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Original Article

Behavior of the oral diadochokinetic parameters in primary school students and its relationship with the sociocultural level and phonetic-phonological performance

Claudia Badilla Díaz [a,*], Jaime Soto-Barba [a], Hernán León Valdés [b] & Katia Sáez Carrillo [c]

[a] *Department of Spanish Language, Faculty of Arts and Humanities, University of Concepción, Chile*
[b] *Department of Speech-Language Pathology, Faculty of Medicine, University of Concepción, Chile*
[c] *Department of Statistics, Faculty of Math and Physics, University of Concepción, Chile*

ABSTRACT

This research aimed to assess the behavior of oral diadochokinetic parameters in first-grade students who belong to two different sociocultural environments and show different levels of phonetic-phonological performance. To reach this objective, the oral diadochokinetic parameters were evaluated using monosyllabic repetition of the syllables [pa], [t̪a], and [ka], through the method of syllable emission in a specific time frame. The samples were subsequently analyzed using the Motor Speech Profile program, which provided measurement values for five diadochokinetic parameters (DDKavp, DDKavr, DDKcvp, DDKjit, and DDKcvi). On the other hand, the phonetic-phonological performance was evaluated through the Classification of Phonetic and Phonological Adjustments [Clasificación de Ajustes Fonético-Fonológicos] (CLAFF) guideline. The results showed differences between both sociocultural groups only for the parameters DDKcvp/%/ y DDKjit/%/, while the rest of the diadochokinetic parameters showed similar behaviors when comparing both groups. The group of children with a low sociocultural status showed higher variability and a higher percentage of disturbances in the DDK parameters. Significant correlations were found between some phonetic-phonological adjustments and some diadochokinetic parameters.

Keywords:
DDK; Oral diadochokinetic; Sociocultural level; Phonetic-phonological performance

Comportamiento de los parámetros diadococinéticos orales en escolares de primero básico y su relación con el nivel sociocultural y el desempeño fonético-fonológico

RESUMEN

El objetivo de esta investigación es evaluar el comportamiento de los parámetros diadococinéticos orales en una población de escolares de primero básico, pertenecientes a dos niveles socioculturales y con diferente desempeño fonético-fonológico. Para alcanzar este objetivo se evaluó el rendimiento diadococinético oral de los participantes a través de la repetición monosilábica de [pa], [t̪a] y [ka] utilizando el método de emisión de sílabas en un tiempo determinado. El análisis de las emisiones se llevó a cabo con el programa Motor Speech Profile, el cual entregó los valores de medición para cinco parámetros diadococinéticos (DDKavp, DDKavr, DDKcvp, DDKjit, DDKcvi). Por otra parte, el desempeño fonético-fonológico fue analizado a través de la Pauta de Clasificación de Ajustes Fonético-Fonológicos (CLAFF). Los resultados obtenidos mostraron diferencias significativas entre ambos grupos socioculturales solo para los parámetros DDKcvp/%/ y DDKjit/%/, mientras que el resto de los parámetros diadococinéticos se comportó de manera similar. El grupo de niños del nivel sociocultural bajo tuvo una mayor variabilidad de la tasa DDK y mayor porcentaje de perturbaciones. Se observaron relaciones significativas entre algunos ajustes fonéticos-fonológicos y algunos parámetros diadococinéticos.

Palabras clave:
DDK; Diadococinesias orales; Nivel sociocultural; Desempeño fonético-fonológico

**Corresponding author:* Claudia Badilla Díaz
Email: *clau.badilla.diaz@gmail.com*

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INTRODUCTION

Oral diadochokinesis (DDK) has been studied extensively as an indicator of the efficiency level of speech motor control. Some authors, including Fletcher (1972) and Williams & Stackhouse (2000), have defined it as the ability to voluntarily, alternately, and rapidly execute successive and antagonistic movements of the articulatory structures. It has also been conceptualized as a speech task in which a monosyllabic or multisyllabic sequence is repeated as quickly as possible in a clear and intelligible manner. Thus, DDK is considered a correlate of articulatory agility, especially because they are used to evaluate the coordination of the articulatory structures during the production of syllabic sequences (Karlsson et al., 2020; Modolo et al., 2011; Neel & Palmer, 2012). This task, in which the neuromuscular and phonatory systems work in coordination, has been widely used for the evaluation and characterization of motor speech disorders, since it not only provides information regarding the speed at which a stimulus is produced but also helps evaluate the consistency of the execution, through difference in variation and intensity control (Wang et al., 2008).

DDKs involve the production of isolated consonant-vowel sequences, generally /pa/, /t̪a/, and /ka/, and the multisyllabic sequence /pa.ˈt̪a.ka/. It is mentioned throughout the literature that these stimuli are used because they represent multiple levels of physiological complexity. That is to say, DDKs involve different places of articulation that require the joint participation of lips, jaw, tongue, and vocal folds (Prathanee et al., 2003).

The quantitative analysis of this task delivers a DDK index or rate, which is determined by an examiner who calculates the number of syllables that the subject produces per second.

In children, the assessment of articulatory skills has been thoroughly studied, since its implication in diagnoses and clinical pictures of disturbances in speech development is considered relevant. The following studies carried out on children have made it possible to explore the behavior of the DDK index.

Robbins & Klee (1987) proposed a clinical protocol to evaluate the oropharyngeal motor development of children aged 2 to 6 years old, who had a typical speech development. The study showed that the rate of syllabic repetition increased significantly with age, with children around 2 years old reaching monosyllabic repetition rates of 3.68 s/s, while children around 6 years old showed rates of 5.24 s/s.

