

**Complementary approaches for voice disorder assessment**

Alain Ghio  
Laboratoire "Parole et Langage", Aix-Marseille University France

Congresso de Fonética e Fonologia Niterói, Brasil Novembro de 2008

**A team with complementary partners**

Timone Hospital (laryngo)  
✓ A. Giovanni, J. Révis, D. Robert, B. Amy de la Brétèque, M. Ouaknine, R. Garrel

Speech sciences (phonetics)  
✓ A.Ghio, B. Teston, T. Legou, Y. Meynadier, A. Marchal

Computer Sciences  
✓ C. Fredouille, JF Bonastre, G. Pouchoulin

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**History...**

- LPL (Speech and language lab) develops and uses tools for speech analysis in phonetics : acoustic, aerodynamic, EPG, EMA, EMG...
- 1990 : Collaboration between phoneticians and clinicians from ENT dept, Timone Hospital

GIOVANNI, A.; MOLINES, V.; NGUYEN, N.; TESTON, B. (1991) L'évaluation objective de la dysphonie: une méthode multiparamétrique. Proceedings of International Congress of Phonetic Sciences (ICPhS), p. 274-277

Giovanni A, Molines V, Nguyen N, Teston B, Robert D, Cannoni M, Pech A. (1992) Une méthode multiparamétrique d'évaluation vocale objective assistée par ordinateur. Ann Otolaryngol Chir Cervicofac, 1992;109:200-206

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**Phonetics and voice quality**

**Phonetics and voice quality**

- Voice quality : paralinguistic phenomenon in relation with
  - Emotions
  - Socio-cultural and/or dialectal specificities
  - but also...
- Physiological state of speaker
  - Dysphonic patients
  - ENT dept, CHU Timone, Marseille
  - For 18 years (Giovanni, Molines, Nguyen, Teston, ICPhS, 1991)
- Voice assessment = report
  - Disorder severity
  - Temporal follow-up of patient
  - Therapy efficiency
  - Comparisons of patients, groups
  - Knowledge

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**Dysphonia**

- Symptom of laryngeal failure in producing periodic sound
- Bad voice quality which has an impact on
  - (non) natural voice
  - (non) pleasant voice
  - social image degraded
  - Intelligibility
- A problem of society
  - Professionnals of voice (teachers, business, ...)

D. Morsomme, s. Russel, J. Jamart, M. Remacle, and I. Verduyck, "Evaluation subjective de la voix (vhi) chez 723 enseignants en région bruxelloise," in Actes du congrès de la Société Française de Phoniatrice, Paris, 2008.

10.5% of 723 school teachers are dysphonic and need therapy

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**Voice assessment in a clinical context ?**

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Imaging

Questionnaire

Phonetics

Instrumental assessment

Postural assessment

Perceptual assessment

Gesture And voice

NIVEL H LANGUAGE

**Overview of voice disorder**

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**Voice disorder : an acoustic phenomenon ?**

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**Voice disorder : an aerodynamic phenomenon ?**

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**Voice disorder : an "organic" phenomenon ?**

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**Voice disorder : a neuro-anatomic phenomenon ?**

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**Voice disorder : a behavioral phenomenon ?**

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**Voice disorder : a contextual phenomenon ?**

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**Voice disorder : a communication disorder ?**

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Hergé: le trésor de Rackham le Rouge, Casterman

**Voice disorder : a complex problem**

- Linked to the complexity of speech production and spoken communication
- Needs a multidimensional assessment

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**Perceptual assessment of voice quality**

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**Perceptual assessment**

- Why ?
  - ✓ Speech is produced to be perceived
  - ✓ Patients consult because of changes in their voice
  - ✓ Perception is the first and most available « tool » for clinicians
- Perceptual analysis of connected speech is widely used for voice quality assessment
- Several methods

