THE USE OF ELECTROGLOTTOGRAPHY, ELECTROMYOGRAPHY, SPECTROGRAPHY AND ULTRASOUND IN SPEECH RESEARCH – THEORETICAL REVIEW

O uso da eletroglotografia, eletromiografia, espectografia e ultrassom nos estudos de fala – revisão teórica

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ABSTRACT

The use of new technologies in the evaluation and speech therapy from a review of articles published over the past 5 years is the theme of this study which also has as a purpose to conduct a literature review of national and international studies that used the keywords: electroglottography, spectrography, *ultrasonography* and electromyography in the evaluation and therapy of speech disorders. There is a growing interest in the integration of these resources in studies of speech; however, the existing studies that correlate the assessment are still scarce.

KEYWORDS: Phonation; Electromyography; Ultrasonography; Spectrography; Speech Acoustics

INTRODUCTION

In recent decades, the technological advances have progressively been employed in the health area. In Speech Therapy, specifically in the area of speech, it is not different, since there has been an increasing number of papers using resources such as electroglottography, electromyography, spectrography and ultrasonography.

Because the electroglottography is an objective and non-invasive method, it is widely used to investigate vibrating functions of the vocal folds in adults who present or not voice disorders[1-3]. Recently, this method has begun to be employed in order to evaluate the speech alterations in children, mainly the alteration of voicing.

The electromyography is most known in the areas of Orofacial Myology and Voice, although there is an increasing number of studies that show the application of electromyography in the area of speech. In this area, the electromyography appears in studies that show the physiology [4-6] and also in some pathologies such as Parkinson's Disease[7] and Myalgia[8]. In Brazil, the major application of this resource occurs in researches about stuttering [9-14] .

The spectrography has been used almost exclusively for voice evaluation for a long time. Nevertheless, the necessity of more precise transcription and description of phonetic components has inserted it in the speech studies. The spectrography has the potential of supplying quantitative, objective and precise means to aid in reflecting about the presence, the severity and the characteristic of the speech disorders, as well as helping monitor the progress or regress during the disease, rehabilitation or treatment of the speech disorders[15].

Similarly to the resources mentioned, the ultrasound in Speech Therapy is used mainly in the area of Orofacial Myology and Voice. However, nowadays the ultrasound method has been used

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in the area of speech, mainly to monitor the tongue movement during articulation, as well as in the area of language, as therapy, in order to verify the hemispheric lateralization during speech. The ultrasound is based on the phenomenon of interaction of the sound and the tissues, that is to say that from the transmission of the sound wave through the medium, it is possible to observe the mechanical properties of the tissues[16].

There is also another objective technique for speech evaluation, the electrognathography. This evaluation consists of a computed examination used to collect the movements of the mandible [17]. Although this method can be used for speech analysis, the studies about it are scarce and the existing studies focus mainly on the oral myology, especially on the analysis of temporomandibular disorders [18,19] and mastication [17,20].

Based on the brief review presented, the objective of this study is to conduct a review of literature of the Brazilian and international studies that used the following resources: electroglottography, electromyography, spectrography and ultrasonography in the evaluation and therapy of speech disorders. Due to the fact that the studies on electrognathography are focused on oral myology mainly, this evaluation has not been considered for this theoretical review.

METHOD

This article presents a bibliographical research about the use of electroglottography, electromyography, ultrasonography and spectrography, aiming to seek gaps of knowledge. A bibliographical data collection was developed in November and December of 2011, seeking on the database of LILACS (Latin-American and Caribbean Center on Health Sciences Information), IBECS, MEDLINE (Medical Literature Analysis and Retrieval System Online), The Cochrane Library and SCIELO from the Virtual Health Library – VHL – BIREME.

In order to search the articles about electroglottography, the expressions "*electroglottography*" and "*speech*" have been associated, using them as keywords. 21 studies from the last 5 years have been found. To refine the search according to the objective of this research, the expression "*and not voice*" has also been associated. This way, only three papers have been found, and, according to their abstracts, none was specific about the use of electroglottography for speech disorders. Due to the scarcity on the number of publications related to this topic, some other papers that were relevant to the topic have been added.

