



# Tools and Protocols Used in Criminal Skills Related to Voice: Literature Review

## Ferramentas e Protocolos Utilizados na Perícia Criminal Relacionados à Voz: Revisão de Literatura

## Herramientas y Protocolos Utilizados en la Experiencia Criminal Relacionados a la Voz: Revisión de Literatura

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### **Abstract**

The criminal investigation aims to compose evidence to clarify crimes, and in Speech Therapy, among the possibilities of action, voice-related phonetic expertise may be one of these tools. Objective: To verify the tools or protocols used by Brazilian professionals to perform phonetic forensics related to vocal parameters. Method: Research of integrative bibliographic review from the isolated and combined consultation of the descriptors in health sciences: legal medicine, voice, criminal expertise, crimes and speech therapy in the Lilacs, Scielo, Google Scholar, Open Gray and Open Thesis databases. Results: Of 457 collections, eight were selected for reading in their entirety. The identification of a criminal through

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ANW and CPHARC: substantial contribution to the conception and design of the scientific work, survey of literature, participation in writing, critical review of the work and final approval of the content to be published.

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the voice has been carried out in forensic examinations since the voice presents possible characteristics of comparison, mainly the fundamental frequency, the vowels formants, the voice onset time. Registration care must be carried out so that the evidence is not excluded from criminal prosecution, being analyzed in an impartial manner. It is a recent area in Speech Therapy that lacks publications in the area. Conclusion: The resources used in phonetic forensic expertise related to vocal parameters range from the qualified professional, from different areas of knowledge (Linguistics, Speech Therapy, Engineering, Law, etc.) to the use of software that can compare the voice of different speakers. There is a shortage of literature and the practice of such practice requires interdisciplinary professional training.

**Keywords:** Legal Medicine; Voice; Speech therapy.

### Resumo

A perícia criminal tem como objetivo compor provas para esclarecer crimes, sendo que na Fonoaudiologia, dentre as possibilidades de ação, a perícia fonética relacionada à voz pode ser uma destas ferramentas. **Objetivo:** Verificar quais as ferramentas ou protocolos utilizados pelos profissionais brasileiros para a realização da perícia forense fonética relacionada aos parâmetros vocais. **Método:** Pesquisa de revisão bibliográfica integrativa a partir da consulta isolada e combinada dos descritores em ciências da saúde: medicina legal, voz, perícia criminal, crimes e fonoaudiologia nos bancos de dados Lilacs, Scielo, Google Scholar, Open Grey e Open Thesis. **Resultados:** De 457 acervos, oito foram selecionados para leitura na íntegra. A identificação de um criminoso através da voz tem sido realizada nas perícias forenses tendo em vista que a voz apresenta características possíveis de comparação, principalmente a frequência fundamental, os formantes das vogais, o *voice onset time*. Cuidados quanto ao registro devem ser efetivados para que as provas não sejam excluídas dos processos criminais, sendo analisadas de forma imparcial. É uma área recente na Fonoaudiologia que carece de publicações na área. **Conclusão:** Os recursos utilizados na perícia forense fonética relacionada aos parâmetros vocais vão desde o profissional capacitado, de diferentes áreas do conhecimento (Linguística, Fonoaudiologia, Engenharia, Direito etc.) até o uso de *softwares* que possam comparar a voz de diferentes falantes. Há escassez de literatura e o exercício de tal prática requer capacitação profissional interdisciplinar.

**Palavras-chave:** Medicina Legal; Voz; Fonoaudiologia

### Resumen

La pericia criminal tiene como objetivo componer pruebas para aclarar crímenes, siendo que en la Fonoaudiología, entre las posibilidades de acción, la pericia fonética relacionada a la voz puede ser una de estas herramientas. Objetivo: Verificar cuáles son las herramientas o protocolos utilizados por los profesionales brasileños para la realización de la pericia forense fonética relacionada a los parámetros vocales. En el presente trabajo se analizaron los resultados obtenidos en el estudio de los resultados obtenidos en el estudio de los resultados obtenidos en el estudio. Resultados: De 457 acervos, ocho fueron seleccionados para lectura en su totalidad. La identificación de un criminal a través de la voz ha sido realizada en las pericias forenses teniendo en vista que la voz presenta características posibles de comparación, principalmente la frecuencia fundamental, los formantes de las vocales, el *voice onset time*. Los cuidados en cuanto al registro deben ser efectivos para que las pruebas no sean excluidas de los procesos criminales, siendo analizadas de forma imparcial. Es un área reciente en la Fonoaudiología que carece de publicaciones en el área. Conclusión: Los recursos utilizados en la pericia forense fonética relacionada a los parámetros vocales van desde el profesional capacitado, de diferentes áreas del conocimiento (Linguística, Fonoaudiología, Ingeniería, Derecho, etc.) hasta el uso de *softwares* que puedan comparar la voz de diferentes hablantes. Hay escasez de literatura y el ejercicio de tal práctica requiere una capacitación profesional interdisciplinaria.

