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Oral-diadochokinesis rates for Spanish, German and Czech: reference values for normotypical adults

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Abstract. Oral diadochokinesis (oral-DDK) is one of the common maximum performance tasks used in clinical practice to evaluate the oral motor mechanism. Although there are reference values for some languages, there are no recent publications of the adult population speaking Spanish, German or Czech. The aim of the study is to describe the reference values of oral-DDK in adult speakers of Spanish, German and Czech, 2) to determine the influence of gender on the values of oral-DDK, 3) to determine the influence of age on the values of oral-DDK and, 4) to compare the inter-language values of the oral-DDK. Recordings taken from three previous studies of 189 healthy adults were considered (between 26 to 86 years), 94 females and 95 males, while producing the sequential motion rate (SMR) /pa-ta-ka/. Count-by-time method was used using acoustic analysis software. Oral-DDK averages were established for each language and the effect of gender and age was determined. The variability of the measure among languages was also established. Reference data were obtained for each language. Age did not show any significant effect on oral-DDK despite its decline as age advanced; there was no gender effect on the oral-DDK, and the comparison of the oral-DDK among languages showed statistically significant differences. This study determined the reference data of the oral-DDK for Spanish, German and Czech and found significant differences among the three languages and no significant effects of age or gender on the measure studied.

Keywords: Oral-diadochokinesis; normative data; adults, Spanish; German; Czech.

[es] Diadococinesia oral para el español, el alemán y el checo: valores de referencia para adultos normotípicos

Resumen. La diadococinesia oral (DDC oral) hace parte de las tareas de máximo rendimiento, más comunes, que se utilizan en la práctica clínica para evaluar el mecanismo motor oral. Aunque existen valores de referencia para algunas lenguas, no hay publicaciones recientes de población adulta hablante del español, el alemán o el checo. Los objetivos de este estudio son: 1) describir los valores de referencia de la DDC oral en adultos hablantes del español, el alemán y el checo, 2) determinar la influencia del género en los valores de la DDC oral, 3) determinar la influencia de la edad en los valores de la DDC oral y, 4) comparar los valores interlingüísticos de la DDC oral. Se analizaron datos tomados de tres estudios previos con 189 adultos sanos (entre 26 y 86 años), 94 mujeres y 95 hombres, mientras producían el movimiento secuencial (SMR) /pa-ta-ka/. Se utilizó el método de conteo por tiempo utilizando un software de análisis acústico. Se establecieron promedios de la DDC oral para cada idioma y se determinó el efecto del género y la edad. También, se estableció la variabilidad de la medida entre idiomas. Los resultados muestran datos de referencia para cada lengua. La edad no mostró ningún efecto significativo sobre la DDC oral a pesar de su disminución a medida que avanzaba la edad; no hubo efecto de género en la DDC oral y la comparación de la DDC oral entre lenguas mostró diferencias estadísticamente significativas. En definitiva este estudio determinó los valores de referencia de la DDC oral para el español, el alemán y el checo encontrando diferencias significativas entre las tres lenguas y ningún efecto significativo de la edad o el género en la medida estudiada.

Palabras clave: adultos; alemán; checo; datos normativos; diadococinesia oral; español.

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Introduction

Oral diadochokinesis (oral-DDK) is one of the most common maximum performance tasks used in clinical practice to evaluate the oral motor mechanism (Manasco, 2021). It is usually done through the rapid repetition of single syllables such as /pa/ or /ka/, which is known as alternating motion rate (AMR) or through the rapid repetition of sequences of syllables, e.g., /pa-ta-ka/, known as sequential motion rate (SMR) (Novotny et al., 2020; Duffy, 2020). Its measurement has traditionally been done through two methods: Count-by-time and Time-by-count. In the first one, the number of syllables produced in a time interval is measured and, in the second one, the number of syllables to be repeated is preset and the duration time is determined (Fletcher, 1972).

Different languages have established reference values for oral-DDK to allow clinicians and researchers to have data to compare people's performance in this task (Zamani et al., 2017). This is because it has been found that when the oral-DDK values are not within the reference ranges, they can be indicators of speech disorders (Alshahwan et al., 2020). Some of the values reported today in typical people between 15 and 65 years old range between 5.29 and 7.12 syllables per second. See Table 1.

Table 1. Oral-DDK rates in different languages

Study	Language	Age range (years)	Mean Oral- DDK rate[a]	SD[b]
Icht & Ben-David (2014)	English (USA)	18 – 43	6.23	.82
	Hebrew	20 – 45	6.37	.80
Seifpanahi et al., (2008)	Farsi (Iran)	15 – 18	7.12[c]	.52
Padovani et al., (2009)	Portuguese (Brazil)	30 – 46	6.58[c]	.85
Konstantopoulos et al., (2011)	Greek	20 – 65	6.97[c]	.85
Chu et al., (2020)	Malaysian-Mandarin	18 – 83	5.29	1.23

[a] syllables/second. [b] standard deviation. [c] data base on Icht & Ben-David (2014).

