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Variability of speech rate and articulatory transition ability

Variabilidade da velocidade de fala e habilidade articulatória de transição

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ABSTRACT

Purpose: To analyze speech rate by applying two different methods: speech rate analysis considering the ratio of time/ fluent stretches of the sample and considering the ratio of time/200 fluent syllables **Methods:** The speech samples from 73 participants of both genders, Brazilian Portuguese speakers, were analyzed. The analysis was carried out based on the parameters of Fluency Profile Assessment Protocol and compared regarding: speech rate (syllables per minute) and total time of the speech sample (in both reference and proposed methodology). **Results:** The significant positive correlations found in the three analyses indicate that the variables concerning the measurement of speech rate by the two methods of analysis are related and move together. **Conclusion:** Although the proposed methodology has proven to be effective, it proved unfavorable in comparison because it reflects proportionally the same results as the traditional methodology, but demands more time and manual resources.

Keywords: Speech, language and hearing sciences; Speech disorders; Speech production measurement; Speech acoustics; Reference standards

RESUMO

Objetivo: Analisar a velocidade de fala aplicando dois métodos distintos: análise da velocidade de fala considerando a relação tempo/trechos fluentes da amostra e considerando a relação tempo/200 sílabas fluentes. **Métodos:** foram analisadas as amostras de fala de 73 participantes de ambos os gêneros, falantes do português brasileiro. As análises foram realizadas a partir dos parâmetros do protocolo Perfil da Fluência da Fala e comparadas quanto à velocidade de fala (sílabas por minuto) e ao tempo total da amostra de fala (na metodologia de referência e na metodologia proposta). **Resultados:** As correlações positivas significativas encontradas nas três análises indicaram que as variáveis referentes à medição da velocidade de fala pelos dois métodos de análise estão relacionadas e se movem juntas. **Conclusão:** Embora a metodologia proposta seja eficaz, revela-se desfavorável na comparação, porque reflete proporcionalmente os mesmos resultados da metodologia tradicional, porém demanda maior tempo e recursos manuais para sua realização.

Palavras-chave: Fonoaudiologia; Distúrbios da fala; Medida da produção da fala; Acústica da fala; Padrões de referência

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Conflict of interests: No.

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INTRODUCTION

Speech production occurs as a process that follows a series of steps, initially with conceptualization, in which thoughts are generated, passing through formulation, recovering words and grammatical structures, and then, reaching articulation, in which the phonetic plans can finally be executed. The speech rate is one of the objective measures of fluency in speech production. The speech rate is recognized as an important factor in an individual's ability to effectively communicate a message. The speech rate is a product of several factors, including sensorimotor and language processes. The rate of speed is a common target in speech intervention to improve speech production in individuals with changes in speech motor processing. The rate of speed, added to other measurable and clinical data, is a significant indicator of the severity of stuttering. A rate of speed low or below the expected for the profile of age, gender, education, and other sociocultural variability is indicative of effort and difficulty in communication. There are new studies whose main focus is the identification of factors such as age and cognitive-linguistic load, that influence the speech rate[1-8].

The speech rate is the product of three neuromotor processes: the speed at which the person can produce the flow of information (measured by the interlocutor's ability to understand the message), the speed that the articulators move to produce an utterance (i.e., articulation rate) and the pause time between segments. Articulation rate is considered a reflection of speech-motor control. Pause time is considered to reflect cognitive-linguistic processes related to the load (for example the formulation demands) of the speaking task. An increase in speaking rate is achieved by increasing articulation speed and decreasing pause time. The maturation of speech articulation skills can also lead to increases in this rate[5,9-15].

An emerging area of research is how cognitive-linguistic and motor loads interact in regulating the speech rate. Evidence suggests that both the articulation rate and the pause time vary according to the cognitive-linguistic load. Articulation rate appears to be highly sensitive to the impact of sentence length, while a higher cognitive-linguistic load may be required to see the effects of sentence length on pause time. Cognitive-linguistic load is influenced by sentence length and/or complexity within a task (for example four-word sentences versus five-word sentences in a repetition task) or by the complexity of the task itself (spontaneous speech, being a more complex control condition)[16-21].