For the research on articles relating electromyography to the researches about speech production, the keywords used were "*electromyography" and "speech", and the main subject used was* "*Speech*", only considering papers published in the last five years. This search resulted in 45 occurrences. Therefore, a pre-selection has been made, according to the papers` abstracts, and 12 have been selected. From the abstracts selected, only four were fully available. Thus, the other papers have been sought on CAPES journals, and only one has not been found. Therefore, 11 articles have been used in the review about electromyography. One master`s thesis has also been used, since it was considered extremely relevant for the subject.

In regards to the articles related to spectrography applied to the speech area, the keywords employed were "spectrography" associated to "speech disorders" or "speech" and another search was conducted, using the descriptors "speech acoustics". In both of them, the articles regarding voice were omitted (by using ''not voice''). Through the search, 350 articles from the last 5 years have been found, and, by reading the abstracts, 26 articles have been selected: three of them from Brazilian journals and 23 from international journals.

In order to seek articles related to ultrasonography applied to speech, the keywords employed were "speech" or "speech disorders" and "ultrasonography". There have been found 67 articles in the last five years, all of them from international publications. Subsequent to the analysis of the abstracts, three articles which emphasized the aspect of speech and/or speech disorder have been selected, according to the focus of this paper.

For all the subjects, a pre-selection of the papers has been conducted by the reading of the abstracts and, afterwards, the papers have been read in full.

REVIEW OF LITERATURE

The total number of papers used in this review was 43, from which 12 are articles written in Portuguese, 30 are articles written in English, one is a thesis in Portuguese and one is an abstract from a seminar written in Portuguese. The papers presented here are organized according to their subject matter, in order to make the reading easier.

Electroglottography

The electroglottography (ECG) is an objective non-invasive method, which has a simple measuring, used to monitor the movements of the vocal folds during the phonation [20,21]. This movement of the vocal folds is what produces the voicing and differs the plosives and voiced fricative phonemes from the voiceless correlated ones.

A study [22] indicated that the ECG is an efficient technique to analyze and characterize speech, in regards to the phonic contrast of voicing in speech

situations without alterations. The pieces of information referring to the dynamics of the vibration cycle of the vocal folds, obtained through the ECG, can contribute to show the efficiency of the contact of the vocal folds in a short period of time. In this context, such data also point to the characteristics of the production of speech sounds, specifically of the phonic contrast of voicing, which involves a refined coordination of glottis and supraglottis adjustments for its realization.

Children with speech alterations characterized by the devoicing can have difficulty in controlling the larynx. Due to this difficulty, these children produce a similar phoneme, in which the production is easier, due to the absence of the glottis participation, sounding as its voiceless correlate [23].

The devoicing is a repair strategy performed by children during both normal and abnormal phonological acquisition. On devoicing, there is a substitution of one voiced phoneme by a voiceless one. For example, in Portuguese, a child who wants to play ball would say: ['famu 'ʃoka 'pɔla], instead of pronouncing all the voiced phonemes present in ''vamos jogar bola''. On this example, devoicing has occurred many times, which can be observed in the ECG due to the child's not moving or moving less the vocal folds during the production of the phonemes /v/, /ʒ/, /g/, /b/.

A research[22] claims that the measures extracted from the electroglottographic signal showed the statistically significant differences regarding the contrast of voicing production among the pairs [p,t,k] and [b,d,g].

The ECG can be used to confirm the auditory-perceptual evaluation performed in the speech therapy clinic. In fact, it is not uncommon for the speech therapist, whilst evaluating or re-evaluating a child who presents voiceless phonemes in speech, to have doubts whether the child has produced the voiced or the voiceless phoneme.

The ECG provides an indirect measure of the vocal folds contact in the phonation[21] , which is the ratio of the openings of the vocal folds, showing the proportion of time during which the glottis is maintained abducted in relation to the total time of the phoneme production. This measure can contribute in the identification of a possible motor difficulty for the production of voiced and voiceless phonemes, since the opening ratio should be superior in voiceless than in voiced phonemes due to the absence of vibration of the vocal folds [23]. For this reason, if this difference is present in the movement of the vocal folds for the production of voiced and voiceless phonemes, it is presupposed that there is a difference in the production of these phonemes by children with speech disorders that use the devoicing repair strategy.