Williams & Stackhouse (1998) examined the diadochokinetic skills of children with typical and atypical speech development. Thirty children with typical speech development, aged 3 to 5 years, participated. In addition, the authors carried out a case study of three children with speech disorders, aged between 4 and 8 years. Regarding the group of children with typical speech development, it was observed that the accuracy of their productions increased significantly with age, with variations in performance found only at age 3. Additionally, the consistency of the productions improved significantly between the ages of 3 and 4 years. However, no significant progression in the rate of production was observed. With regards to the children with speech disorders, they presented a much lower performance (on all tasks) compared to children with typical development. Differences were also found between the performances of the children with speech disorders, suggesting that different profiles of DDKs may correspond to different etiologies of speech disturbances.

Similar to the above, Prathanee et al. (2003) studied the rate of DDKs in Thai children with typical speech development, establishing reference data for the child population in Thailand. These data were meant to serve as a guide for the evaluation, diagnosis, and intervention of children with disturbances in oral motor control or oral structures.

In Chile, some studies can be found on the DDK index in children. One of them is the study by Velásquez (2008), which provided normative data for the DDK rate in Spanish-speakers with typical development. The Motor Speech Profile software was used for the analysis, and it provided the following results for ages between 72 and 83 months (6 years to 6 years 9 months): an average DDK period (DDKavp) of 266.25 ms.; an average DDK rate index (DDKavr) of 3.88s.; a coefficient of variation of the DDK period (DDKcvp) of 33.88%.; a DDK period disturbance (DDKjit) of 9.13%; and a coefficient of variation of the peak intensity of DDK (DDKcvl) of 4.50%. Additionally, this study provided normative data for the DDK rate in children aged 10 to 13 years 11 months.

According to the above, the assessment of diadochokinetic performance is generally framed within the motor function of speech. However, a relationship with the phonological representation of speech is also proposed, since mental representation and manipulation of sounds show that the refinement of speech is a continuous process (Wertzner et al., 2008). In this regard, it is argued that motor errors are not exclusive to speech disorders, and that phonological representation errors are not exclusive to phonological disorders, but that both are a reflection of the feedback between the phonetic and phonological aspects of speech (Rvachew et al., 2005). Some contemporary phonology theories emphasize the phonetic or articulatory bases of phonological representations, stating that the movements involved in the production of speech are the means of representation of the phonological system (Kent, 2000). Moreover, the study by Namasivayam et al. (2020) mentions that there have been several attempts to integrate phonetics and phonology. In those attempts, the idea that child speech patterns are solely the product of their articulatory limitations is questioned, whether to meet the phonetic requirements derived from anatomical and motor differences, or merely as a consequence of their phonological skills. Thus, in order to construct phonological representations, it is necessary to include the individual's specific production experience, together with the motor development of speech.

Considering the aforementioned, this study observes a group of children with different phonetic-phonological performances, in order to analyze whether those differences are expressed similarly regarding articulatory agility. This agility is measured using the DDK parameters.

In addition, the relationship between the sociocultural level of the participants (low and middle-high) and their performance in the DDK task is analyzed. It is important to mention that the subjects in this study have shown, in an earlier study, differences in phonetic-phonological performance according to socioeconomic level. Performance was measured in both groups by analyzing the number of phonetic-phonological modifications produced by the speakers (Alarcón et al., 2021). The fact that in the linguistic field research has focused mainly on the relationship between sociocultural level and vocabulary was also taken into consideration since it has been found that families with a high level of vulnerability show a less varied language output (Balladares et al., 2016; Fernald et al., 2013). Moreover, the study by Alarcón et al. (2021) mentions other investigations that link sociocultural status to phonetic-phonological performance in children (Dioses et al., 2006; Dodd et al., 2003; Vivar & León, 2007). These studies state that sociocultural background is strongly related to linguistic abilities during the preschool stage.

On the other hand, and considering that diadochokinetic parameters have been useful to describe variations in the typical development of children's speech, it becomes interesting to observe if these parameters help identify associations between patterns of phonetic-phonological performance and patterns of articulatory agility.

In summary, this study aims to evaluate the behavior of the diadochokinetic index, in a population of first-grade students with different phonetic-phonological performances, belonging to two different sociocultural levels.

To that end, the following objectives are formulated: a) to describe the behavior of the DDK parameters in a population of first-grade children; b) to compare the behavior of the DDK parameters between the group of children belonging to the middle-high sociocultural level and those who belong to a low sociocultural level; c) to analyze the relationship between the children's DDK performance and their phonetic-phonological performance.

METHODOLOGY

Variables of the Study

The following variables were included: a) articulatory agility, measured through the analysis of DDK performance, b)articulatory performance, measured through the analysis of phonetic-phonological modifications, and c) sociocultural level, determined by the type of educational establishment which the children attended. This study considered two perspectives for the analysis: the first perspective establishes sociocultural level as the independent variable and DDK performance as the dependent variable. The second identifies DDK performance as the independent variable and articulatory performance as the dependent variable.

Participants

The sample was made up of 46 subjects, all of whom were part of the partnership project, code 218.083.036-1.0, of the Vice-Rectory of Research and Development (VRID) at the University of Concepción. Phonetic-phonological performance assessments, carried out using the CLAFF guideline, were obtained from the project (Soto-Barba, León, and Torres, 2011), as were the audios containing the oral productions necessary to carry out the analysis of the oral DDK task during the present research. This study was approved by the Ethics, Bioethics, and Biosafety Committee of the University of Concepción, with the number CEBB 876-2021.

The participants were first-graders in primary school, and at the time of admission to first grade each of them was 6 years old. Seventeen of the children attended a public school and 29 received private education.