Considering that the speech rate (integrating articulation speed and speech fluency) can be described by its phonetic properties, directly reflecting speech motor functions such as movement speed, articulatory sequencing, or respiratory control[21-23], this research aimed to compare two methodologies for analyzing the speech rate:

1. Methodology A – as proposed[8] for people who speak Brazilian Portuguese, with and without complaints of changes in speech fluency. This method of evaluating the speech rate time analyzes the number of words and syllables per minute in a stretch of spontaneous speech containing 200 fluent syllables.
2. Methodology W – as proposed[23] for people who speak Brazilian Portuguese, with and without complaints of changes in speech fluency. This time assessment method only considers the fluent excerpts of the speech sample.

The contribution of the study, through the application of different speech rate analysis models, was to investigate whether there is a more accurate method that allows verifying the speaker's real speech rate and the variability of this speed in the severity levels of persistent stuttering.

METHODS

This is a retrospective observational clinical study, based on the analysis of speech samples collected between January 2012 and December 2022 which are part of the database of the Speech-Language Therapy Division of the Central Institute of the Hospital das Clínicas of the Medical School of the University of São Paulo (ICHC-FMUSP). The sample selection process only began after the study was approved by the institution's Ethics Committee (CAPPesq 6.529.522.9). As this was a retrospective study, based on a database, the signing of the Informed Consent Form by all participants or their guardians was not required. The data used for the study were accessed manually on the division's computer, through analysis of the medical records of individuals who met the research inclusion criteria. This data was tabulated in a specific online database and will be kept securely on the Hospital das Clínicas network, managed by the Specialized Center for Information Technology (NETI). Only researchers directly involved in the research had access to the database.

Participants

Speech samples from 73 participants, with and without complaints of stuttering, were analyzed. The participants' ages ranged between 18 and 47 years old, of both genders, without distinction of race and restrictions on socioeconomic-cultural level. Speech samples were obtained according to the following criteria: participants must be monolingual speakers of Brazilian Portuguese or have acquired another language(s) after acquiring Brazilian Portuguese; they could not have oral communication comorbidities (diagnosed or identified in a specific screening test); they could not have a hearing loss of any level (also diagnosed or identified in a specific screening test), and could not have a history of neurological and/or degenerative diseases.

Collection of speech samples

The speech samples were obtained in a spontaneous speech situation, using a stimulus figure or dialogue directed by the evaluator. Each speech sample (video and audio) was digitally recorded with a high-definition microphone. Spontaneous speech was only interrupted by comments and questions if there was a need to encourage speech production. All samples were recorded on video and transcribed for analysis.

Speech samples analysis

This study was carried out with a blinded analysis of speech samples to avoid biases, prejudices, misinterpretation of test results, and other information that could affect judgment during transcription. The analyses of the speech samples were carried out by qualified speech therapists who did not participate in the collection of the original speech samples and who were not aware of the identification of the participants and the presence, or not, of complaints of stuttering.

The same speech samples were subjected to two different methodologies to analyze speech rate and variables:

Methodology A[8] - the total sample time was considered as the entire interval used to obtain 200 fluent syllables. In this methodology, the total sample time included fluent and non-fluent syllables; the timer started when the participant started speaking and paused when the speaker finished speaking. The excerpts of the evaluator's speech (when intervention was necessary) were not timed and/or counted.

Methodology W[23] – the total sample time was considered the interval used to obtain, exclusively, 200 fluent syllables. In this methodology, the total sample time excluded the time intervals spent by non-fluent syllables, that is, when the participant had disfluency (common or stuttering), the time spent by this disfluency was disregarded from the total sample time.

For both methodologies, non-fluent syllables included common disfluencies (hesitation, interjection, revision, unfinished word, word repetition, segment repetition, and phrase repetition) and stuttering disfluencies (syllable repetition, sound repetition, prolongation, blocking, pausing, and sound or segment intrusion).