A specific research[23] about this topic has been found in the literature, aiming to describe the opening ratio of the vocal folds through the use of the ECG in children with and without speech disorder and to compare the differences obtained between children with speech disorder who present or do not present the devoicing repair strategy of plosive and fricative phonemes. This research has indicated that there are differences on the vibration of the vocal folds among children with and without phonological disorders for the voiced phonemes, and children with phonological disorder present a greater opening of the vocal folds and, therefore, less vibration. In regards of the group of children with phonological disorders, the authors have emphasized that the measure of the opening ratio was superior for children who performed the strategy of devoicing, what suggests some difficulty to move the vocal folds, damaging the production of voiced phonemes.

There are various studies [1-3] using the ECG, despite the fact that most of them investigate the vibrating functions of the vocal folds in adults who have or do not have voice pathologies, which have not been focused on in this research.

Despite the contribution of the studies of ECG in pointing the refinement of the glottis activity, the majority is not focused on investigation and segmental descriptions of the speech sounds characteristics [22]. The use of the ECG to evaluate children with speech disorders is recent and there are few publications focusing directly on this subject.

Given the scarce literature found about the subject, the development of further studies using the ECG on this population is suggested, so that it is possible to approve its utility, confirm evidence and normative parameters for comparison between children with and without phonological disorder.

Electromyography

The electromyography is a resource that is widely used in the areas of Orofacial myology and Voice, although there is an increasing number of researches relating it to the production of speech in general.

One of the applications of the electromyography in speech consists in the analysis of the physiology of movements. Thence, a research [4] conducted in 2007 aimed to clarify the differences in the activities of the elevator muscle of the soft palate during swallowing, speech and blowing through electromyography. Five normal adults have participated in the study. Each participant has been instructed to speak, blow and swallow. Each participant has

been requested to swallow saliva 15 to 20 times. The speech task was the production of the syllable /pu/, which has also been repeated 15 to 20 times separately, with isolated utterances. For the blowing task, each participant was instructed to blow as strong as they could through a tube for 10 seconds. The air of the blowing has been captured by a pressure transducer. Each task has been performed with a long pause between one and the next. The participants could not perform activities of velopharyngeal closure and were instructed to rest with nasal breathing during the pause, in order to reduce possible effects of latent fatigue, what would influence the following procedure. For all the participants, there was no difference in the electromyographic signal between speech and blowing; and the electromyographic signal was higher during swallowing than during pneumatic activities. This indicates that the motor units of the elevator muscle of the soft palate participating on the contraction were different during breathing and swallowing activities.

This study can be applied to the participants with cleft palate or cleft lip and palate, because it aids in the comprehension of the velopharyngeal mechanism, which is compromised in this patients. The same methodology could be applied on the evaluation of patients with cleft, so that a pattern of this population is established, as well as on their therapy monitoring.

Also analyzing the physiology of the movements, another study [5] has attempted to specify how the mandible motor control varies among different syllables produced in the period of babbling; if there is relation between the mastication or the mandible oscillation with the syllables precociously produced and if the organization of the motor control varies among different types of non-speech behavior. The study was longitudinal, considering one child from 9 to 22 months of age. The electromyographic signals were collected from muscle groups of the mandible during its activities of oscillation, mastication and several types of precocious babbling. The results indicated that the myoelectric activity depends on the syllable produced and that there was a difference between babbling and non-speech behavior. Differences in the motor control have also been observed among non-speech behaviors. The motor control of the babbling seems to be influenced by the interaction between motor development and linguistic systems, that is, the variation on linguistic complexity systematically evidences changes in the motor organization, apparently to meet this demand. The same effect has been perceived between mastication and mandibular oscillation.

In regards to babbling, it is clearly observable that there is an interrelation between motor programming and linguistic complexity, leading to a reflection upon to what extent purely phonological therapies (in case of phonological disorders, for example) can be effective, if there is an evident and direct relation of the phonological with the phonetic system

Another case study [6] has analyzed the inter-experimental similarities in the muscle activation during the production of a vowel. The surface electromyography has been employed, with the electrodes positioned in four muscle groups of the face: zygomaticus major muscle of the right side, masseter and mentalis and depressive of the mouth angle on the left side. The patient has produced the vowels a/e/i/o/u, and this has been repeated several times. The results indicated that there is a relation among the muscle activity of the correspondent muscles when the experiments are repeated. Furthermore, when people speak, they use similar muscular groups when they repeat the same sound. Nonetheless, there is a variation when the same sound is produced with different velocities and duration. This can be attributed to the lack of auditory feedback when the same sound is produced.