Dejonckere P, Bradley P, Clemente P, Comut G, Clever-Buchanan L, Friedrich G, Van de Heyning P, Remacle M, Wolszak V. "A basic protocol for functional assessment of voice pathology, especially for investigating the efficacy of (phonosurgical) treatments and evaluating new assessment techniques.", Eur Arch Otorhinolaryngol; 238:77-82, 2001

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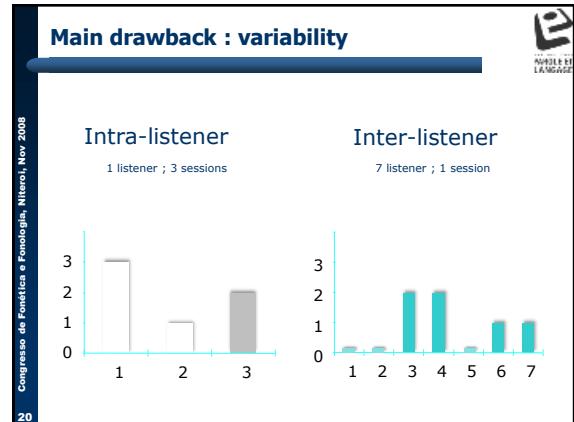
## GRBAS Scale

Proposed by Hirano, 1981  
Hirano M. Clinical Examination of Voice. Wien, Springer Verlag, , 1981

- Speaker read a standardised text
- Listener(s) listen(s) and assign a note between 0 (normal) and 3
- Multidimensional Scale
  - G = global quality
  - R = Roughness
  - B = Breathy
  - A = Asthenia
  - S = Strength
- 4 groups : G0, G1, G2, G3
  - normal
  - dysphonia severity

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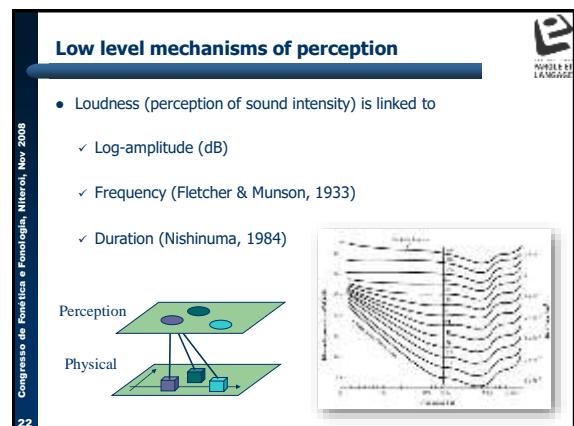


## Why such a variability ?

- Perception is considered as a "GOLD STANDARD" reference by clinicians but...
- ... perception is not an exact copy of reality

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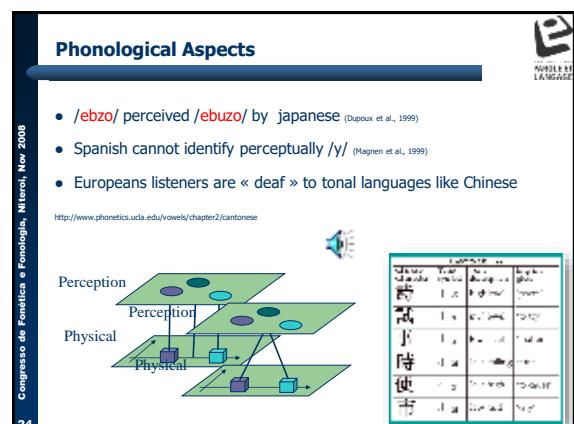


## Importance of the context

Meunier C., Floccia, C. (1999) "Syllabe ou mot : quelle unité permet d'identifier les catégories phonétiques?", Actes des 2èmes Journées d'Etudes Linguistiques, "Syllabes", Nantes, pp. 87-92.

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**Perception of Voice quality**

- Perceptual voice assessment
  - ✓ Not a linguistic processing (= intelligibility)
  - ✓ Not usual (= emotions)
  - ✓ No common and shared references => high subjectivity
- Learning as a second language ??