**Palabras clave:** Medicina Legal; Voz; Fonoaudiología.

## Introduction

The search to improve the quality of public services is a challenge today with an emphasis on public security and justice. Within this network of services, Criminal Forensics (CF) is highlighted, being responsible for the production of the material to be used as evidence, helping decisively in the elucidation of crimes and compliance with human rights<sup>1</sup>.

Some features assist CF, such as biometric data. These refer to information on the measurements and physiological and morphological characteristics of people, collected through manual or technological techniques. Biometric systems have two objectives: the first is to identify the individual, matching the information collected with a database - thus allowing the subject to be recognized by comparing the gathered characteristics and the second is to verify individual authenticity, confirming or refuting its identity<sup>2</sup>. Among these characteristics are the iris, retina, fingerprint, voice, face shape, hand geometry, DNA and body odors. The use of these biological traits for personal identification can be effective since they are unique and particular to each person<sup>3</sup>.

Amid the various forms of action in forensic science, there is the analysis of speech through the assessment of linguistic, vocal and articulatory features<sup>4</sup>. This happens because everyone has a peculiar way of speaking and also of writing<sup>5</sup>.

Another possibility of analysis is the application of forensic acoustics, whose purpose is to compare the vocal patterns to prove the guilt or innocence of an individual involved in a criminal process<sup>6</sup>, such as, for example, to analyze whether or not the voice of a kidnapper belongs to a certain suspect<sup>7</sup>.

For that, there must be a good quality of the collected sound material for an efficient investigation. The absence of sound quality at the time of recording is linked to several factors, among which the literature cited:

- Low quality and lack of adjustment of the equipment used, as exacerbated noise in the recordings, making it difficult to identify the desired voice<sup>8</sup>.
- Incorrect positioning of the recording equipment, leaving the recording with low signal levels, emphasizing other sounds and not the criminal's voice<sup>8</sup>.

- Inadequate location at the time of recording, such as in bags, jackets, places with a lot of noise (people talking, horn sounds, squares, connected televisions), tiled environments (such as bathrooms, for example), large and without furniture environments, which can cause reverberation. These factors interfere with the recording, leaving the sound muffled, emphasizing unwanted noise<sup>8</sup>.
- The use of low quality media (such as cassette tape, for example), as this material has a frequency of approximately 4,000 Hz, making speech intelligibility difficult<sup>8</sup>.
- Recordings containing more than one speaker or hidden microphones that may, for this reason, have the signal picked up with noise that may interfere with the sound quality<sup>9</sup>.

It is also worth considering that it is possible to disguise the voice. However, even with great disguises, it is possible to obtain the specific marks of each speaker through the vowel triangles<sup>10</sup>.

Thus, besides being necessary to know the factors that add quality to a criminal investigation, there is a need for qualification on the part of speech therapists who work or wish to work in CF, to favor the necessary tools to work in this area<sup>11</sup>. Literature pointed out that the analysis of the evidence must occur without prejudice from the expert, that is, without personal or third party interference<sup>12</sup>. Currently, experts do not identify criminals by vocal assessment, but check whether the questioned voice matches or not the investigated suspect<sup>13</sup>.

To understand how this is done, initially, it is necessary to know if the material acquired was obtained legally<sup>14</sup>. If the answer is affirmative, the speech sample (in audio or video) is converted into “.avi” (for videos) and the audio in “.wav”, to be later analyzed by acoustic analysis with software such as PRAAT (pitch, loudness and vocal stress can be observed by such analysis) and for the sample edition, Adobe Audition. To analyze supra-segmental aspects (such as intonation, pauses and prolongations), for example, Gram and WinPitch<sup>15</sup> are used.

For these reasons, the training of human resources to act as a forensic expert is essential. A study indicated that CF is rarely addressed in undergraduate and graduate courses in Speech, Language and Hearings Sciences, causing professionals not to have enough knowledge, resulting in restrictions for acting in this area<sup>7</sup>.