The type of educational establishment that the children attended was used to determine their sociocultural level, a practice commonly used in linguistics studies to classify the child population (Balladares et al., 2016). According to the Student Vulnerability Index (*índice de vulnerabilidad escolar*, IVE-SINAE), the socioeconomic level is associated with the socio-demographic characteristics of educational establishments *(Junta Nacional de Auxilio Escolar y Becas* [JUNAEB], 2005). The municipal school in this study, which will be referred to as School 1, has a mean IVE-SINAE of 97.44%, which indicates that the families of the children who attend this school belong to a low sociocultural level. In contrast, the private school, which will be referred to as School 2, does not have an analysis of vulnerability available, since the funds that finance this establishment come exclusively from the parents. Therefore, it is considered to belong to a middle-high sociocultural level (Balladares et al., 2016).

Inclusion and Exclusion Criteria

The sample was obtained through non-probabilistic, intentional sampling, with the following inclusion criteria: children attending first grade in primary school (aged 6 and 7 years), without diagnoses of language disorders or special educational needs, who were not a part of the integration program of the school (as informed by parents and teachers). All children who had the informed consent signed by their parents or guardians were included.

Regarding the exclusion criteria, children who presented anatomical disturbances of the articulators which interfered with their oral functions were not considered. For this, an anatomical and functional assessment of the articulators was carried out, which allowed the researchers to observe the size, muscle function, range, and functionality of the structures. In addition, the Teprosif-R test (Pavez et al., 2008) was applied in order to exclude participants who presented a phonological disorder. Students with communicative, cognitive, and/or sensory impairments derived from a primary and/or secondary disorder were not considered for this study either. This information was provided by the parents.

Sample Collection Instrument

A word repetition test called *Test de Repetición Fonético-Fonológica* (TREFF), proposed by Hamdan-Rosales et al. (2020), was used to collect the speech samples. This test was validated by expert judgment and the reliability analysis was performed using the Intraclass Correlation Coefficient (ICC) and the Lin Concordance Correlation Coefficient (CCC). Both showed a value of 0.9, with 1 being the maximum possible value. (Vásquez, 2020). The TREFF test is made up of 104 words that allow eliciting, through direct repetition, the entirety of the phonemes and phoneme sequences that exist in Chilean Spanish.

A list of syllables created specifically for this study was also applied, as indicated in the application instructions of the Motor Speech Profile software. This kind of test is widely used in populations with similar characteristics to the one in this study (Brisso Véliz, 2007; Velásquez, 2008; Vergara Miranda, 2008). The assessment involves performing repetition tasks with monosyllabic and multisyllabic stimuli, as quickly as possible, to evaluate the execution and coordination of the movements involved in the production of speech.

Procedures

The sampling process, carried out by speech-language pathologists who were trained for this task, required the use of the record sheet of the TREFF test. At the moment of assessing the DDKs, the children were asked to repeat the sequences [pa], [t̪a], [ka], and [pa.ˈt̪a.ka] as quickly and as clearly as possible. The method used to calculate the rate was the number of syllables produced in a specific time frame (approximately 12 seconds).

The oral productions of each child, both from the TREFF test application process and from the evaluation of diadochokinetic sequences, were recorded using a Tascam DR-40 digital audio recorder, at a sampling frequency of 44.1 kHz, and saved in 16-bit WAV in a 4 Gb Kingston SD HC memory card. The samples were subsequently imported to a computer.

Phonetic-Phonological Analysis

The phonetic-phonological analysis of the samples was carried out using the guideline *Clasificación de ajustes fonético-fonológicos*, CLAFF (Classification of Phonetic-Phonological Adjustments) (Soto-Barba et al., 2011), which allows to identify, classify, organize, and quantify the phonetic-phonological adjustments (AFF for its acronym in Spanish) made both to segments and to syllables. AFFs are phonetic-phonological modifications made by developing children when they attempt to reproduce words from adult speech. For this research, only AFFs related to features were considered from the CLAFF guideline, since they relate more to phonetics, and this is directly related to the motor skills measured by the DDK index used in this study. The included AFFs were: vowel adjustment (V), vowel per consonant adjustment (VxC), consonant per vowel adjustment (CxV), voicing adjustment (S), distal adjustment to the place of articulation (ZcL), proximal adjustment to the place of articulation (ZcC), and manner adjustment (M). Adjustments that combine the different features mentioned above were also considered. Examples of the types of adjustments and their acronyms can be found in Annex 1.

The CLAFF guideline was chosen because it has shown to be effective when comparing a range of variables in different groups of children (age: León [2012]; English as a second language: Fuica & Soto-Barba [2014]; children with Specific Language Impairment: Torres & Soto-Barba [2016]; children with autism spectrum disorder: Torres et al. [2018]; children with typical speech development: León et al. [2019]; the relationship between passive lexicon and phonetic-phonological performance in preschool children: Hamdan-Rosales et al. [2020], gender and type of establishment attended by the children: Alarcón et al. [2021]).

DDK Analysis

Before performing the DDK analysis, it was necessary to evaluate the acoustic quality of the recordings, in order to ensure that the parameters were reliable. This was achieved by applying a Praat script that measured the signal-to-noise ratio of each recording. The analysis showed an index equal to or greater than 30 dB for all the samples, which indicates an adequate signal-to-noise ratio. This procedure has been applied in other studies with the same purpose (Deliyski et al., 2005, 2006; Figueroa Candia et al., 2019).

Once the signal quality was analyzed, the recordings were edited, by selecting only the segment corresponding to the DDK tasks and subsequently identifying the beginning and end of each task. There were four segments for each child, each containing one isolated syllable sequence ([pa], [t̪a], [ka]) or the multisyllabic sequence ([pa.ˈt̪a.ka]).

