to conduct the recording. Please note that this video is conducted in Mandarin (with English subtitles) so that SLPs could get an idea of typical instruction for their patients.

Supplemental data for this article can be accessed at https://doi.org/10.1080/17549507.2020.1808701

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