Also regarding the physiology of the movement during speech, an author[24] had the objective of analyzing the electromyographic activity of perioral muscles and the path of the facial movement during speech, as well as the correlation between them. The results have suggested that there is a greater activation of the muscles of the lower lip and of the chin, in relation to the upper lip. The correlation between the electromyographic activity and the facial movement has shown to be significant in 33 of the 36 relations analyzed. Yet, before the emission of plosive and fricative consonants, there has been a delay on the movement in relation to the electromyographic signal, since there is an isometric force situation, as the articulators are maintained in fixed positions.

In Brazil, there is already a considerable production of studies using the electromyography in the evaluation and monitoring of the therapy in stuttering patients. In 2007, a research was conducted [9] aiming to compare fluent and stuttering patients through the electromyographic activity of the muscles of the upper and lower lips. For that, the authors used two groups with ten participants each. One group was composed by stuttering speakers and the other by fluent speakers (or control). The participants were paired according to age and gender. A linguistic test has been employed in order to analyze the spontaneous speech and, in order to analyze the lips' muscular activity, an

electromyography device with double disposable silver electrodes was employed. Thus, an investigation of the movements performed during speech, orofacial movements of non-speech and rest period has been carried out. The results indicated that there was difference between the groups concerning the electromyographic activity of the upper lip on the lips lateralization and on the resting after the exercises, and the greatest activity occurred in the participants of the control group. In the lower lip, no statistically significant difference was observed. On the conclusion, the authors emphasize the fact that the results do not confirm superior levels of activity in the labial muscles in speakers who stutter, going against other studies of the area.

Similarly to the previous study, another one [10] aimed to compare the muscular activation in fluent and stuttering speakers during activities of speech and non-speech. With this objective, the authors have evaluated three fluent participants (G1) and three participants suffering from stuttering (G2) through the following situations: resting muscular tension, time of speech reaction, non-verbal activity and verbal activity**.** The electrodes for the capitation of the muscular activity have been fixed in four regions: in the middle portion of the lower perioral region; suprahyoid muscles; neck – middle portion of the sternocleidomastoid muscle and middle portion of the trapezius muscle. The results obtained by the authors were similar to the previous study, as no high muscular activity of resting has been observed on the groups of stuttering participants. However, in this case, this finding can be attributed to the fact that the participants of the group which suffered from stuttering have undergone 12 sessions of speech therapy through a program that is specific for stuttering. The muscular activity of the suprahyoid region regarding the time of speech reaction was inferior for the group of the stutterers, that is, the participant of the group needed half the muscle force employed by the fluent participants so that speech would occur free from disruptions. During the activity of non-verbal speech, the group of the fluent speakers had a greater muscular activity than during the resting period, considering the orbicularis muscle. The same did not happen for the stutterers, because there is no readiness for speech as it happens with the fluent speakers.

Both studies lead to a reflection about the role of the exhaustive realization of speech therapy techniques of resting in cases of stuttering, when their muscle activation is not high, as it was hypothesized.

An article focused on the publication of therapy results [11] aimed to verify the effectiveness of a treatment based exclusively on the use of surface electromyography. Four adult stutterers have been evaluated pre and post-treatment (speech sample collection, analysis of resting muscle tension and time of speech reaction) and they have participated in 12 therapy sessions of 20 minutes, monitored by electromyography. The researchers used a therapy program that is based on the learning and application of a specific technique for reduction of the speech disruptions and is structured in four progressive modules of complexity. The procedure of monitoring through the electromyography was introduced simultaneously to the application of the specific techniques for stuttering reduction. After the therapy, there was a reduction of the stuttering and normative disfluencies, what evidences the efficiency of the therapy program, although the other parameters and the variation of electromyographic data did not present any statistically relevant difference.

The technique mentioned can be a good resource to be used in speech therapy clinics.