As it is a recent area in Speech, Language and Hearing Sciences, it is necessary to present the history of Forensic Speech Therapy in Brazil, made available by the Brazilian Academy of Forensic Speech Therapy (Acadefor), described below.

In 1994 there was the initial milestone of voice identification in Brazil, when this possibility was presented at the First National Seminar on Forensic Phonetics of the Brazilian Association of Criminalistics<sup>16</sup>.

In 1998, in 2003 and 2004 the Speech Therapist Maria do Carmo Gargaglione was hired by the court for voice expertise. For her contributions to justice and expertise in the area, in 2005, the Laboratory for Audio Visual Analysis (LIAAV) was opened at the Foundation for the Support of Teaching, Research and Development of the Civil Police (FAEPOL), being appointed as a forensic expert technician by the State Prosecutor's Office from Rio de Janeiro. In the same year, the Forensic Speech Therapy Sector of the Public Ministry of the State of Rio de Janeiro began to be structured and, currently, it has five speech therapists.

In May 2006, the Court of Justice of the State of Rio de Janeiro signed an agreement with FAEPOL, due to the increasing use of telephone interceptions as evidence, mainly concerning police investigations.

Besides, the Carlos Éboli Institute of Criminalistics, which is an organism of criminal expertise in the State of Rio de Janeiro, was not sufficiently equipped to perform voice identification. Thus, there was no efficient basis for the judges to conclude the proceedings, justifying the existence of a Speech, Language and Hearing Sciences support team.

On May 25, 2008, the Brazilian Academy of Forensic Speech Therapy (Acadefor) was founded, a non-profit scientific entity, and has been a reference in the country ever since.

In 2009, Acadefor started the development of scientific activities at the national level, offering courses promoted in partnership with different entities (Ministry of Justice, National Public Security Secretariat, National Public Security Force and State Magistrates' Schools in Rio de Janeiro and Bahia). In addition, the board of Acadefor participated in the international conference of the "American College of Forensic Examiners", held in the state of Nevada, United States.

On April 16, 2010, the First National Congress of Forensic Speech Therapy took place in Vila Velha (Espírito Santo), in partnership with the Public Ministry of the State of Espírito Santo. From September 15 to 16, 2011, the second edition of this Congress took place, at the Universidade do Vale do Itajaí (UNIVALI), in Itajaí, Santa Catarina and in 2012, the third edition took place in São Paulo.

Thus, the objective of the present study was to verify which are the tools or protocols used by Brazilian professionals to perform the phonetic forensic expertise related to vocal parameters.

## Methods

The adopted methodology had as a strategic base, the search for articles with the established eligibility criteria. These were observational studies (controlled, transversal, prospective or retrospective longitudinal) carried out with phonetic expertise related to vocal parameters. The exclusion criteria were ambiguity or insufficient presentation of results; duplication of studies from the search in databases; review articles; communications, comments or editorials; case reports, summaries of scientific events and monographs.

For the elaboration of the research, the PVO strategy was adopted: Patient, Variable and Outcome - PVO: "What are the tools or protocols (variable) used by Brazilian professionals (participant / subject) to perform the phonetic forensic expertise related to vocal parameters (outcome)?"<sup>17</sup>. This research proceeded without the year of publication restriction. However, as the objective was to verify how Brazilian professionals work in phonetic forensic expertise related to vocal parameters, the language was restricted to Portuguese (Brazil).

The research was divided into three phases. The first, by reading the title and abstracts, being carried out by two eligibility reviewers (ANW and PJA), not blind to the authors and journals, and the aforementioned eligibility criteria were applied. The reviewers performed the survey autonomously and, after matching results, they examined which studies were or were not elected. In case of divergence of results, a third evaluator was consulted (CPHARC) to resolve the doubt regarding the exclusion or not of the study, as recommended by the literature<sup>17</sup>.

The second phase consisted of reading the introduction and conclusion of the study and, if

the article was selected, the scientific text was read in its entirety.

As search strategies, keywords were selected by the Health Sciences Descriptors of the Virtual Health Library (DeCS) “Forensic Medicine”, “Voice”, “Criminal Expertise”, “Crimes” and “Speech Therapy” in the following electronic databases SciELO, LILACS and Google Scholar (up to page 10 of search) and in order to avoid risk

of bias, the research was extended to Open Gray and OpenThesis.

The data analysis proceeded in a qualitative way, since the methodology applied between the surveys was heterogeneous.

**Results**

The amount of literature found in the databases from the selected keywords is presented in Chart 1.

