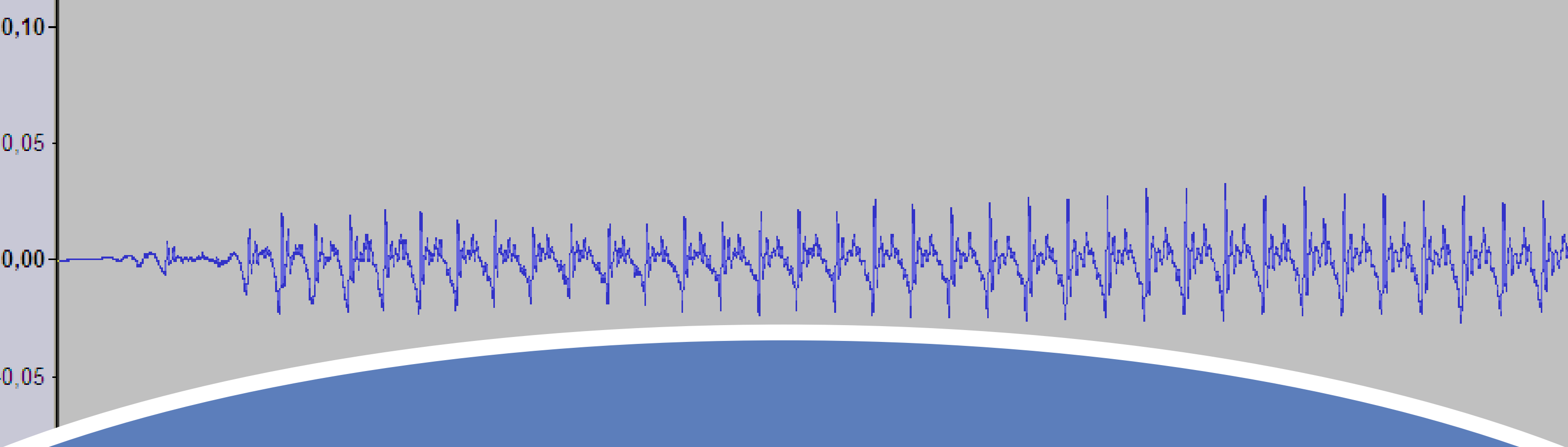


Hrsg.: Deutscher Bundesverband für Logopädie e.V. dbl

Meike Brockmann-Bauser

Improving jitter and shimmer measurements in normal voices

ausgezeichnet mit dem dbl Forschungspreis

Das Gesundheitsforum

Schulz-Kirchner Verlag

Meike Brockmann-Bauser

Improving jitter and shimmer measurements in normal voices

Das Gesundheitsforum

Schulz-Kirchner Verlag

Bibliografische Information Der Deutschen Bibliothek
Die Deutsche Bibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.ddb.de abrufbar.

Die vorliegende Arbeit wurde im Rahmen eines PhD Studiums in Biomedizinischen Wissenschaften an der Medizinischen Fakultät der Universität von Newcastle upon Tyne, Great Britain, erstellt.

Betreut wurde die Arbeit durch Prof. Dr. Paul N. Carding und Dr. Michael J. Drinnan.

Die Prüfer waren Prof. Dr. Janet Mackenzie Beck, Queen Margaret University, Edinburgh (GB) und Dr. Philip Langley, Institute of Cellular Medicine, Faculty of Medical Sciences, University of Newcastle upon Tyne.

Die Informationen in diesem Werk sind von der Verfasserin und dem Verlag sorgfältig erwogen und geprüft, dennoch kann eine Garantie nicht übernommen werden. Eine Haftung der Verfasserin bzw. des Verlages und seiner Beauftragten für Personen-, Sach- und Vermögensschäden ist ausgeschlossen.

1. Auflage 2013
ISBN E-Book 978-3-8248-0927-1
Alle Rechte vorbehalten
© Schulz-Kirchner Verlag GmbH, 2013
Mollweg 2, D-65510 Idstein
Vertretungsberechtigter Geschäftsführer: Dr. Ullrich Schulz-Kirchner

Besuchen Sie uns im Internet: www.schulz-kirchner.de

Abstract

Instrumental acoustic voice analysis is a widely used clinical assessment technique to assist differential diagnosis, documentation and evaluation of treatment for voice disorders. However recent reports criticise an unsatisfactory reliability and validity of acoustic assessments. The present work examines confounding factors associated with the usual clinical measurement procedure and how their influence might be reduced. Further, it was investigated what jitter and shimmer indicate, and how this could be applied in voice clinics.