The time of speech reaction was investigated in another study [12], whose objective was to verify the resting and the time of reaction for speech in fluent and adult stutterers. 22 adults were investigated, of which 11 were fluent and 11 were stutterers. An electromyographic analysis was conducted on the lower lip orbicularis muscle during a resting period and during a situation of speech reaction activity. The results obtained indicated that the groups diverged in terms of muscular tension during resting, as the group of stutterers presented higher values. For this group, there was also a strong positive correlation between time of speech reaction and muscular activity on speech – the longer the time of speech reaction, the greater the muscular activity involved in the production of speech. There was no difference between the groups for time of speech reaction and for speech muscular activity, differently than what occurred in another study conducted by the same research group [10]. Therefore, the authors conclude that the stutterers present alterations on the motor speech output during the production of fluent speech.

In the area of stuttering, researches with children are still conducted. One of them [13] investigated the velocity of the oral movements of children with persistent developmental stuttering and fluent children during the repetition of articulatory segments (diadochokinesia). 50 children were investigated, 19 with a diagnosis of stuttering and 31 who were fluent. The data collection involved tasks in sequential and alternating movements. The first determines the velocity and regularity of the reciprocal movements of the mandible, lips and tongue, as well as the articulatory precision and phonation and respiratory support. The second

measures the ability to quickly move the articulators from one position to another in a predetermined sequence. The electromyographic recordings were collected by a pair of surface electrodes fixed on the lips' orbicularis muscle. The results indicated a difference between the groups for sequential motor activity only – the group of fluent children presents greater ability to move the position of the articulators quickly and in sequential segments.

Thus, the realization of isotonic orofacial exercises seems to be important in the therapy with stuttering children, what could assist in the time of speech reaction.

In order to find the genetic influences in stuttering, a research investigated the family profile of speech fluency, analyzing linguistic, electromyographic and acoustic aspects in children with and without family history close to stuttering [14]. The participants of the study were 17 probands with stuttering diagnosis; 17 fathers; 17 mothers; 10 brothers and 13 sisters constituting group 1; and 15 fluent probands; 15 fathers; 15 mothers; 0 brothers and 8 sisters, constituting group 2. The procedures were: collection of the typologies of speech disruptions; electromyographic collection and acoustic collection. The data found was that 41.1% of the mothers were affected; 35.3% of fathers; 16.7% of sisters and 40% of brothers. Additionally, there was a similarity on the typologies of speech disruptions in all the affected members of the same family, even though there was a tendency of greater severity of disorder on probands. In regards to the muscle activation, there was similarity for the diadochokinesia rates in all the affected members of the same family. For that reason, the authors suggest a motor pattern for speech, in a relationship that can be measured by capturing peripheral muscle activation, within the same family. In acoustics, similarities were also observed among all the affected members of the same family.

In addition to stuttering, different conditions are investigated through the electromyography, such as the Parkinson's disease and myalgia. In regards to the first condition mentioned, a study was conducted [7] with the objective of determining if the analysis of the electromyographic and electroencephalographic corticomuscular coherence could reveal differences concerning the frequency between the cortical control elicited by speech and non-speech activities in participants with Parkinson's disease and in normal control speakers. The sample of the speech and non-speech activities of 20 healthy participants and 20 participants with Parkinson's disease has been analyzed through electromyography and simultaneous electroencephalography. It was verified that the corticomuscular coherence occurred for both groups in all activities, but in different degrees in the primary sensorimotor cortex and the supplementary motor area. The authors suggested that the organization of the corticomuscular control of speech can be conceptualized as an orchestra of frequencies that can be used differently to produce correct motor programs. Also, abnormalities have been found concerning the frequency of the cortical control and in the orbicularis muscle in the Parkinson's disease, in relation to the control group.

Regarding myalgia, a research [8] aimed to compare the average frequency of energy during the speech between groups of patients with myalgia and control groups. The control group consisted of 20 asymptomatic volunteers and the group with myalgia was composed by 19 patients. Electromyography has been performed with electrodes of the surface of the masseter muscles, bilaterally, during speech movements. In the patients with myalgia, the rates of activation or motor unit recruitment innervated by motoneurons of high threshold can lessen and lead to a higher average frequency of energy. The results suggest that the muscular pain, which is a subjective experience, can be evaluated through objective data, calculated according to the electromyographic activities during speech.