**Chart 1.** Results obtained from the keywords [legal medicine or speech, language and hearing sciences] and [voice] and [criminal expertise] in databases

Database / Keywords	Number obtained	Database / Keywords	Number obtained
Database: Google Scholar (5,350, however, up to the 10th page of the search: 100) Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	100	Database: Google Scholar (5,350, however, up to the 10th page of the search: 100) Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	100
Database: Google Scholar (224,000, however, up to the 10th page of the search: 100) Keywords: [Identificação] AND [Voz]	100	Database: Google Scholar (224,000, however, up to the 10th page of the search: 100) Keywords: [Identificação] AND [Voz]	100
Database: Google Scholar (43.600, however, up to the 10th page of the search: 100) Keywords: [Crimes] AND [Voz]	100	Database: Google Scholar (43.600, however, up to the 10th page of the search: 100) Keywords: [Crimes] AND [Voz]	100
Database: Lilacs Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	zero	Database: Lilacs Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	zero
Database: Lilacs Keywords: [Identificação] AND [Voz]	82	Database: Lilacs Keywords: [Identificação] AND [Voz]	82
Database: Lilacs Keywords: [Crimes] AND [Voz]	zero	Database: Lilacs Keywords: [Crimes] AND [Voz]	zero
Database: Scielo Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	zero	Database: Scielo Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	zero
Database: Scielo Keywords: [Identificação] AND [Voz]	60	Database: Scielo Keywords: [Identificação] AND [Voz]	60
Database: Scielo Keywords: [Crimes] AND [Voz]	02	Database: Scielo Keywords: [Crimes] AND [Voz]	02
Database: Open Grey Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	13	Database: Open Grey Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	13
Database: Open Thesis Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	0	Database: Open Thesis Keywords: [Medicina Legal OR Fonoaudiologia] AND [Voz] AND [Perícia Criminal]	0
Total	457	Total	457

The first research identified on the subject was in 1994<sup>23</sup>, and from 2007 there was a greater increase in investigations in the area.

The characteristics of the studies are summarized in Chart 2, showing that six (75%) studies used some technological resource for vocal assess-

ment<sup>23,25,31-33,35</sup>, two (25%) performed documentary analysis and infrastructure<sup>25,34</sup> and two (25%) mentioned the development of either a protocol 21 or technological resources<sup>35</sup>. Only one study (12.5%) proposed subjective analysis of vocal parameters<sup>21</sup>.

**Chart 2.** Summary of the studies obtained according to the authors and year of publication, objective(s) of the study, characteristics of the sample, method adopted, results obtained and conclusion

Author (year) number	Objective(s) of the study	Sample characteristics	Adopted Method	Obtained results	Conclusion
Figueiredo (1994) <sup>23</sup>	Examine different vocal acoustic parameters in speaker identification	Voice recordings of 8 male subjects (23 and 45 years old)	Recording the oral reading of a scientific text using a microphone at two speeds: normal and fast. Acoustic analysis performed with a digital sonograph and the computerized speech lab, being analyzed the formants of the stressed vowels	There are different formants for the vowels and the speed did not seem to directly influence the formants. When the speaking versus speed interaction was analyzed, there was a change in the formants, but this did not occur homogeneously in the studied group. The differences were also found in monozygotic twins.	The analysis of the formants for the identification of speakers requires safe criteria for their evaluation and there seems to be a dependency between the speaker and the formants produced, but without being able to affirm that it is a characteristic that identifies the subject. F0, on the other hand, seems to provide greater identification subsidies, revealing greater differences regarding the emotional-affective state. The acoustic aspects that most identified the speakers were the long-term spectrum (LTS), the voice onset time (VOT), followed by the formants F3 and F4.
Porto e Gonçalves (2007) <sup>21</sup>	To question the pertinence and to conjugate in an instrument the parameters used in the Perceptual-Auditory Assessment of voice and speech in the forensic scope (FPAA).	Elaboration of a pilot protocol for subsequent analysis of Forensic Phonetics Section of the Criminalistics Department of the General Institute of Forensics of Rio Grande do Sul (IGP - RS) cases.	Protocol containing 22 items for FPAA: vocal characteristics regarding gender, age range, presence or absence of vocal pathology (GRBASI, vocal type and record), resonance, vocal attack, pitch, tonal range, loudness, quality and vocal habits, articulation, phonetic-phonological changes, speed and rhythm of speech, fluency, pneumophonoarticulatory coordination, dialectal elements, and others.	The elaborated protocol allowed the real analysis of the IGP-RS cases with a comparison of the questioned audios and the standard ones, and the criminal expert must be a professional in the area for a correct analysis.	The elaborated protocol proved to be effective and relevant to forensic practice.
Mattos (2008) <sup>31</sup>	To compare electroglotography (EGG) and glottal (OFG) signals obtained by reverse filtering the voice signal	Voice recordings of 11 speakers in an acoustic booth, 6 male (20 to 38 years old) and 5 female (18 to 28 years old) participants.	Manual removal of 10 concatenated speech vowels and 05 sustained vowels from each speaker, captured using a microphone and electrode in the external region of the larynx and with subsequent analysis of the EGG. For the analysis of the glottal reverse filtering signal (OFG), it was only necessary to record the voice signal of the participants. The data were submitted to the Audacity software, totaling 380 files (extension ". wav").	Some vocal characteristics can facilitate the identification of the speaker, such as pitch and double peaks by DEGG. It was possible to visually verify the difference in the emission of the concatenated vowel / a / in 6 participants, although there is a need for a larger sample of subjects.	The use of the glottal reverse filtering signal can be compared to the EGG by analyzing the vowels, despite the small synchronization error of the OFG (1 ms). The DEGG, due to the presence of double peaks, allows the semi-automatic identification of the speakers and analysis of the pitch, although the equipment is of high cost and the collection requires the authorization of the speaker. The analysis of vocal parameters can serve as an instrument for criminal expertise in the identification of speakers.