Although the oral-DDK rates reported in the previous table seem to be close, authors such as Icht & Ben-David (2014) have compared the values of some of these languages (English, Portuguese, Farsi and Greek) and have found that there are statistically significant differences among them, which suggests that the nature of each language, and the variations in the same language (Alshahwan et al., 2020), impact articulatory performance when performing oral-DDK tasks (Chu et al., 2020).

Regarding the impact of gender and age on oral-DDK rate, the former has shown not to have a significant influence (Icht & Ben-David, 2014; Chu et al., 2020; Alshahwan et al., 2020) while the second does. Different studies have found that the young population tends to perform faster in oral-DDK tasks than the older population and, as age advances, the rate decreases more and more (Ben-David & Icht, 2017; Chu et al., 2020; Pierce et al., 2013; Kikutani et al., 2009; Watanabe et al., 2017). This has in part been attributed to the combination of several factors, including a reduction in respiratory capacity and tongue strength (Bennett et al., 2007), as well as a decrease in the coordination of movements due to loss of muscle mass (Haywood & Getchell, 2020).

To the best of the authors' knowledge, there are no published reference values for oral-DDK rate in adult monolingual speakers of Spanish, German, or Czech that can serve as a basis for clinicians and researchers to compare with the values of people with possible speech disorders. For this reason, this study aims to: 1) describe the reference values of oral-DDK in adult speakers of Spanish, German and Czech, 2) determine the influence of gender on the values of oral-DDK, 3) determine the influence of age on the values of oral-DDK and, 4) compare the inter-language values of the oral DDK.

Methods

This study took information from three different databases that contained audio recordings of people with no hearing, neurological, or speech-impaired backgrounds, speakers whose mother tongue was Spanish, German, and Czech, provided informed consent and authorized to record them while producing different oral-DDK tasks. The recording process was similar along the three corpora. The examiner asked the patients to perform the task at a normal rate and as long as their air was run out. The examiners also did an example to make it clear the way of producing the phonation. The patients were allowed to practice a couple of times in all cases. Not all of them took this chance because some of them (unknown number) were already familiar with the task. We encourage the readers to see Icht and Ben-David (2014) for a complete reference about which aspects need to be considered to perform sequential motion rates tasks like the oral-DDKs.

Spanish database

The recordings used were extracted from the PC-GITA database (Orozco-Arroyave et al., 2014) which includes the speech of 50 healthy people, 25 men between 31 to 86 years (mean 61.2 ± 11.3) and 25 women between 43 to 76 (mean 60.7 ± 7.7). Recordings were sampled at 44.1 kHz with a resolution of 16 bits. The recording procedure was performed in noise-controlled conditions, in a soundproof booth using a professional audio card and an omni-directional microphone (Shure, SM 63L).

German database

The recordings used were extracted from the corpus presented in Orozco-Arroyave (2016). A total of 88 healthy people, 44 men between 26 to 83 years (mean 64 ± 12.7) and 44 women between 28 to 85 years (mean 63 ± 15.2) were recorded. The sampling frequency was 44.1 kHz and the resolution was 16 bits. Although in this case a soundproof booth was not used, the recording conditions were controlled and the recording process was performed in a clinical room, where the patients are typically evaluated by the neurologist. Recordings were made using commercial audio software (Steinberg WaveLab ©) and a head-set microphone (Plantronics Audio 550 DSP ©).

Czech database

In this case, the DDK tasks were extracted from the PARCZ database (a part of the database with other speech task is described in Galaz et al. (2016) and Gómez-Vilda et al. (2017)) which consists of 51 healthy people, 26 men between 49 to 83 years (mean 66 ± 8.9) and 25 women between 45 to 87 years (mean 62 ± 9.1). Recordings were sampled at 48 kHz with a resolution of 16 bits in a quiet room with an environmental noise lower than 30 dB sound pressure level (measured with NTI Acoustilyzer AL1). The tasks were recorded using a large capsule cardioid microphone M-AUDIO Nova and audio interface M-AUDIO Fast Track Pro.