The studies presented still demonstrate inconclusive and conflicting results. Because of that, it is suggested that other researches are conducted, using electromyography in the same conditions as previously mentioned and in other pathologies, such as dysarthria, phonological disorder and cleft lip and palate. Moreover, the electromyography seems to be a great therapy resource for monitoring the results by the patients themselves during the realization of activities, especially in the stages of the automation of correct speech.

Spectrography

The spectrography can be employed in different ways in the speech evaluation and therapy. The studies analyze formant characteristics to the interference of the perception in the phones' production. The speech spectrography is regarded as a powerful resource in the description and acquisition of the children's phonological system, as presented in the study [25] which evaluated the phonetic transcription and encoding of the children's vocalizations. The results obtained with the research, according to the authors, are highly applicable to other cases of difficult transcription, such as the ones found in severe speech disorder.

The formant characteristics of the vowels are a powerful tool for the speech evaluation. A study [26] obtained values for the vowels after analyzing 175 speakers, determining the frequency bands for the first formant (F1) and for the second formant (F2) of the vowels (a,e,i,o,u). The results obtained for the

vowel “a” were from 850 to 1150 Hz for F1 and 1200 to 2000 for F2; for “e” they were from 700 to 950 Hz for F1 and 1700 to 3000 Hz for F2; vowel “i” 300 to 450 Hz for F1 and 2000 to 3600 Hz for F2; vowel “o” 600 to 800 Hz for F1 and 600 to 1400 Hz for F2; and vowel “u” 100 to 400 Hz for F1 and 400 to 1200 Hz for F2.

The description of the formants has been researched in another study [27] in which the formants of the liquids /l, λ, r/ have been analyzed and compared (F1, F2, F3) regarding their production by children with and without speech alteration. The production of 59 children has been analyzed, divided into three groups, of which one was the control group. The children have been requested to repeat syllables containing liquids and words containing the evaluated phones in different positions. The results have demonstrated that the children without speech alterations displayed clear differences among the three sounds studied in relation to the formants. And the alterations on the liquids found in the participants with speech disorder had similar characteristics.

Aiming to verify the acoustic properties of the fricative consonants of the English language in different situations of communication, the study [28] has evaluated 20 speakers, who were equivalent regarding gender, aged from 19 to 34 years old concerning the production of eight fricatives of English combined with the vowel /ɑ/. From the experiment, it has been observed that the production of fricatives was influenced by the nature of the communication situations demonstrating acoustic modifications. The most frequent modifications observed were the duration of the fricative and the duration of the spectral peak.

A study[29] with Serbian speakers has evaluated the acoustic characteristics of the consonants murmured in comparison to the consonants emitted in connected speech. The researchers have observed that the whispered consonants have a prolonged duration in comparison to the consonants emitted in normal speech articulation.

Another study [30] has acoustically analyzed the substitutions between the phones /t/ and /k/ in the speech of children with typical and atypical acquisition with the objective of identifying and quantifying the existence of covert contrasts. Through an experiment in which the repetition was requested, the production of children was evaluated according to burst spectral characteristics, cv transition and durational characteristics. With the results obtained, the author concluded that several substitutions that are present in the speech production of children in typical and atypical process of acquisition are in fact covert phonic contrasts, outstanding that the spectrography contributed to the identification of subtle differences in the children’s speech production.

The voice onset time (VOT) is an important measure employed in the distinction of the contrast voiced/voiceless. A study evaluating the threshold for the detection of perception of the English occlusive consonants voicing has demonstrated the existence of gaps among the different acoustic markers and the categorical perception of the VOT, suggesting that they share the same basis of perception temporal mechanisms [31].

A study [32] reaffirms that the VOT is a parameter used to differentiate the English occlusives, although sometimes it is used to evaluate the pauses on the connected speech. This study suggests a physiological representative model for the evaluation of these pauses, and the VOT functions only as a parameter of the beginning of the voicing in the speech synthesis.