After extracting the DDK tasks for each child, the samples were submitted for a perceptual evaluation. At this stage, an examiner listened to the recording in order to determine if the productions presented any interference from the evaluator or from background noises. Only the participants who correctly produced each isolated CV sequence were included. Additionally, a decision was made to exclude the sequence [pa.ˈt̪a.ka] from the stimuli, due to articulatory inconsistencies being found in several samples. There are two possible explanations for this fact: one is that the children did not understand the sequence, be it due to fatigue or to the articulatory complexity of the task; the other might be the fact that the stimulus did not present a lexical-semantic reference.

The Motor Speech Profile program was used to measure the DDK rate. Each recording was processed by the program, delivering results for eleven parameters, of which five were considered for this research: average length of the syllable (DDKavp); average syllables per second or DDK rate (DDKavr); coefficient of variation of the DDK average, or percentage of variability of the production of CV syllables in a period of time /%/ (DDKcvp); disturbances of the DDK period, or percentage of variability of the production of CV syllables cycle by cycle /%/ (DDKjit); coefficient of variation of the maximum DDK intensity /%/ (DDKcvi).

Statistical Analysis

A database was created in Excel for the statistical analysis, in which both the data obtained for phonetic-phonological performance and the data for the DDK performance were registered, as well as their variables, and were analyzed using SPSS 24.0. The mean, standard deviation, and the quartiles of the variables were presented, and the Student's t-test and Mann-Whitney U test were used for comparing the groups. Spearman's correlation coefficient was obtained to determine the relationship between the variables. In addition, the Shapiro-Wilk test was applied to evidence the distributional assumption of normality. In all cases, a significance level of $\alpha=0.05$ was used, meaning that every time the p-value associated with a test was inferior or equal to 0.05, the result was considered statistically significant.

RESULTS

Results of the DDK Analysis per Parameter, Considering the Three CV Sequences and Sociocultural Level

Significant differences were found between both schools only for the DDKcvp and DDKjit parameters in the analysis of the [pa] syllable sequence.

Table 1 shows the values in milliseconds (ms) for the average length of the syllable. For the sequence [pa], in school 1, a mean of 226.71 ms and a standard deviation of 29.98 were obtained, while for school 2 the mean was 227.23 ms and the standard deviation 24.38. For the sequence [t̪a], in school 1, a mean of 223.42 ms and a standard deviation of 30.03 were obtained, while school 2 presented a mean of 228.95 ms and a standard deviation of 24.29. For the sequence [ka], in school 1, a mean of 257.93 ms and a standard deviation of 37.4 were obtained, and school 2 obtained a mean of 246.57 ms and a standard deviation of 33.00. No significant differences were found between both schools.

Table 1. Measures of central tendency and of dispersion for the parameter average length of the syllable (DDKavp), considering sociocultural level and type of syllable.

		Low SCL		Middle-High SCL			
	Variable	Mean	S.D.	Mean	S.D.	Statistic	P-Value
U	[pa] avp (ms)	226.71	29.98	227.23	24.38	383.0	0.7073
T	[t̪a] avp (ms)	223.42	30.03	228.95	24.29	-0.7	0.4988
U	[ka] avp (ms)	257.93	37.41	246.57	33.00	442.0	0.3335

Table 2 shows the DDK rate values in syllables per second (s/s). For the sequence [pa], in school 1, a mean of 4.48 s/s and a standard deviation of 0.57 were obtained, while school 2 showed a mean of 4.45 s/s and a standard deviation of 0.47. For the sequence [t̪a], in school 1, a mean of 4.55 s/s and a standard deviation of 0.56 were obtained, while school 2 presented a mean of 4.42 s/s and a standard deviation of 0.47. For the [ka] sequence, in school 1, a mean of 3.95 s/s and a standard deviation of 0.51 were obtained, and for school 2, a mean of 4.13 s/s and a standard deviation of 0.55 were found. No significant differences were observed between both schools.

Table 2. Measures of central tendency and of dispersion for the parameter "average syllables per second" (DDKavr), considering sociocultural level and type of syllable.

		Low SCL		Middle-High SCL			
	Variable	Mean	D.E.	Mean	D.E.	Statistic	P-Value
T	[pa] avr (s/s)	4.48	0.57	4.45	0.47	0.2	0.8371
T	[t̪a] avr (s/s)	4.55	0.56	4.42	0.47	0.9	0.4026
T	[ka] avr (s/s)	3.95	0.51	4.13	0.55	-1.1	0.2770

Table 3 shows the percentage values (%) for the coefficient of variation of the DDK period. For the sequence [pa], in school 1, a mean of 32.03% and a standard deviation of 14.62 were obtained, while school 2 presented a mean of 19.05% and a standard deviation of 11.57. For the sequence [t̪a], school 1 showed a mean of 18.93% and a standard deviation of 12.62, while school 2 presented a mean of 21.33% and a standard deviation of 18.20. For the sequence [ka], school 1 showed a mean of 25.73% and a standard deviation of 13.10, and school 2 presented a mean of 26.94% and a standard deviation of 21.94. There was a significant difference in the [pa] sequence between both schools.

Table 3. Measures of central tendency and dispersion for the coefficient of variation of the diadochokinetic period (DDKcvp), considering sociocultural level and type of syllable[1].

		Low SCL		Middle-High SCL			
	Variable	Mean	S.D.	Mean	S.D.	Statistic	P-Value
U	[pa] cvp /%/	32.03	14.62	19.05	11.57	530.0	***0.0030**
U	[t̪a] cvp /%/	18.93	12.62	21.33	18.20	389.0	0.8111
U	[ka] cvp /%/	25.73	13.10	26.18	21.94	434.0	0.4324

[1] Correlation was considered significant at 0.05

Table 4 shows the percentage values (%) for the disturbances in the DDK period. For the sequence [pa], school 1 presented a mean of 4.24% and a standard deviation of 1.87, while for school 2, a mean of 2.89% and a standard deviation of 1.56 were obtained. For the sequence [t̪a], school 1 showed a mean of 2.79% and a standard deviation of 1.39, while school 2 presented a mean of 3.83% and a standard deviation of 2.63. For the sequence [ka], in school 1, a mean of 4.29% and a standard deviation of 2.99 were obtained, and school 2 presented a mean of 4.73% and a standard deviation of 4.43. This parameter showed a significant difference in the production of the sequence [pa] between both schools.