To increase the reliability of the study, a total of 15% of the speech samples were subjected to reanalysis by three speech-language therapists judges with experience in this type of analysis. A level of agreement of 85% (k=0.48) was obtained, indicating high agreement in the analysis of the results.

Grouping criteria

The first control variable in the study was the rate of stuttered syllables. According to literature data, there is a consensus that speech samples with a percentage of stuttering interruptions greater than or equal to 2% are samples strongly suggestive of people who stutter, ranging from mild to very severe (research group)[17-20]. Speech samples with a percentage of disruptions less than or equal to 1.9% are speech samples strongly suggestive of fluent people (control group). Figure 1 shows the distribution flowchart.

RESULTS

Descriptive analysis of the results, divided by group

Table 1 shows the descriptive results of the traditional measurement of speech rate, according to Methodology A (MA), and the one obtained from the measurement of the rate of speech, according to Methodology W (MW).

Correlation between the different speech rate measurement alternatives, divided by group

As shown in Table 2, there was a moderate positive correlation between the rate of syllables per minute obtained with the two methodologies, using Spearman's correlation coefficient. Also, Table 2 shows that there was a strong positive correlation between the total duration of the segment, obtained from the traditional measurement of speech rate using the MA, and the one obtained with the two methodologies, using Spearman's correlation coefficient. In all cases, the correlations found were significant (p<0.05).

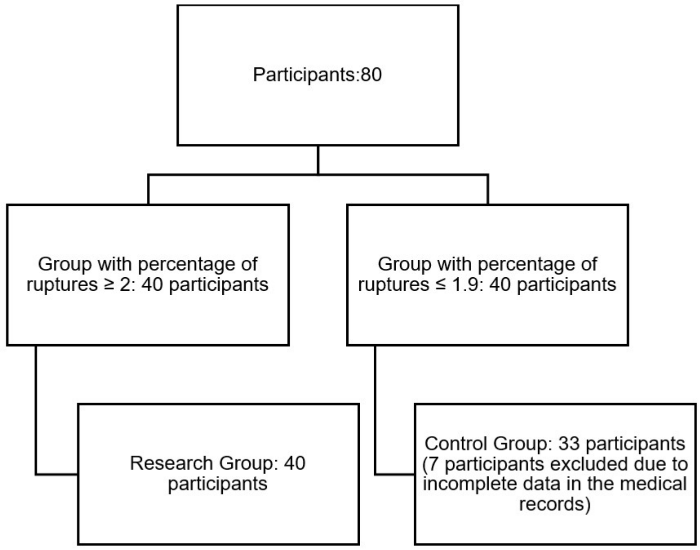

Figure 1. Grouping flowchart
Subtitle: ≥ = greater than or equal to; ≤ = less than or equal to

Correlation between the different alternatives for measuring speech rate, divided by stuttering severity, according to the Stuttering Severity Instrument – 3 (SSI-3)

This analysis was applied only to the 40 participants in the research group who were analyzed according to the severity of stuttering, determined by the SSI-3[24]. As shown in Table 3, there was a significant strong positive correlation ($p<0.05$) for participants with mild and very severe stuttering between the rates of syllables per minute and the total duration of the segment, calculated by Methodologies A and W. For participants with moderate and severe stuttering, no correlation was found between the two ways of measuring speech rate.

Correlation between the different alternatives for measuring speech rate, divided by adequacy to normality for speech rate

In this third analysis, all 73 participants were redistributed according to the reference values for Brazilian Portuguese[25]: participants with normal speech rate (n=26); participants with increased speech rate (n=18), and participants with decreased speech rate (n=29). Table 4 shows a significant strong positive correlation ($p<0.05$) for participants with increased speech rate, between the rates of syllables per minute, measured by Methodologies A and W ($\rho=0.708$), and the total duration of the segment, measured by Methodologies A and W ($\rho=0.708$). For participants with normal or decreased speech rate, no

Table 1. Descriptive summary of measurement results between Methodologies A and W