In a routine clinical voice assessment the individuals` speaking voice SPL and F_0, gender and the vowel significantly influence both jitter and shimmer. Differences in habitual voice SPL have by far the strongest influence, which may even underlie gender effects. It was shown for the first time, that clinical jitter and shimmer measurements might be considerably improved when patients phonate at a predefined level of 85dBA (10cm distance) without control of F_0, and always use the vowel /a/.

In healthy adults jitter and shimmer were not associated with perceptual voice irregularity. However clinical measurements in a variety of voice tasks showed that jitter and shimmer were always lower in higher voice intensities. Also in vocally healthy teachers increased voice SPL and F_0 after a working day were associated with lower jitter and shimmer. Higher voice SPL is accompanied by increased vocal fold tone, which might result in more regular voice vibration patterns and thereby in lower jitter and shimmer values.

From a clinical perspective this would be highly relevant information, especially in patients with impaired vocal fold tone regulation such as in functional or neurogenic voice disorders. Future research should clarify sources of jitter and shimmer and revise current normative values considering the proposed assessment protocol and gender. This might establish the clinical potential of instrumental acoustic voice analysis.

Vorwort des Herausgebers

Im deutschsprachigen Raum ist eine stetige Weiterentwicklung im Bereich der Stimmdiagnostik zu verzeichnen. Dies zeigt, dass Stimmstörungen zunehmend präziser zu diagnostizieren und somit gezielter zu therapieren sind. Die Stimmdiagnostik basiert auf subjektiven Eindrücken und objektiven akustischen Messverfahren. Nicht nur zur Erstdiagnostik wird die Stimmdiagnostik eingesetzt, sondern ebenso zur Zwischen- und Endevaluation einer Stimmtherapie.

Angesichts der Tatsache, dass objektive Stimmfeldmessungen im Rahmen von evidenzbasiertem Arbeiten ein wichtiges Element geworden sind, häufig aber kritisiert wird, es lägen keine ausreichenden Normwerte für Stimmfeldmessungen vor, ist die Auseinandersetzung mit den objektiven Messergebnissen von besonderer Bedeutung.

Was die computergestützten Messergebnisse von Jitter und Shimmer für die Praxis aussagen und was diese Ergebnisse für die Therapie bedeuten können, sind die Fragen, mit denen sich die Forschungspreisträgerin Meike Brockmann-Bauser in ihrer Arbeit auseinandersetzt. Angesiedelt ist diese Fragestellung im Spannungsfeld von Theorie und Praxis und sie zeigt erneut, wie wichtig die Weiterentwicklung der Theorie für die Praxis ist.

Frau Brockmann-Bauser arbeitet mit ihrer Studie heraus, welch hohen Informationsgrad Jitter und Shimmer für den Therapeuten haben können. Dadurch erhöht die dbl Forschungspreisträgerin die Relevanz von computergestützten Stimmfeldmessungen auch im Rahmen der evidenzbasierten Praxis.

Der dbl-Forschungspreis, der vom Schulz-Kirchner Verlag dankenswerterweise mitgetragen wird, trägt dazu bei, wissenschaftliche Master- oder Promotionsarbeiten zu unterstützen, die einen wichtigen Beitrag dazu leisten, die aus intensiver theoretischer Arbeit gewonnenen Erkenntnisse zum Wohle der Patienten in der Praxis anzuwenden. Die vorliegende Studie trägt in herausragendem Maße dazu bei, neue Erkenntnisse in die Praxis integrieren zu können.

Christiane Hoffschildt

Präsidentin des dbl

Foreword

Acoustic analysis has been a topic of fierce debate amongst voice professionals for many years, yet still hasn't found its place in most clinical environments. Meike Brockmann-Bauser has set herself the unenviable task of understanding why this was the case, and how matters might be improved.

In 2004, Meike started her MSc at Newcastle University, and made an immediate impact such that we encouraged her to continue with a PhD. Meike's thesis was concerned with improving the reliability and validity of acoustic analysis of the human voice. The work you are about to read is a major contribution to our understanding of how to apply acoustic measurements to the voice disordered clinical population. As you will see, she made a series of carefully controlled experiments using normal voices, to determine the best clinical protocol for the most reliable acoustic assessments. The standard of the work is such that she has published her findings in several internationally renowned journals, and now in this book.