Table 4. Measures of central tendency and of dispersion for diadochokinetic period perturbations (DDKjit), considering sociocultural level and type of syllable[2].

		Low SCL		Middle-High SCL			
	Variable	Mean	S.D.	Mean	S.D.	Statistic	P-Value
U	[pa] jit /%/	4.24	1.87	2.89	1.56	504.0	***0.0174**
U	[t̪a] jit /%/	2.79	1.39	3.83	2.63	337.0	0.1549
U	[ka] jit /%/	4.29	2.99	4.73	4.43	407.0	0.8645

[2] Correlation was considered significant at 0.05

Table 5 shows the percentage values (%) for the coefficient of variation of the maximum intensity. For the sequence [pa], school 1 presented a mean of 4.06% and a standard deviation of 1.30, while school 2 showed a mean of 3.79% and a standard deviation of 1.33. For the sequence [t̪a], school 1 showed a mean of 3.21% and a standard deviation of 1.01, while for school 2 a mean of 3.61% and a standard deviation of 1.33 were obtained. For the sequence [ka], school 1 presented a mean of 3.94% and a standard deviation of 1.23, and school 2 had a mean of 4.10% and a standard deviation of 1.20. No significant differences were found between both schools.

Table 5. Measures of central tendency and of dispersion for the coefficient of variation of the maximum intensity (cvi), considering sociocultural level and type of syllable.

		Low SCL		Middle-High SCL			
	Variable	Mean	S.D.	Mean	S.D.	Statistic	P-Value
U	[pa] cvi /%/	4.06	1.30	3.79	1.33	427.0	0.5314
U	[t̪a] cvi /%/	3.21	1.01	3.61	1.33	357.0	0.3335
T	[ka] cvi /%/	3.94	1.23	4.10	1.20	-0.4	0.6690

Results of the DDK Analysis, Related to Phonetic-Phonological Performance

Table 6 displays the values for the correlation between AFF behavior and DDK analysis parameters that were measured in all subjects.

For the production of the [pa] sequence, the distal adjustment to place of articulation shows a significant correlation coefficient of 0.338 with the parameter average length of the syllable, and a significant correlation coefficient of -0.338 with the parameter average syllables per second. The distal adjustment to manner and place of articulation shows a significant correlation coefficient of 0.293 with the parameter coefficient of variation of the DDK period (cvp /%/), a significant correlation coefficient of 0.330 with the parameter disturbance of the DDK period (jit/%/), and a significant correlation coefficient of 0.356 with the parameter coefficient of variation of intensity (cvi/%/). The proximal adjustment to voicing, manner, and place of articulation shows a significant correlation coefficient of -0.296 with the parameter coefficient of variation of the DDK period (cvp/%/), a significant correlation coefficient of -0.294 with the parameter average length of the syllable, a significant correlation coefficient of 0.294 with the parameter average syllables per second, and a significant correlation coefficient of 0.372 with the parameter disturbance of the DDK period (jit/%/).

Regarding the sequence [t̪a], the adjustment to the manner of articulation shows a significant correlation coefficient of -0.338 with the parameter coefficient of variation of intensity (cvi/%/). The proximal adjustment to manner and place of articulation shows a significant correlation coefficient of 0.294 with the parameter average length of the syllable and a significant correlation coefficient of -0.294 with the parameter average syllables per second. The distal adjustment to manner and place of articulation shows a significant correlation coefficient of 0.366 with the parameter coefficient of variation of the DDK period (cvp/%/). The proximal adjustment to voicing, manner, and place shows a significant correlation coefficient of -0.308 with the parameter perturbation of the DDK period (jit/%/).

For the [ka] sequence, the proximal adjustment to manner and place of articulation shows a significant correlation coefficient of 0.306 with the parameter average length of the syllable, a significant correlation coefficient of -0.306 with the parameter average syllables per second, and a significant correlation coefficient of 0.307 with the parameter coefficient of variation of the DDK period (cvp/%/). The distal adjustment to manner and place of articulation shows a significant correlation coefficient of 0.362 with the parameter average length of the syllable (avp/ms/), a significant correlation coefficient of -0.362 with the parameter average syllables per second, and a significant correlation coefficient of 0.304 with the parameter coefficient of variation of the DDK period (cvp/%/).

Table 6. Measures of correlation between the values of the DDK parameters for each CV sequence, and the feature adjustments.

	[pa]					[t̪a]					[ka]				
	avp /ms/	avr /s/s/	cvp /%/	jit /%/	cvi /%/	avp /ms/	avr /s/s/	cvp /%/	jit /%/	cvi /%/	avp /ms/	avr /s/s/	cvp /%/	jit /%/	cvi /%/
ZcL	**.338***	**-.338***	-.113	-.140	-.209	.056	-.056	.070	.019	-.114	.087	-.087	.003	.025	-.085
M	.161	-.161	.101	.145	-.246	.143	-.143	-.094	-.253	**-.338***	.288	-.288	-.080	-.097	-.154
MZcC	.191	-.191	.136	.156	.033	.294*	**-.294***	.210	.107	.240	**.306***	**-.306***	.307*	.237	.076
MZcL	.095	-.095	**.293***	**.330***	**.356***	.273	-.273	**.366***	.198	.242	**.362***	**-.362***	**.304***	.230	.193
MZcCS	-.110	.110	**-.296***	-.285	-.215	.064	-.064	-.081	-.174	.000	-.151	.151	-.116	-.064	.099
MZcLS	**-.294***	**.294***	.221	**.372***	.217	-.080	.080	-.153	**-.308***	-.080	.125	-.125	-.034	-.089	-.071