Author (year) number	Objective(s) of the study	Sample characteristics	Adopted Method	Obtained results	Conclusion
D'Almeida (2009) <sup>35</sup>	To propose, implement, evaluate, and validate four new techniques that seek to reduce the computational cost for the automatic identification of speakers	Technological development of four techniques.	Application of different methods (persistent condition - MCP and dominant Gaussians - MGD) and models (adaptive multi-conditionals - MMA and mix of multi-resolution Gaussians - MR-GMM) in automatic speaker recognition (RAL).	<p>The MCP made it possible to reduce costs by more than 70% without affecting the correct RAL. MMA provided a cost reduction of up to 75% and increased RAL in noise situations. MGD reduced the computational effort of identifications by approximately 80% without affecting the average RAL rate and, associated with MMA, it reduced this computational effort by up to 90% and increased RAL by more than 2%. MGD reduced the computational effort of identifications by approximately 80% without affecting the average RAL rate and, associated with MMA, it reduced this computational effort by up to 90% and increased RAL by more than 2%.</p> <p>MR-GMM enabled 50% reductions in computational effort, without harming the RAL. The combination of MR-GMM / MMA / MGD, enabled a reduction of up to 95% in computational cost, with a 1% increase in RAL.</p>	The Systems created, tested, validated, and used together (MR-GMM / MMA / MGD) have a computational cost lower than that of a single multi-conditional model of Gaussian mixture (GMM), making it feasible even in applications that require low times response to research in databases with a high number of speakers, reducing computational cost by up to 90%, without affecting the RAL.
Rodrigues, Silva e Truzzi (2010) <sup>25</sup>	To analyze the value of criminal expertise in Minas Gerais, Brazil	Documentary and infrastructure	Analysis of documents and resources of criminal expertise in Minas Gerais	Regarding the scope of the research: existence of software for the comparison of voices (without specifying which ones).	In criminal trials, the judges interviewed highlighted the objectivity and impartiality of the expert evidence associated with Science. The main resources of the service are the skills of professionals from different fields of knowledge and the technological apparatus available.
Moraes (2013) <sup>34</sup>	To check the general, structural and methodological aspects of the audio-visual expert coordination (AEC) environment of the Afrânio Peixoto Criminalistic Institute (ICAP) of the Technical Police of Bahia.	Documentary, infrastructure and interview with 7 magistrates, 3 civil police delegates and 10 criminal experts	Documentary analysis, criminal expert resources and interviews from ICAP, Bahia.	The criminal expertise in audio records in Bahia, with its forensic expert typifications and the expertise of verifying the announcer, presented, at the time of collection, an insufficient number of criminal experts. For example, the absence of programs for the renewal and training of human and technological resources, the absence of quality management models, requests for extensive expert examinations, that is, the CF in audio, failed to meet the demands of criminal justice. Regarding computational tools, the institute has 1 equipment for voice capture and analysis (Computerized Speech Lab); an Edit Track operating license (version 5.0), used in audio editing or authenticity verification exams; an operating license for Sound Cleaner (version 2), for the treatment of audio signals; 2 audio capture cards (Edirol brand, version 15.1); a Multi-Speech license (software for acoustic speech signal analysis); Adobe Audition package (audio analysis, versions 2.0 and 3.0) and PRAAT software (free).	Negative mismatch in the relationship between demand for exam requests and attendance completed in audio examinations; need for acquisition, maintenance and renewal of material, technological and human resources, as well as professional training.