In order to compare the VOT values of plosive phonemes produced by children with phonological disorder and difficulty in the production of the voicing contrast, a research [33] has been conducted with speech data of five boys with difficulties to establish the contrast [+voice] on the plosives. The VOT has been measured from words containing plosives inside a carrier sentence. The results indicated that only the VOT is not a decisive clue for the perception of the voicing distinction in the cases of atypical development. Nevertheless, the VOT influences in the distinction of the phonemes according to the articulation points in the atypical cases.

Another study [34] investigating the VOT measures in English in children who were in acquisition process has demonstrated that they originally avoid words in which the initial occlusive is voiceless. The VOT values found presented higher variation in the voiceless occlusives in comparison to the voiced occlusives. Broadly speaking, the results indicated that there is a model of acquisition concerning the gestural coordination field, as opposed to the segmental acquisition of contrasts.

Spectrography can also be employed to evaluate the acoustic profile of the hypernasal speech[35]. For this purpose, an evaluation of the effects of the soft palate implant over the articulation of speech sounds has been conducted. With the results observed, the authors could conclude that the insertion of the implant has not had significant effects over the parameter of fundamental frequency, although there was evidence that the articulation of the velar region had been affected due to alteration of the average values of the VOT for /k/ [36].

Another study[37], evaluating the spectral aspects of the frequencies of F1, F2, F3, nasal formant and anti-formant for the vowels [a] and [ɐ] in the

presence of opening made in the bulb of palate prosthesis replicas of a patient with velopharyngeal insufficiency. The results demonstrated significant alterations in the spectral values studied according to the alteration in the size of the velopharyngeal openings.

A study evaluated the dysarthric speech, in relation to the Vowel Space Area (VSA), since this acoustic measure has been employed as a parameter in the speech of people who suffer from dysarthria in varying degrees of success. The objective of this study was to test a metrical alternative for the VSA in relation to the Formant Centralization Ratio (FCR), aiming to more effectively differentiate the dysarthric from the typical speech and to quantify the effects of the treatment. The results evidenced a strong correlation between the values registered and the effects of the treatment. Furthermore, they indicate the FCR as a sensitive, reliable and valid marker for the distinction of the dysarthric discourse and monitoring of the treatment [38].

Regarding apraxia, a study[15] has investigated the production of vowels in adults with acquired apraxia in relation to adults with no alterations. Seven adults at 48 to 74 years old with acquired apraxia and Broca's aphasia have participated in the study. The analysis of the vowel has been conducted through 15 repetition in /hCV/ structure (hid, head, hat, hot, hub, hoot) produced by the participants. The authors observed that the vowel production in the evaluated participants was similar to the production of speakers with no speech alterations.

Speakers with Down syndrome had their speech acoustically analyzed for different aspects of intonation and phonation. The results of the intonation and phonation spectrography indicated that the adults and the young adults with Down syndrome present a reduction in the organic and laryngeal tessitura, little melodic variation and reduced intonation patterns [39].

Another usage for the spectrography is the evaluation of the prosodic rhythm. A study[40] has evaluated the durational variation through 15 measures of rhythm in five languages, aiming to classify and differentiate the languages from the duration measures and develop a system of automatic recognition of speech. The authors highlighted that there is an independent segmentation for the languages, and each language presents specific patterns of durational variation (rhythm) and due to this variation the identification of a language exclusively by the duration would not be reliable.

In the same area of research, a Finnish study[41] aimed to investigate how the prosodic and syntactic structures interact on the prosodic focus during speech. The authors considered the focus as part of a certain utterance that requires attention, contrast or importance within the discourse. Evaluating the pieces of formant information of the utterances, the study suggests that, as in the perception of the prosodic emphasis, the piece of information of higher interest obtained a superior structural order. Moreover, the word order interacts with the basic prosodic parameters, in order to guarantee coherent semantics and pragmatics for the interpretation of the utterance.

The application of spectrography is wide, as it can be observed in the study which aimed to identify the perceptive capacity upon the speech perception and the access to lexicon. The results revealed that the nature of the exposition of the speaker considerably influences his behavior in speech activities, suggesting that the phonetic details of the speech are found and stored in the lexicon together with information of of the speakers' regional origin[42].