DISCUSSION

This research analyzed the relationship between articulatory agility and phonetic-phonological performance in first-grade children with typical development, coming from low and middle-high sociocultural levels. Only the syllable [pa] was considered for comparing the results of this study and other similar investigations since this is the most common sequence used to measure oral-DDK (Velásquez, 2008; Williams & Stackhouse, 1998). The results for the parameters DDKavr, DDKcvp, and DDKjit are discussed hereunder, with the first one representing the average number of syllables produced per second (that is to say, the DDK rate) and the last two being the only parameters to show a significant difference between groups. The average DDK rate (DDKavr) for the syllable [pa] behaved similarly to what has been reported by other studies, showing a rate of 4.48 s/s for the low sociocultural level group, and 4.45 s/s for the middle-high level group. The results are similar to those obtained by Robbins & Klee (1987) who reported a rate of 5.51 s/s for English-speaking 6-year-old children. On the other hand, Velásquez (2008), who worked with a population very similar to the one in this research, obtained similar values for the age range of 72 to 83 months (6 years to 6 years 9 months), with an average DDK rate of 3.88 s/s.

With regards to the variable of sociocultural level, the DDKavr parameter behaved similarly in both groups for each of the stimuli, and no significant differences were found. For the stimulus [pa], the low sociocultural level group presented a mean rate of 4.48 s/s and the middle-high sociocultural level group a mean of 4.45 s/s. As for the stimulus [t̪a], the low sociocultural level group obtained a mean rate of 4.55 s/s and the middle-high group a mean rate of 4.42 s/s. Finally, for the [ka] stimulus, the low sociocultural level group showed a mean rate of 3.95 s/s and the middle-high group a mean rate of 4.13 s/s. These findings indicate that sociocultural level does not directly impact the performance in DDK tasks, specifically regarding the DDKavr parameter. This is contrary to what is found in the literature, which is that the child's sociocultural level influences different areas of development since environmental factors play an important role in the integration of knowledge (Jadue, 1997). However, the fact that the children in this study presented typical speech development should be taken into consideration, since it would be expected that the DDK rates in both groups are similar even when they belong to different sociocultural levels. This similarity indicates that differences in children's oral motor control stem from a gradual maturation of the oral control system or neurological or organic disturbances (Prathanee et al., 2003).

The coefficient of variation of the period for the sequence [pa] showed significant differences between both groups. Indeed, in the low sociocultural level group, 32.03% was obtained, while the middle-high group showed a 19.05% of variation. This indicates that children in the first group were less able to maintain a consistent rate when producing the CV combinations than the latter during the window of analysis. It is important to remember that this parameter measures the percentage of variation in the number of syllables produced per second, resulting in a low percentage if the subject produces the CV combination with little variation over time, and increasing as the variation in the DDK rate increases (Pérez et al., 2015). This aspect could be explained, in part, by the rhythmic control of the motor production of speech. Henry (1990), in a study carried out on English-speaking children, states that rhythm is an important element of the level of efficiency of articulatory movements since it acts as an organizer of oral productions. This is observed in the fact that children who perform DDK tasks with more ease organize the repetitions rhythmically, that is to say, they present a constant sequence repetition. In line with the above, the findings in this study show that the productions in the group of children belonging to a middle-high sociocultural level had a more consistent rhythm, as opposed to the productions in the low sociocultural level group, where there was greater variability. It would be interesting to consider this aspect for future research, since observing the regularity of oral productions is as important as knowing the mean number of syllables per second (Cohen et al., 1998; Yaruss & Logan, 2002).

Another parameter where significant differences were found was the period perturbation, which measures the degree of cycle-to-cycle variation in the period, and it is expressed in percentage. This difference was found in the [pa] sequence. For this parameter, in the low sociocultural level group, a 4.24% period perturbation was obtained, whilst for the middle-high group, it was 2.89%, meaning that the first group showed greater variation in the length of each syllable compared to the latter group. In other words, if the CV vocalization is repeated with little cycle-to-cycle variation (length in milliseconds), the value of the period perturbation parameter will be low. However, if the length of each syllable is highly variable during the analysis window, this value will increase (Pérez et al., 2015).

Since there were only two parameters for which significant differences were found between groups, and considering the performance in each index, it is not possible to affirm that sociocultural level influences DDK performance in children.

Regarding the variable of phonetic-phonological performance, no significant correlation was found between the adjustments total and the DDK parameters. Relationships were found between each type of adjustment and some phonetic-phonological features, and specifically only for some of the DDK parameters in some of the three syllabic stimuli. At this stage of the analysis, the performance in speech production was expressed in AFF, which means that a child with better performance would have a lower tendency to produce phonetic-phonological adjustments.

Concerning the phonetic-phonological adjustments to features, it was observed that adjustments to voicing were not significantly related to any of the DDK parameters (see Annex 2). This may be because voicing is a feature present in some speech sounds, that requires the participation of the larynx and vocal folds (Ladefoged & Johnson, 2011; Quilis, 1997). These structures are relatively independent at an anatomical and physiological level from the motor control of oral structures whose specific performance is measured during the oral- DKK tasks.