Author (year) number	Objective(s) of the study	Sample characteristics	Adopted Method	Obtained results	Conclusion
Passetti (2015) <sup>33</sup>	To evaluate the effects caused to the speech signal by the telephone transmission of mobile lines and, thus, determine the degree of phonetic-acoustic modification caused by the band filter of the telephone channel to the usual voice and the effects that the telephone transmission has on the oral vowels in Brazilian Portuguese.	Voice recordings of 10 male announcers	Recording performed simultaneously via cell phone and direct (with the placement of a microphone in front of the subjects while talking on the cell phone). The Brazilian Portuguese vowels were transcribed and segmented, analyzing the frequencies: fundamental (F0), their baseline and interpeak duration; F1, F2 and F3 formants, as well as the spectral emphasis.	In general, there was a global decrease in the vowel space in telephone recordings, influenced by the increase in the frequencies of F1, considering the filters of the cell phone itself, distorting the vowels [i] and [u]. The decrease in F2 values for the previous vowels and the increase in the values of this formant for posterior vowels compressed the vowel space of most subjects, probably due to the data compression rate and the coding of the Brazilian Global Systems Mobile Telecommunications (GSM). The changes in the dispositions of the vowels had perceptual implications and may sound more open on the cell phone.	The analysis of changes in the speech signal by the use of cell phones has direct applicability in real forensic practices, given the increasing technological evolution and the increase in the number of crimes using these means of communication, with variations (in F1 and F3 by the filters of the device itself) in F2 due to data compression rates and the GSM system and some distortions in the vowels [i] and [u]). This shows that forensic analysis, in forensic practice, should be used with caution when recording using a mobile phone. It also revealed that open vowels are more resistant to the telephone effect, as well as the baseline and interpeak duration of F0. However, they suffered interference from the F0 mobile phone, the spectral emphasis.
Oliveira (2017) <sup>32</sup>	Assess whether the consonant, vocalic and total laryngealization rates allow the identification of the speaker, as well as the phonetic-acoustic and prosodic parameters	Semi-spontaneous speech by 10 subjects from Alagoas / Brazil (5 women), aged between 20 and 30 years.	Recording of the recount of a short film, with prosodic units being analyzed by the PRAAT software, checking the F0, the jitter, the shimmer, the harmonic noise ratio and the relationship between the harmonics: H1 and H2.	There was a differentiation in the voice profile of the prosody of the group of women when compared to the male group, especially in the vowels and in total laryngealization, with a decrease in intensity in the modal and laryngealized registers.	The variation in prosody in Brazilian Portuguese between the sexes can characterize the speaker through the rates of vocal and total laryngealization. Such rates influenced the jitter, H1-H2, and the intensity. Thus, prosody analysis can be used in the study of phonetics in forensic practice, since it allows distinguishing speakers.

## Discussion

Criminal expertise is the search for the veracity of evidence of a crime. From the crime evidences initiated by the accused, these are analyzed with technical - scientific knowledge in order to have a conclusion by the day of the trial, which is shown by the forensic experts<sup>18</sup>.

The crime evidences are clues that must be carefully analyzed and preserved, because through these clues, the technical report begins, which in turn has the function of solving a legal cause.

For the analysis of a forensic examination, it is necessary that all evidence be identified, preserved, analyzed and presented. It is up to the expert to identify the evidence and preserve it, so that doubts about the prosecution are avoided. The technical report of the investigation presents the fact, the procedure, the analysis and the result of

the evidences found at the crime scene, and it is up to the court to decide whether or not to prosecute<sup>19</sup>.

In the case of phonetic forensic expertise, the evidence is not present at the crime scene most of the time, but the recordings indicating criminal evidence are analyzed by criminal experts.

The criminal expert is a technician whose job it is to provide data information about the materials and carry out the crime. Phonetic transcription is not only attributed to the criminal expert, since any and all public order officials are authorized to do the phonetic transcription. Thus, it is up to the Judge to have the free will to take or not as evidence for the prosecution a transcript that is not conducted by an expert<sup>20</sup>.