In another study[43], spectrography is employed to evaluate when and how different speech styles socially emerge. The research has analyzed the speech of 30 preschool children aged from 3 to 5 years old in different situational contexts. The frequency acoustic measures of formants have not shown any evidence to difference in regards to the different speech styles at any age, and there was no difference in initial times of voicing. The results suggested that the different speech styles develop slowly and, originally, the styles depend on the differences on the discourse of the children. Also, an important fact is that children do not develop communicative styles until they have acquired a minute articulation control.

Ultrasonography

One of the main peculiarities of the ultrasonography method is the possibility of a non-invasive study due to the Doppler Effect. The Doppler Effect is defined as the alteration in the frequency sensation resulting from a situation in which the sound source is mobile, moving at a constant speed, and the receptor is stationary at some point of the trajectory. With the approximation of the sound source to the receptor, it receives a higher number of waves per time unit (higher frequency) and as it moves away it receives a lower number of waves (lower frequency) [16].

The ultrasonography provides a direct representation of the movements of the tongue during the speech articulation, and it is a safe, direct and non-invasive technique [44].

A study [44] was based in the fact that there are gaps on the knowledge about the paths taken by children and adults on the development of the speech motor control. The correct control of the

articulators during speech is manifested adequately by the coarticulation (superposition of speech sounds). The researchers compared coarticulatory properties of the tongue on the speech of children and adults, using images of tongue ultrasonography. The participants were speakers of British English, and there were ten adults and ten children aged 6-9 years old. Syllables formed by consonant-vowel have been presented in a transportation stage. The distances among the tongue curves have been used to quantify coarticulation. In adults and children, the pairs of the vowels /a/, /i/, /e/, /a/ and /u/ significantly affected the consonant, and the vowel pair /i/ and /u/ did not. The extension of the coarticulation was significantly higher in children than in adults, providing support for the notion that the speech production of children operates with higher units than the adults'.

In another study[45], it has been proposed to analyze the potential utility of the ultrasonography in remediation of North American English on the phoneme /r/. Two Canadian adolescents who were speakers of English and had not acquired the phoneme /r/ participated in the research. The study included an initial period without ultrasonography, and 13 treatment sessions of one hour using the resource. Speech samples have been recorded in the triage and immediately before and after the treatment. Afterwards, the samples were acoustically analyzed by three speech therapists who were not familiar with the participants. Additionally, ultrasound images displayed an expected reduction of the third formant after the treatment. The qualitative observation of the images after the ultrasound treatment displayed that the position of the tongue was more similar to the adult target than it had been observed before the treatment. The researchers concluded that greater samples should be analyzed in order to prove the efficacy of the ultrasound use.

A research with nine speakers of Canadian English [46] has also evaluated the production of the phoneme /r/ using the ultrasound combined with the optical tracking, in order to measure the gestural relations in the production of the phoneme. The results showed a temporal pattern of tongue movement forwards and backwards on initial syllables. Also, there was a reduction of the extent of the labial gestures in final position syllables.

CONCLUSION

Based on this bibliographical review, it becomes evident that it is necessary to employ objective resources in the evaluation and accompaniment of the speech therapy**,** mainly in the cases of speech alteration. The technological resources described here are extremely important for a more effective and efficient therapy, since more thorough and detailed evaluations can lead to a more precise intervention, conducted according to the difficulties of each patient.

Therefore, based on the studies presented here, the increasing interest in the employment of these techniques in the Speech Therapy field is noticeable. Nonetheless, the studies which have researched about these resources in the area of speech are still scarce, but due to the importance of the use of these techniques it is necessary that other researches in the area are conducted.

RESUMO

O emprego de novas tecnologias na avaliação e terapia de fala a partir de uma revisão de artigos publicados nos últimos 5 anos é o tema deste estudo, que tem por objetivo realizar uma revisão bibliográfica dos estudos nacionais e internacionais que utilizaram os recursos: eletroglotografia, espectrografia, ultrassonografia e eletromiografia na avaliação e terapia das alterações de fala. Existe um crescente interesse da inserção desses recursos nos estudos de fala, contudo, os trabalhos existentes que os correlacionam ainda são escassos.

DESCRITORES: Fonação; Eletromiografia; Ultrassonografia; Espectografia; Acústica da Fala

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