Speech stimuli and data analysis

From all the databases the recordings of the SMR /pa-ta-ka/ were extracted. Using the Praat software (Boersma & Weenink, 2018), the oral-DDK rate was manually established using the count-by-time method. For this calculation, all the syllables produced by the people were counted and the duration time was determined.

$$\text{Oral-DDK rate} = \frac{\#\text{syllables}}{\text{seconds}}$$

Statistical analyzes were performed with the JASP software version 0.14.1 (JASP Team, 2020). The reference values for each of the languages were established by applying descriptive statistics. T-student Test, to normal data, and Mann-Whitney U test, to non-normal data, were used to establish the relationship between gender and the oral-DDK rate. Analysis of Variance (ANOVA) was used to determine the existence of statistically significant differences in the DDK rates according to the age range of the participants and according to the language evaluated. After that, in the cases where significant differences were found, post hoc analyzes were carried out with the Tukey-Kramer test to compare and establish in which groups these differences were located.

Results

Values of oral-DDK rate in Spanish, German and Czech are reported in Table 2. For each language, a general value of all participants has been reported, as well as separate values for women and men.

Table 2. Spanish, German, and Czech oral-DDK rates (syllables/s)

	Spanish			German			Czech		
	General	**w [a]**	**m[b]**	**General**	**w**	**m**	**General**	**w**	**m**
Participants	50	25	25	88	44	44	51	25	26
Mean	6.708[c]	6.531	6.886	3.672	3.773	3.570	5.715	5.698	5.732
Std. Deviation	0.971	0.827	1.084	1.262	1.373	1.148	0.843	0.867	0.836

	Spanish			German			Czech		
	General	**w [a]**	**m[b]**	**General**	**w**	**m**	**General**	**w**	**m**
Minimum	4.839	4.839	5.028	1.413	2.228	1.413	3.704	3.704	4.455
Maximum	9.399	8.377	9.399	9.677	9.677	6.897	7.843	6.897	7.843
Skewness	0.183			1.719			-0.126		
Kurtosis	0.198			5.462			-0.105		

[a] women. [b] men. [c] syllables/second.

The Shapiro-Wilk test, with a significance level of 95%, for Spanish and Czech showed a normal distribution, so parametric tests were used to determine the effect of gender on oral-DDK rate. For German the data did not show normality, so the Mann-Whitney U test was applied (see Table 3). No gender effect on the oral-DKK rate was observed in the three languages (see Table 4).

Table 3. The Shapiro-Wilk test

	W[a]	**p-value of Shapiro-Wilk**
Spanish	0.979	0.525
German	0.887	< .001
Czech	0.986	0.794

[a] W-value.

Table 4. Gender effect on oral-DDK rate

Student's t-test	**t[a]**	**Df[b]**	**p[c]**
Spanish	-1.299	48	0.200
Czech	-0.144	49	0.886
Mann-Whitney U test	**W[d]**	**Df**	**p**
German	1.015		0.699

[a] t-value. [b] degrees of freedom. [c] p-value. [d] W-value.

To perform the analysis exploring the influence of age, the participants of each language were divided into four age groups: 1) under 50; 2) between 51 and 60; 3) between 61 and 70; and 4) over 71 years of age (see Table 5). Intra-language ANOVA analysis was performed ($p < .001$) and showed that age (group age) has no effect on the oral-DDK rate in any of the languages studied (see Tables 5 and 6) despite the fact that a decrease in rate is observed as age advances. For the German data, the Welch correction and the Kruskal-Wallis test were also applied and these confirmed the non-existence of statistically significant differences for this language.

Table 5. Oral- DDK rate by age group

Age range	Spanish			German			Czech		
	Mean[a]	**SD[b]**	**N[c]**	**Mean**	**SD**	**N**	**Mean**	**SD**	**N**
1	7.666	1.078	7	4.145	1.206	16	5.631	1.116	5
2	6.759	0.944	11	3.913	1.212	14	5.761	0.778	13
3	6.580	0.810	26	3.614	1.401	28	5.845	0.869	24
4	6.057	0.949	6	3.360	1.135	30	5.347	0.725	9

[a] syllables/second. [b] standard deviation. [c] number of participants.

Table 6. Age effect on oral-DDK rate

Language	Cases	Sum of Squares	df[a]	Mean Square	F[b]	p[c]
Spanish	Age range	9.420	3	3.140	3.927	.014
	Residuals	36.781	46	.800		
German	Age range	7.394	3	2.465	1.577	.201
	Residuals	131.252	84	1.563		
Czech	Age range	1.689	3	.563	0.782	.510
	Residuals	33.807	47	.719		

ANOVA analysis. $p < .001$.
[a] degrees of freedom. [b] F-value. [c] p-value.

The ANOVA test determined that there are statistically significant differences between the oral-DDK rate and the language. Similarly, the post hoc analysis indicated that these differences are present between the three languages (see Table 7 and Table 8).

Table 7. Oral-DDK rate and interlingua comparison

Cases	Sum of Squares	df[a]	Mean Square	F[b]	p[c]
Language	327.157	2	163.578	138.082	<.001
Residuals	220.343	186	1.185		

[a] degrees of freedom. [b] F-value. [c] p-value.