		Mean (±SD)	CI 95%
Research Group (n=40)			
MA	Rate of syllables per minute	146.4 (±56.8)	128.2 – 164.6
	Total segment duration	93.4 (±34.2)	82.5 – 104.4
MW	Rate of syllables per minute	250.9 (±51.2)	234.5 – 267.3
	Total segment duration	49.4 (±9.9)	46.2 – 52.5
Control Group (n=33)			
MA	Rate of syllables per minute	236.7 (±45.9)	220.4 – 253.0
	Total segment duration	52.5 (±10.0)	49.0 – 56.1
MW	Rate of syllables per minute	278.3 (±47.7)	261.4 – 295.2
	Total segment duration	44.3 (±7.0)	41.8 – 46.7

Subtitle: n = Number of participants; % = Percentage; SD = Standard deviation; 95% CI = 95% confidence interval for the mean; MA = Methodology A; MW: W Methodology

Table 2. Bivariate correlation between methodologies A and W

		Correlation between measurements: MA and MW	
		Spearman correlation coefficient – ρ	p-value
Rate of syllables per minute	Research Group (n=40)	0.651	*<0.001**
	Control Group (n=33)	0.623	*<0.001**
Total segment duration	Research Group (n=40)	0.881	*<0.001**
	Control Group (n=33)	0.882	*<0.001**

***** = significance
Subtitle: n = number of participants; MA = Methodology A; MW = W Methodology

Table 3. Bivariate correlation between the traditional measurement of speech rate using Methodology A and the speed measurement carried out using Methodology W - (division by stuttering severity, according to the Stuttering Severity Instrument – 3)

Speech rate measurement criterion	Severity of stuttering (SSI-3)	Correlation between measurements: MA and MW	
		Spearman correlation coefficient – ρ	p-value
Rate of syllables per minute	Mild (n=11)	0.709	*0.015**
	Moderate (n=15)	0.366	0.199
	Severe (n=8)	0.095	0.823
	Very Severe (n=6)	0.886	*0.019**
Total segment duration	Mild (n=11)	0.709	*0.015**
	Moderate (n=15)	0.366	0.199
	Severe (n=8)	0.095	0.823
	Very Severe (n=6)	0.829	*0.042**

***** = significance
Subtitle: n = number of participants; SSI-3 = Stuttering Severity Instrument – 3; MA = Methodology A; MW = W Methodology

Table 4. Bivariate correlation between the traditional measurement of speech rate using Methodology A and the speed measurement carried out using Methodology W - (division according to adequacy to normal speech rate standards for the age group)

Speech rate measurement criterion	Speech rate classification	Correlation between measurements: MA and MW	
		Spearman correlation coefficient – ρ	p-value
Rate of syllables per minute	Normal (n=26)	0.104	0.613
	Decreased (n=29)	0.277	0.146
	Increased (n=18)	0.708	*0.001**
Total segment duration	Normal (n=26)	0.111	0.588
	Decreased (n=29)	0.221	0.248
	Increased (n=18)	0.708	*0.001**

* = significance
Subtitle: n = number of participants; MA = Methodology A; MW = W Methodology

correlation was found between the two ways of measuring speech rate.

DISCUSSION

This study aimed to analyze speech rate by applying two different methods to people with and without complaints of stuttering. According to Methodology A[8], the entire time interval used to obtain 200 fluent syllables was considered as the total time of the speech sample. In this methodology, the total sample time includes fluent and non-fluent syllables. In Methodology W[23], the total sample time was considered the time interval used to obtain, exclusively, the 200 fluent syllables. In this methodology, the total sample time excludes the time intervals spent by non-fluent syllables.

As well explained by authors[23], speech rate is a predictor of communication capacity, that is, stable speech rate allows the individual to produce the message effectively. There are questions about how to define and what factors impact speech rate. For authors[17], speech rate is the product of the rate at which the articulators move to produce an emission, plus the natural pauses in that emission. For these authors, speech rate is the product of the relationship between articulation rate, pause time, and the cognitive-linguistic load of the message.

This study also contributed to understanding the articulatory speed of coarticulation transition. Total articulation time is a simple measure of duration. The articulation time starts from the production of an initial movement, which generates the temporal organization of the speech, with the time of pauses (total duration of silent spaces in the speech) being subtracted from the total utterance time (total duration of a given utterance)[8,23]. When the time of disfluencies is removed from the total articulation time, this articulation rate determines the average duration of each syllable produced.