As for the rest of the feature adjustments, significant correlations were found between DDK parameters and adjustments that appeared more frequently in boys (see Annex 2). There were also significant relationships with adjustments that include more than one feature. Lastly, there were significant relationships with the adjustments that imply a greater displacement of the articulators in an anteroposterior dimension. For example, the distal adjustment to place of articulation showed a significant direct relationship with the average length of the syllable. This would mean that the greater the effort needed to displace the articulators, the longer the time to produce a syllable, which would, in turn, affect the number of syllables per second, explaining the negative correlation with the parameter of average syllables per second. In other words, these variables are inversely proportional. The same situation occurred regarding the proximal adjustment to manner and place, distal adjustment to manner and place, and distal adjustment to voicing, manner, and place. It is worth mentioning that these relationships are evident only for some of the stimuli, probably because the DDK performance was not the same for every indicator. In this regard, future research should delve further into these findings, replicating the methodology on a larger sample. This will allow analyzing the results with a wider perspective, and observing whether there are similar manifestations regarding the behavior of DDK parameters.

The fact that the subjects in this research represent a population with typical speech development is noteworthy since the number of adjustments obtained is what is expected for this age range. In atypical-developing populations, the opposite could take place, since in children with atypical development the number of AFFs tends to increase, as shown in the study by Torres & Soto-Barba (2016). Here, the number of AFFs was considerably higher in speakers with specific language impairment. Thus, it is probable that in this type of population the relationship between phonetic-phonological performance and DDK performance is more notorious.

The work presented here has some limitations. Firstly, the selection of stimuli used to measure the DDK performance did not include the multisyllabic sequence [pa.ˈt̪a.ka], having been discarded during the stage of audio analysis. This was because the children presented many difficulties to produce this sequence correctly. Secondly, the population was made up only of children with a typical phonetic-phonological development, which might have prevented the emergence of contrasts in articulatory agility that are more evident in populations with atypical development. Finally, the fact that five indexes were used to measure DDK behavior may have diverted the discussions from the main objective. However, this could be considered a partial limitation, since it allowed for more information regarding articulatory skills to emerge.

CONCLUSION

The oral diadochokinetic performance of children observed in this study showed similar behavior for both sociocultural groups, with significant differences only being found in some of the parameters analyzed. Thus, it is possible to affirm that the sociocultural level is a variable that partially influences DDK performance. On the other hand, the phonetic-phonological performance of the children was significantly related to some of the DDK parameters. Although there were no correlations found with each one of the AFFs, there were associations between some of these adjustments and specific DDK parameters. Finally, the DDK rate in both groups of children behaved according to what is expected for the age range of 6 to 7 years.

This research offers a description of the behavior of the oral-DDK index in a population of children with typical development. It is considered that this index constitutes an important aspect of the speech assessment, both in adults and in children, as has been widely documented by other research. In particular, the relationship of the proposed methodology and the observation of the DDK index with the sociocultural level of children is deemed important. The relationship between DDK parameters and the phonetic-phonological performance of the participants is relevant for the work of speech-language pathologists, since this tool can be used for the observation and diagnosis of the oral motor behavior of different Chilean populations.

Lastly, future research should evaluate DDK parameters in a greater number of subjects, both with typical and atypical development and in different age groups, in order to be able to generalize these findings and observe the relationship of certain indicators with other linguistic phenomena, such as reading comprehension and oral production. Furthermore, this would contribute to the diagnosis and treatment of pathologies associated with DDK performance, an issue that concerns speech-language pathologists directly.

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ANNEX 1

Pauta de Clasificación de Ajustes Fonético-Fonológicos

Ajustes fonético-fonológicos efectuados a los rasgos articulatorios de los fonemas.

	Ajuste de Rasgos	Abreviatura	Ejemplo
AFF aislados	Ajuste vocálico	V	[e.li.'kop.t̪e̞.ɾo] por [e.li.'ko.t̪**i**.ɾo]
	Ajuste de vocal por consonante	VxC	['kwo.t̪a] por ['k**ɾ**o.t̪a]
	Ajuste de consonante por vocal	CxV	[dɾa.'ɣ̞on] por [d**j**a.'ɣ̞on]
	Ajuste de Sonoridad	S	[pa.'ɾeð] por [pa.'ɾe**t**]
	Ajuste de Zona con cercanía	ZcC	['ap.t̪o] por ['al̞.t̪o]
	Ajuste de Zona con lejanía	ZcL	['t̪ɾen] por ['**k**len]
	Ajuste de Modo de articulación	M	[t̪e̞.'le.fo.no] por [t̪e̞.'ne.fo.no]
AFF combinados	Ajuste de modo y zona con cercanía	MZcC	[re.'lox] por [re.'lo**k**]
	Ajuste de modo y zona con lejanía	MZcL	[ɲan.'d̞u] por [ɲan.'**d͡ʒ**u]
	Ajuste de modo y sonoridad	MS	['t͡ʃi.ko] por ['**ɲ**i.ko]
	Ajuste de sonoridad y zona con cercanía	SZcC	['ob.xʲe.t̪o] por ['o**t̞**.xʲe.t̪o]
	Ajuste de sonoridad y zona con lejanía	SZcL	['af.t̪a] por ['a**s**.t̪a]
	Ajuste de modo, sonoridad y zona de articulación con cercanía	MSZcC	[a.t̪a.'uð] por [a.t̪a.'u**f**]
	Ajuste de modo, sonoridad y zona de articulación con lejanía	MSZcL	['sig.no] por ['si**s**.no]

Ajustes fonético-fonológicos efectuados a la estructura de la sílaba

	Ajustes de Sílaba	Abreviatura	Ejemplo
AFF de adición de segmentos	Adición de segmentos al inicio de palabra	Aseg1	['**d̞**ɾo.xo] por ['ro.xo]
	Adición de segmento al interior de palabra	Aseg2	['ai.**ɣ̞**ɾe] por ['ai.ɾe].
	Adición de segmentos al final de palabra	Aseg3	['rei̯ **k**] por ['rei̯].
	Adición de sílaba al inicio de palabra	Asil1	[**ko**.'ko.t̪au̯] por ['kwo.t̪a].