We must explain that Meike's PhD studies were most unusual. Most English PhD students hold regular meetings with their supervisors, attend frequent seminars and courses, and have many reviews of progress. This arrangement is not so easy when the student lives in Konstanz, and when also she has a challenging job in Zurich. Fortunately for us, Meike did not behave like a typical English student. She has been an experienced and valued colleague and many times, her attention to detail has taken us by surprise. Meike has been the perfect German student in our very English institution.

Research is never the result of one person alone. During Meike's PhD studies we had the opportunity to visit her in Zurich. We were greatly impressed by the work there, and it was clear that Meike was supported by a strong team of scientists and clinicians. We must mention Prof. Dr. R. Probst, KD Dr. J. Bohlender, U. Vith, T. Kirchgraber, B. Balandat, S. Riedmüller and Drs. C. Mathys, E. Blaschek and K. Castiglioni.

Like any good researcher, Meike raises more questions than she answers. We know you'll find much value in the text, and hope you will be motivated to fill in some of the gaps.

Paul Carding
Michael Drinnan
Newcastle, 30th November 2012

Dedication

Dedicated to my beloved family, Christopher and Sarah.

You are my source and inspiration.

I am grateful every day.

Acknowledgements

First I would like to thank Paul N. Carding and Michael J. Drinnan of the University of Newcastle upon Tyne for being exemplary supervisors, for their tireless mentoring, for helping herd my ideas and questions, and for always providing the most comprehensive feedback one could imagine. You made it a pleasure to pursue the PhD.

Research could not develop without people providing the opportunity and background to test ideas. Plenty of thanks to KD Dr. J. Bohlender and Prof. Dr. R. Probst of the University Hospital Zurich for enduring support. A special thank goes to my colleagues B. Balandat, T. Kirchgraber, S. Riedmüller, U. Vith and Drs. C. Mathys-Zulauf, E. Blaschek and K. Castiglioni of the Phoniatrics and Speech Pathology Team, who patiently tested one novel perceptual voice analysis task after the other. Also I would like to thank all volunteers of the University Hospital and of several schools in Zurich who performed many voice tasks for the research presented here. Without all this, my work would have been impossible.

Thanks to all patients who keep telling me what a voice problem is. I am listening.

Table of Contents

List of Tables

List of Figures

List of Appendices

Preface: Organisation of the thesis

The present thesis grew out of a need to improve our understanding of clinical instrumental acoustic voice assessments. Instrumental measurements determine defined acoustic properties of the human voice sound. It is assumed that the acoustic voice waveform represents the vibratory characteristics of the vocal folds. However, despite widespread application in voice diagnostics and documentation, the reliability and validity of instrumental assessments has not been sufficiently established to date.

This thesis presents an in-depth study of confounding factors associated with the clinical measurement procedure and focuses on the two most widely used acoustic parameters jitter and shimmer. Further, it will be investigated what jitter and shimmer might indicate and how this could be usefully applied in voice clinics. Below the organisation of the thesis is described.

Chapter 1 provides the broad theoretical context for instrumental acoustic voice assessments. First, the main vibratory principles of the human voice are described, since these are basic to a valid interpretation of jitter and shimmer. The most commonly used clinical voice examination techniques are evaluated and placed in context with acoustic assessments. *Chapter 2* gives a comprehensive introduction into the measurement technique underlying instrumental acoustic analysis. A critical literature review documents how strongly the reliability, validity and sensitivity of clinical jitter and shimmer measurements are restricted to date. Confounding factors associated with the measurement technique and the clinical voice assessment protocol are evaluated. This chapter concludes with the main questions to be addressed in the present thesis.

Chapter 3 summarises the selection criteria for all study participants and the main voice analysis technique of the present work. The experimental chapters 4 to 8 follow the same broad structure: Introduction (including a specific literature review), Specific Study Aims, Methods, Results, Discussion and Conclusion.

Chapter 4 presents a summary only of the first research study. This work was conducted as MSc project prior to the present PhD work and was submitted to Newcastle University in August 2006. This initial study showed a dramatic influence of differences in the habitual speaking voice Sound Pressure Level (voice SPL) on both jitter and shimmer, which may even underlie gender effects. In *chapter 5*, the relative effects of voice SPL, fundamental frequency (F_0), gender and vowel and their interactions were assessed. To determine how clinical measurements of jitter and shimmer might be improved, in *chapter 6* healthy adults were assessed under a range of voice tasks. Based on the results, a revised clinical instrumental acoustic assessment protocol is proposed.