It seems to us that, despite the possibility of another professional performing phonetic transcription, the ideal would be for a linguist or a speech therapist to do it, avoiding mistakes and analyz-



ing other aspects that another professional would have more difficulties in performing. An example of the above concerns the perceptual-auditory analysis (PAA) of the voice, which is a subjective assessment and which, according to Porto and Gonçalves<sup>21</sup>, can be used in the forensic field, as long as there is professional competence to do so. This is because the voice changes regarding different variables such as sex, age, anatomical and health conditions, racial aspects<sup>22</sup>, tension, emotional state<sup>23</sup>, among other factors. Thus, the best professional to act in the forensic phonetic expertise would be the speech therapist. According to Buriti and Batsita<sup>12</sup>, forensic speech therapy is used worldwide, and the speech therapist is the professional responsible for diagnosing probable speech disorders of a subject, regardless of their origin. They add that this professional uses physical evidence to relate them to anatomical and functional structures (pronunciation, articulation, accent, dialect and figurative language resource), as well as analyzing the characteristics of the subject's personality, behavior and origin. It was in this context that the literature<sup>21</sup> evidenced the need to elaborate a protocol that evaluated beyond the vocal registers in software, but also comprising the vocal parameters (type of voice, vocal attack, resonance focus, pitch, loudness, quality of the broadcast, among others) by PAA and, for forensic practice, Porto and Gonçalves<sup>21</sup> suggested the inclusion of linguistic aspects of speaking and speech, with the analysis of phonetic and phonological characteristics related to speed and rhythm of speech, articulation, fluency, and whether or not dialects are present. Therefore, the performance of this analysis requires technical knowledge and clinical professional experience, especially in voice and language, confirming the importance of the need for a speech therapist in the criminal expertise team.

It can be said that the work with CF in forensic phonetics in Brazil has existed for two decades<sup>24</sup>, and Figueiredo<sup>23</sup>, in 1994, made an extensive evaluation of the acoustic parameters of speech, verifying that there are indicators that help in the identification without, however, being able to be considered as a "vocal fingerprint", in addition to suggesting that the analysis be performed by a team composed of different specialists. Since the 1990s, with the technological increase, there has been the possibility of more objective analyzes, and there must be, according to Figueiredo<sup>23</sup>, safe criteria for

the evaluation. The objective evaluation with the aid of technology attributes value to CF services<sup>25</sup>.

Thus, it is necessary to emphasize and ratify the importance of interdisciplinary teams for the recognition of the voice and comparison of the speaker, such as, for example, Engineering, Computer Science, Speech, Language and Hearing Sciences, Law and Psychology. Also, several fields of applied linguistics<sup>26</sup> are used in the knowledge of forensic science, to identify the authorship of speech by the method of comparison. Such importance is that the studies obtained in this literature review<sup>21,23,25,31-35</sup> reinforce this concept.

The identification of a criminal through the voice aims to determine the main accused, considering that the voice is a unique feature. Thus, it is an essential evidence for forensic expertise, since, in order to assign the subject to a crime scene, concrete evidence is necessary, and the absence of it means that the main author is not incriminated<sup>20</sup>.

The literature has pointed out that the use of biometrics to identify individuals is an effective technique, since the physical characteristics are particular and unique to each person and the constant advancement of technology favors and expands its use<sup>3,27</sup>.

Another important item for the identification of a speaker is the quality of the recording material, as according to the literature<sup>8</sup>. For the conclusion of a correct report, the experts need to identify the coexistence or not of general and peculiar characteristics between the various sound signals of speech and distortions that can impair expert analysis. This aspect was reinforced by the studies obtained in this literature review<sup>25,34</sup>. Besides, for better performance in the investigation, there must be complicity between prosecutors and judges, as the work begins with the experts by investigating the crime scene.

Then, the conclusion of the reports reaches the prosecutors and judges, being important to note that if there is not a good expert, the report may be inconclusive and this fact may hinder the judgment, whether due to lack of evidence or poorly completed evidence<sup>25</sup>. In this review, two studies<sup>25,34</sup> ratified the abovementioned, showing a scarcity of resources of different classes (technological, human and material) for effective forensic analyzes that meet the demands.

Despite the above, phonetic forensic expertise has grown in the last decade, however, there have

been few studies in the area<sup>28</sup>, as we have also seen in this integrative review.

This limitation hinders the training of professionals and the presentation of more robust scientific evidence in the area, since biometric studies need to present reference values to serve as comparative parameters for future expert analysis, according to the literature<sup>22</sup>.