ANNEX 2

	PA.avp /ms/	PA.avr /s/s/	PA.cvp /%/	PA.jit /%/	PA.cvi /%/	TA.avp /ms/	TA.avr /s/s/	TA.cvp /%/	TA.jit /%/	TA.cvi /%/	KA.avp /ms/	KA.avr /s/s/	KA.cvp /%/	KA.jit /%/	KA.cvi /%/
Features	,244	-,244	,056	,154	-,018	,156	-,156	-,034	-,182	-,135	,243	-,243	-,031	-,008	-,061
Syllable	-,018	,018	,232	,252	,069	,053	-,053	-,015	-,131	-,026	,124	-,124	,072	,003	,087
Total	,136	-,136	,105	,180	,000	,100	-,100	-,049	-,201	-,116	,208	-,208	-,052	-,048	-,051
Percentage	,285	-,285	-,341*	-,262	-,180	,224	-,224	,079	-,010	-,043	,162	-,162	-,005	,090	-,149
V	,001	-,001	,134	,111	,099	,024	-,024	-,063	-,147	,022	,065	-,065	,063	,025	,011
CxV	-,044	,044	,100	,114	,074	-,061	,061	,015	-,050	,145	-,101	,101	,155	,091	,118
S	,221	-,221	,108	,086	-,055	-,066	,066	-,009	-,055	-,216	,205	-,205	-,044	-,021	-,180
ZcC	-,100	,100	-,046	,032	,162	-,123	,123	-,206	-,157	-,111	-,214	,214	-,149	-,132	,073
ZcL	,338*	-,338*	-,113	-,140	-,209	,056	-,056	,070	,019	-,114	,087	-,087	,003	,025	-,085
ZcLS	,130	-,130	,069	,058	,067	,145	-,145	,039	,013	-,143	,174	-,174	-,031	,009	-,023
M	,161	-,161	,101	,145	-,246	,143	-,143	-,094	-,253	-,338*	,288	-,288	-,080	-,097	-,154
MZcC	,191	-,191	,136	,156	,033	,294*	-,294*	,210	,107	,240	,306*	-,306*	,307*	,237	,076
MZcL	,095	-,095	,293*	,330*	,356*	,273	-,273	,366*	,198	,242	,362*	-,362*	,304*	,230	,193
MS	,050	-,050	,028	,054	-,108	,241	-,241	,262	,170	,057	-,139	,139	,093	,139	-,047
MZcCS	-,110	,110	-,296*	-,285	-,215	,064	-,064	-,081	-,174	,000	-,151	,151	-,116	-,064	,099
MZcLS	-,294*	,294*	,221	,372*	,217	-,080	,080	-,153	-,308*	-,080	,125	-,125	-,034	-,089	-,071
OSil1	,182	-,182	,043	-,023	,036	,229	-,229	-,050	,169	,010	,275	-,275	,109	,103	-,030
Osil 2	,136	-,136	,150	,210	,144	,195	-,195	,182	-,070	,004	,162	-,162	,027	-,070	-,173
OSeg1	,063	-,063	,177	,203	-,125	,074	-,074	-,078	-,252	-,155	-,032	,032	-,195	-,244	-,151

	PA.avp /ms/	PA.avr /s/s/	PA.cvp /%/	PA.jit /%/	PA.cvi /%/	TA.avp /ms/	TA.avr /s/s/	TA.cvp /%/	TA.jit /%/	TA.cvi /%/	KA.avp /ms/	KA.avr /s/s/	KA.cvp /%/	KA.jit /%/	KA.cvi /%/
OSeg2	,019	-,019	,166	,204	,129	,021	-,021	-,034	-,202	-,074	,141	-,141	,037	-,030	-,014
OSeg3	-,107	,107	,179	,190	,115	-,069	,069	,110	,142	,061	-,126	,126	,223	,185	,214
ASil1	,107	-,107	,185	,118	,107	,062	-,062	,219	,152	,129	,051	-,051	,197	,152	,017
ASil2	,046	-,046	,279	,320*	,093	,134	-,134	,099	-,035	-,122	,244	-,244	-,157	-,116	-,282
ASeg1	-,115	,115	,108	,184	-,345*	-,169	,169	-,051	-,006	-,138	-,092	,092	-,009	-,028	-,215
ASeg2	-,134	,134	,124	,071	-,015	-,206	,206	-,164	-,215	,124	,032	-,032	-,195	-,257	,165
ASeg3	-,170	,170	-,074	-,196	-,111	-,161	,161	-,082	-,096	,071	-,137	,137	-,017	-,087	,045
Metathesis	,041	-,041	,344*	,302*	,201	,105	-,105	,037	-,176	-,254	,385**	-,385**	,027	-,051	-,315*
Diphthongization	-,055	,055	-,062	-,048	,187	,031	-,031	-,017	-,123	,084	-,012	,012	,108	,040	,190
Monophthongization	-,102	,102	,271	,459**	,232	,060	-,060	,125	,086	,029	-,021	,021	,040	,094	-,042
Osil	,233	-,233	,133	,125	,126	,311*	-,311*	,082	,078	,007	,325*	-,325*	,098	,026	-,144
Oseg	,033	-,033	,207	,270	,090	,075	-,075	,006	-,152	-,067	,081	-,081	,075	,008	,059
Asil	,092	-,092	,339*	,345*	,134	,150	-,150	,192	,039	-,050	,245	-,245	-,050	-,034	-,247
Aseg	-,177	,177	,081	,025	-,135	-,213	,213	-,127	-,147	,098	-,023	,023	-,076	-,146	,131

* Correlation is considered significant at 0,05 (bilateral).
** Correlation is considered significant at 0,01 (bilateral).