Chapters 7 and 8 address the question what jitter and shimmer might indicate in healthy voices. In *chapter 7* it was assessed if jitter or shimmer correlate with perceived voice irregularity under the commonly used instrumental acoustic assessment protocol. Since no agreement was found, *chapter 8* describes how refined instrumental acoustic assessment methods, as specified in chapter 6, are applied in practice. Healthy teachers were recorded during a working day to determine if jitter and shimmer track subtle voice changes associated with voice use. The study results imply that jitter and shimmer might indirectly indicate changes in vocal fold tone associated with adaptation to voice use. From a clinical perspective this would be highly useful in the diagnostics of so-called functional voice disorders.

Chapter 9 discusses the experimental work in the context of clinical voice diagnostics (established in chapters 1 and 2). Based on this, useful jitter and shimmer applications and future research directions are developed.

This thesis includes material from papers and abstracts that have been published. *Appendix A* provides full publishing details of peer reviewed publications based on the work presented here (Medline standard).

Appendix B to *Appendix E* provide evidence of ethical approval for all presented experimental studies. *Appendix F* is the participant questionnaire used in the experiments described in chapters 5 to 9. *Appendix G* and *Appendix H* show the oral instructions for judges and the user manual for the specific perceptual analysis software Newcastle Audio Ranking (NeAR). These were used in the studies described in chapters 8 and 9. *Appendix I* is the visual analogue scale for subjective voice assessment as used in chapter 9.

Chapter 1. Vibratory characteristics of voice production

Instrumental acoustic analysis of the human voice is a commonly used assessment technique. Basic to a valid interpretation of instrumental acoustic measurements is a thorough understanding of undisturbed and pathologic voice function. This chapter introduces into the main principles of human voice production. Basic anatomy and physiology as well as the vibratory properties of the vocal folds are explained. The most commonly used clinical voice assessment methods are described and evaluated with emphasis on their diagnostic properties. In this chapter instrumental acoustic assessments are placed into context of the main clinical examination techniques.

1.1 Physiology of phonation: the basis for clinical voice diagnostics

Clinical voice assessments aim to identify the reasons for pathological voice changes in a patient. Based on this the clinician plans an appropriate individual therapy approach. Therefore, the physiologic processes underlying the human voice production are key to understanding voice assessment techniques.

The human voice is generated within the larynx by vibration of the vocal folds and depends on an adequate airflow from the lungs (Titze, 1988). This requires a complex coordination of phonatory and respiratory muscles (Colton et al., 2006). The larynx is composed of muscles, ligaments, mucosa and cartilage, and is attached by ligaments and muscles only at the front of the neck (Figure 1). It is situated between the hyoid bone and the upper end of the trachea (Sobotta, 2006).

The unformed voice sound emitted from the vocal folds is amplified and filtered by the vocal tract (Fant, 1980). Movements of the speech organs in the vocal tract (for example the tongue) actively form the sound to create speech. In the following sections the main principles of human voice production will be described.

Figure 1: Location of the larynx

Please note that copyright permission for this figure was not obtained. Please refer to the original image in:

Stemple, J. C., Glaze, L. E. and Gerdeman, B. K. (2000) Clinical voice pathology: theory and management. 3 ed San Diego (CA): Delmar, Singular Publishing Group. Page 22, figure 2-1.

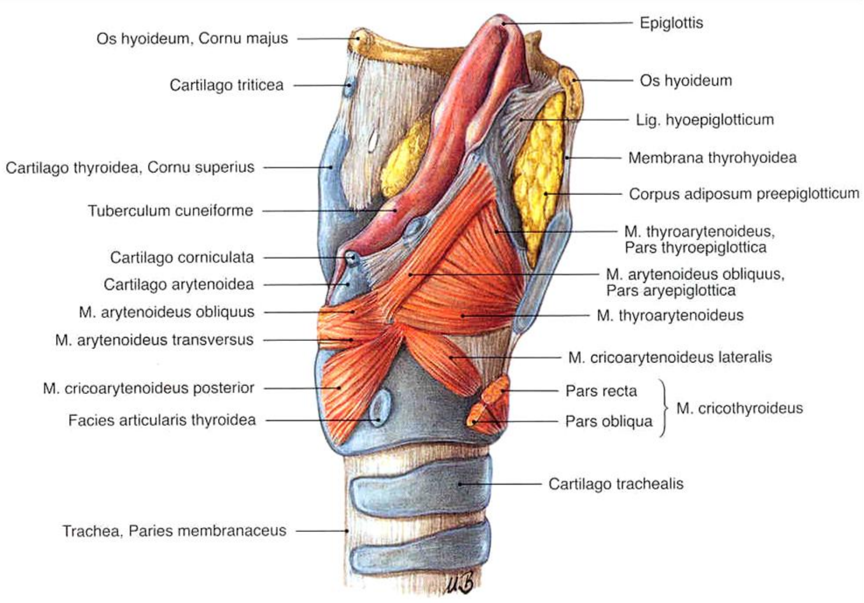
Location of the sound source, the larynx, within the human body. Indicated are the three subsystems of voice production: respiration, phonation and resonance. Origin: figure 2-1; Stemple et.al.2000.