Thus, as Speech, Language and Hearing Sciences study communication and, among the aspects that characterize it, the voice is naturally expected to include this area in the CFs, emphasizing the importance of it being practiced by Speech Therapists who are experts in voice<sup>29</sup> who also master the technology.

The increase in technologies in the contemporary world has also opened the field for the computational expert who, according to the literature<sup>30</sup>, aims to analyze crimes committed with the help of the internet, cell phones, and other technologies. As we could see in this literature review, although the growth trend was mentioned, few studies have been carried out in phonetic forensic expertise by analyzing the vocal parameters<sup>28</sup>, making it necessary for speech therapists to study and publish more in the area, to be entitled to the achievement in this field in the labor market. As verified in this integrative review research, only one study was carried out by speech therapists<sup>21</sup>, with the other studies performed by linguists and engineers.

This is possible because the phonetic CF, which includes voice analysis, is not done in isolation, being considered an interdisciplinary area<sup>4,29</sup>. It is necessary to share knowledge with other areas such as linguistics, engineering, medicine (otorhinolaryngologist, forensic doctor, etc.), psychology, law, civil and military police, computation, among others.

Among the characteristics that make it possible to recognize the speaker by means of recordings are the long-term spectrum (LTS), the voice onset time (VOT), the analysis of the F3 and F4<sup>23</sup> formants, the pitch and, by the electroglotographic signal, the double peaks<sup>31</sup>, the jitter, H1-H2 and the intensity when the prosody is analyzed<sup>32</sup>. When the recordings come from mobile phones, due to their filters, operating system and data compression, the parameters that do not seem to be influenced by the analysis were: open vowels are more resistant to the telephone effect, as well as the baseline and duration fundamental frequency interpeaks (F0),

under the influence of the F0 mobile phone and the spectral emphasis, according to the literature<sup>33</sup>.

The technological resources used in the researches raised in this literature review and that can be used in the phonetic CF for the analysis of the voices were the computerized speech lab<sup>23,34</sup> and the glottal reverse filter signal<sup>31</sup>. The software were: Audacity (for acoustic analysis of speech signals<sup>31</sup>); Edit Track (for audio editing or authenticity); and Sound Cleaner (for the treatment of audio signals). In addition to these tools, audio capture cards were used; Multi-Speech (software for acoustic speech signal analysis) and the Adobe Audition Package (audio analysis)<sup>34</sup>. The use of the PRAAT software, available on the internet for free, was mentioned by Moraes and Oliveira<sup>32</sup>. The combined use of the dominant Gaussian method with adaptive multiconditional models and mixtures of multi-resolution Gaussians seem to offer lower cost and increased speaker identification by voice<sup>35</sup>. Besides, researchers<sup>25</sup> cited the use of software for comparing voices, without mentioning which ones.

Regarding this, it is believed that to work in this area, the expert needs to be qualified and have requirements such as skills in technology, specialization in voice and language, knowledge of laws, professional experience, among others.

The development of human resources in forensic science in Brazil is centered on the training of official experts and is acquired through the professional trajectory, through training courses (updating, improvement, as well as *lato* and *stricto sensu*) and selective processes<sup>36</sup>. It is worth mentioning that the scarce literature does not yet describe how Speech, Language and Hearing Sciences has acted in an integrated manner with other specialists in the forensic field. It also does not specify how the speech therapist experts have obtained the necessary training to work in the area, what protocols they use in professional practice, what are the difficulties in the scope of professional practice in phonetic CF and how much professional and clinical experience facilitate such performance, for example. Thus, much remains to be built in the area for an evidence-based practice, although research has shown the possibility of CF analysis by voice.

## Final Considerations

Criminal forensic voice is an area with few studies, and it is not possible, at the present mo-

ment, to describe how the Brazilian speech therapist has acted in phonetic forensic expertise related to vocal parameters. However, the literature consulted showed that the resources used in vocal criminal expertise range from trained professionals, from different areas of knowledge (Linguistics, Speech Therapy, Engineering, Law, Medicine, among others) to the use of software that can compare the voice of different speakers, in person or by mobile phone.

Despite the above, there is a need for professionals, when choosing this area of work, to be extremely qualified for the demand for crimes in the country, so that, increasingly, we have expertise in the area. It must be considered that this professional dominate technology, legislation, be a specialist in voice and language and have sufficient clinical experience to participate in expert voice analysis.

Thus, the forensic area opens space for new professions, including Speech Language and Hearing Sciences, being considered by the Federal Council of Speech Therapy<sup>37</sup>, an expanding research area.

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