The focus of the analysis in Methodology A[8] is the functionality of speech since the individual is processing the message in real-time, producing message content, that is, it is the speech rate that the interlocutor perceives, it is the speed that most closely matches reality and interlocution situations.

The focus of the analysis in Methodology W[23] is the fluency of speech since it excludes the times of pauses and speech interruptions, that is, the speed of cognitive-linguistic processing to produce fluent syllables.

Both methodologies could be applied to a controlled speech sample. Regarding applicability, Methodology W[23] proved to be more complex in the analysis of spontaneous speech samples because the analysis uses a manual timer that depends on the examiners' reaction time (activating and deactivating the timer during pauses and interruptions). Methodology A[8] presented greater practicality, because, although the transcription of the sample was equally laborious, the counting of fluent syllables was less subject to the variability of the examiners' reaction time.

Regarding the results of the statistical analyses, we observed that the two methodologies are compatible in their objectives, varying the syllable counting format. In the correlation analyses, there were significant positive correlations found in the different formalized analyses, indicating that the variables referring to the measurement of speech rate by MA and those referring to measurement by MW are related and move together. The closer the correlation coefficient ρ approaches 1, the stronger the correlation. Correlation coefficients between 0.4 and 0.69 show moderate correlations, while those between 0.7 and 0.89 show strong correlations.

The analysis in Table 3 indicates that both methodologies, focusing on speech rate measurements, only differentiated the extremes of stuttering severity, that is, speech rate is not a sensitive variable to measure the severity of the disorder.

The analysis in Table 4 indicates that both methodologies, focusing on speech rate measurements, only differentiated increased speed rates, that is, confirming the findings in Table 3, speech rate is not a sensitive variable to measure the speed variability levels for fluent and stutterers.

Although the study contributes to speech-language therapy science, it had some limitations such as the subjective performance of the clinical speech-language therapy assessment and the variation in the presentation of responses, depending on the evaluator. The efforts of the authors of this study to reduce this bias consisted of carrying out training and validating a blind pilot study with independent evaluations to standardize data collection. Also, a control group of patients without changes in fluency could validate the normality data for Methodology W[23] since this normality was obtained using Methodology A[8]. It is important to highlight that the comparison of a study group with a control group must each be based on its standard evaluation method to establish the differences between these groups with reliable results. International research primarily uses measures based on the repetition of words and phrases and not on samples of spontaneous speech, that is, self-generated speech[1-7].

Finally, speech rate can be measured either manually, by stopwatch, or by temporal acoustic measurements in computerized programs. Certain structured situations can reduce the impact of language attributions on speed and better reflect speech production mechanisms. This property can interfere with the diagnosis of stuttering, and it is essential to verify the best analysis methodology and establish reference values for it[8,25]. It is extremely important to analyze the cost-benefit ratio of each of the methodologies for evaluating speech rate in the clinical practice of speech-language therapy, which, being an applied and non-laboratory science, is always in search of articulation between easily applicable and simultaneously effective. Despite all the findings, it is considered that this new method, although valid, does not make the proposed traditional method unfeasible[8], recognized in the literature and widely used. The data show that the difference between the same sample submitted to the two calculation methodologies is only temporal, not quantitative, or qualitative. They are compatible and not conflicting and can be used as complementary tools for different purposes in clinical analysis.

CONCLUSION

In the way how the research was conducted, the initial objective was achieved and the comparison between the two methodologies for analyzing speech rate brought some findings. All significant positive correlations found indicated that the variables related to measuring speech rate, in both methodologies, are suitable for speech analysis. Speech rate is linked to the method used and the total speaking time that is considered for this purpose. Although the scores measured in the different methodologies, regarding the variable of syllables per minute in the research group, may indicate an equivalent ability to recover coarticulation of speech movements, oscillations between individual scores were also present in the control group and may indicate, for example, characteristics specific to each speaker, whether he or she stutters or is fluent.

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