1.1.1 *Inside the larynx: muscle activity and Bernoulli Effect*

In order to produce sound the vocal folds have to close with appropriate tone (Colton et al., 2006). This is done by three paired and one single muscle called the "adductors": the interarytenoid muscle ("m. interarytaenoideus"), lateral cricoarytenoid muscle ("m. cricoarytaenoideus lateralis"), cricothyroid muscle ("m. cricothyroideus"), and the thyroarytenoid muscle ("m. thyroarytaenoideus" or "m. vocalis") which forms part of the vocal folds (Figure 2). The paired muscles close the glottis (the space between the vocal folds) by active movement, whereas the m.vocalis produces intrinsic tension. The only vocal fold abductor ("opener") is the posterior cricoarytenoid muscle ("m. cricoarytaenoideus posterior").

When the vocal folds are in phonation position (closed glottis), the respiratory system has to provide a constant airflow. The closed vocal folds provide resistance to exhaled air from the lungs (Titze, 1988). When the air bursts through the vocal cords, the pressure between the vocal folds drops. This leads to underpressure sucking the vocal folds back together, a phenomenon known as the *Bernoulli Effect*. This happens repeatedly and results in vocal fold vibration, perceived as a natural human voice sound (Baken and Orlikoff, 2000c).

Figure 2: Side view of laryngeal structures and muscles



Laryngeal cartilages and muscles from the right side. The right part of the thyroid cartilage is removed. Origin: figure 225; Sobotta: Atlas der Anatomie des Menschen,© Elsevier GmbH, Urban & Fischer Verlag München 2006.

1.1.2 *Vocal fold structure and its role in phonation*

Alongside an adequate closure and tension the biomechanical structure of the vocal folds influence the vibration patterns. The vocal folds are composed of three main functional layers, the cover, the transition and the body (Figure 3). These comprise histologically different cell types with unequal vibratory properties (Table 1). As the histological layers change from superior to inferior, each level gradually changes in mass, stiffness and compliance for vibration (Hirano, 1974):

(1) The cover layer consists of *mucous membrane* and *squamous epithelium* and is very pliable.

(2) Immediately beneath lies the *lamina propria* composed of three sections. The superficial layer is called *Reinke's space* and consists of loose fibres and matrix (connective tissue). It has a jelly-like texture and easily slides over the deeper structures. Below are the *intermediate layer*, elastic fibres almost parallel to the vocal folds, and the *deep layer*, mostly collagenous fibres. Both the intermediate and the deep layer form the *vocal ligament*, which are more compact and less flexible than the superior layers.

(3) The deepest structure of the vocal folds is the *vocalis muscle (thyroarytenoid muscle)*, mainly composed of muscle fibres. This layer is rather stiff in consistency.

Figure 3: Transverse section of the vocal folds

Please note that copyright permission for this figure was not obtained. Please refer to the original image in:

Rosen, C. A. and Simpson, C. B. (2008) Operative Techniques in Laryngology. Berlin, Heidelberg: Springer-Verlag, Germany. Chapter 1 (Anatomy and Physiology of the Larynx), page 6, figure 1.4.

Coronal transverse section through the vocal folds showing their histologic and functional layers. Origin: figure 1.4; Rosen et al., 2008.

Table 1: Anatomical and functional sections of the vocal folds

Anatomic layer	**Cell type**	**Function**	**Body-cover theory**	**Flexibility**
Epithelium				
	Squamous epithelium	Mucosa	Cover	Very pliable
Lamina propria				
Superficial layer (Reinke`s space)	Loose fibres, matrix	Mucosa	Cover	Very flexible
Intermediate layer	Elastic fibres	Vocal Ligament	Transition	Less flexible
Deep layer	Collagenous fibres	Vocal Ligament	Transition	Less flexible
Vocalis muscle (m. vocalis)				
	Muscle fibres	Muscle	Body	Stiff

Summary of histological and functional vocal fold layers and their vibratory properties. Origin: own table.