Table 8. Post Hoc Comparisons – Language

		Mean Difference	SE[a]	t[b]	p[c] tukey
Czech	German	2.043	0.192	10.668	< .001
	Spanish	-0.993	0.217	-4.586	< .001
German	Spanish	-3.037	0.193	-15.755	< .001

Note. P-value adjusted for comparing a family of 3.
[a] standard error. [b] t-value. [c] p-value.

Discussion

Oral-DDK has been one of the most common tasks for evaluating the oral motor mechanism for several decades. Until now, few languages have established reference values with which clinicians and researchers can compare the measurements they take, which is why in this study it was firstly proposed to establish the measurement in three languages. The data revealed a rate greater than six syllables per second for Spanish, which coincides with measurements greater than six for Portuguese (Padovani et al., 2009), Greek (Konstantopoulos et al., 2011), Hebrew and English (Icht & Ben-David, 2014). In the case of Czech, a value around five was found similar to the reference value of the Malasyan-Mandarin (Chu et al., 2020); and, finally, for the German, the measure was around three, below the values of both Spanish and Czech and those found in other languages. These results are important to the extent that they are providing new information about reference values for languages that until now did not have oral-DDK rate values published in the periodical literature.

Effect of age on oral-DDK

Oral-DDK rate showed a gradual decline in Spanish and German as age advanced. In Czech it did not decrease gradually but it was lower in group 4 (over 71 years) compared to group 1 (under 50 years). However, in none of the three languages the differences were statistically significant, coinciding with the results of Pierce et al. (2013) in which age did not have an effect on oral-DDK rate either. Likewise, although the results seem to coincide with those of Ben-David & Icht (2017) and Chu et al. (2020) when finding a decrease in the measurement, they are not similar because the differences found by these authors were statistically significant. Perhaps not having found a statistical difference responded to the number of participants that made up each age group, since, as seen, the number of participants in both the youngest and oldest age groups was lower than in groups

3 and 4. Even so, the decrease found could be showing the reduction in respiratory capacity and in the coordination of oral movements that other authors have described (Bennett et al., 2007; Haywood, & Getchell, 2020).

Effect of gender on oral-DDK

In this study, the results showed that Spanish and Czech men had a higher value of oral-DDK rate than women, while in German women the oral-DDK rate was the highest one. Even when there were these differences, they were not statistically significant, suggesting that gender had no effect on the oral-DDK rate. This coincides with what was found by Icht & Ben-David (2014), Chu et al. (2020) and Alshahwan et al. (2020) and confirms the idea of comparing the oral-DDK rate with the general measure of languages without being necessary to discriminate by gender.

Reference data across Spanish, German, and Czech

Finally, in this study we wanted to compare the measures of oral-DDK rate between Spanish, German and Czech. The results showed statistically significant differences among the three languages, coinciding with the results that Icht & Ben-David (2014) found when comparing the oral-DDK rate in English, Portuguese, Farsi, and Greek. This is of great importance because it once again confirms that oral-DDK rate varies depending on the language being studied, and that both clinicians and researchers must base their comparisons on reference values specific to their language.

Limitation of the study

The main limitation of this study had to do with the lack of control in data collection, having analyzed information from existing databases. This is because factors such as, for example, the instruction of the task and the modeling given by different people in the three languages could have interfered with the results. Also, the number of speakers in the three languages is small and it is unknown whether with larger cohorts the results may vary. Coupled with the latter, not having controlled the variety of each of the languages limits the generalization of the results. On the one hand, only the variety of Colombian Spanish from the Antioquia region was used in Spanish, but not from other Spanish-speaking regions or countries; On the other hand, the Czech and German did not have information about the origin of the data, since this variable was not reported in the studies.

Future research

It is recommended for future oral rate-DDK studies not only to include more data from people with other variations of the three languages studied, but also to include data in other languages, increasing the number of participants and achieving a balance between different age ranges that allow corroborating or refuting the influence of age on oral- DDK rate. Likewise, it is desirable to establish reference values in languages other than those studied or cited here, since as it could be observed, data showing statistically significant interlanguage differences are being reported so far. Since manual measurements are error prone, further research will be conducted to develop automatic methods, likely based on signal processing and pattern recognition, to measure different oral-DDK features.

Conclusion

This study determined the reference data of the oral-DDK rate for Spanish, German and Czech and found significant differences between the three languages and no significant effects of age or gender on the measure studied.

Author Contributions

Experiment design: MCM. Analysis the data: MCM. Data contribution: EN, JM, JROA. Paper writing: MCM. Paper review: EN, JM, JROA.

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