**Common and shared knowledge**

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**Alternative to perception ?**

**PRODUCTION**

**PERCEPTION**

**INSTRUMENTS**

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**Instruments to complete perception**

**AUDIO**

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**Etienne-Jules Marey (1875)**

- French physiologist who studied movements of animals and humans
- Developed graphical techniques
- Société de Linguistique de Paris consults Etienne-Jules Marey in order to...
  - « d'appliquer la méthode graphique à l'étude des mouvements si complexes et si variés qui se produisent dans la parole [...] pour obtenir une trace objective des mouvements de la tête, du cou, du larynx, de la pharyngie, larynx, langue, lèvres, voile du palais, au cours de l'articulation des différentes unités phonétiques »
- Because
  - « L'oreille, la vue et la palpation ne sont pas suffisants pour apprêhender les mouvements successifs et simultanés nécessaires à la réalisation d'un phonème. »

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**Rosapelly & Havet**

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- First device and document in experimental phonetic : Rosapelly and Havet (1875)
- First classification with experimental data:
  - ✓ Identical Lips dynamic : p, b, m
  - ✓ Identical laryngeal activity : b, v, m
  - ✓ Nasal activity : m

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**Abbé Rousselot & Charles Verdin**

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**Aix-en-Provence tradition:  
Bernard Teston & Denis Autesserre**

« Polyphonometre », 1975

Aérophonomètre (1982)

Physiologia (1990)

EVA 1 (1993)

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**Instrumental assessment**

- E.V.A. workstation
  - ✓ Laboratoire Parole et Langage (CNRS, Aix-Marseille University)
  - ✓ SQuLab

Dessin : A. Michaud

Pneumotachograph (d'obitomètre oral)  
Microphone  
Masque  
Cathéter  
Capteur de pression

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**eVA2 sensors**

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**eVA2 workstation**

EXTERNAL SIGNAL  
Professional microphone  
E.G.G.  
SENSORS  
Airflow sensors  
Microphone  
COMPUTER  
SIGNAL CONDITIONNER

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**Acoustic assessment**

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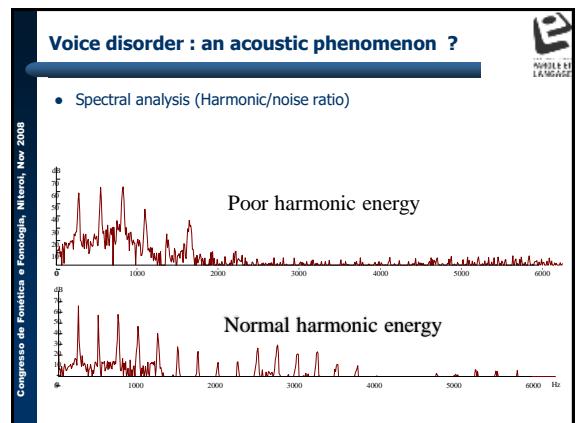
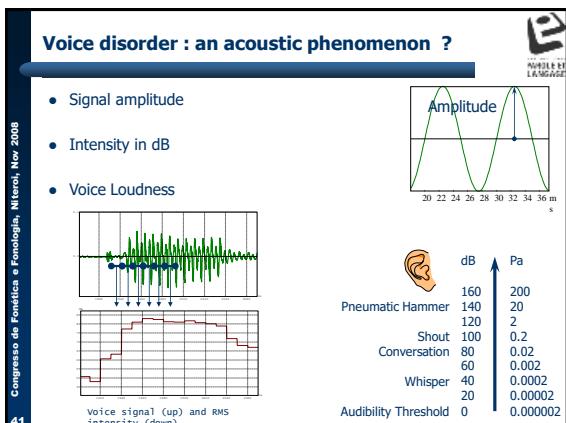
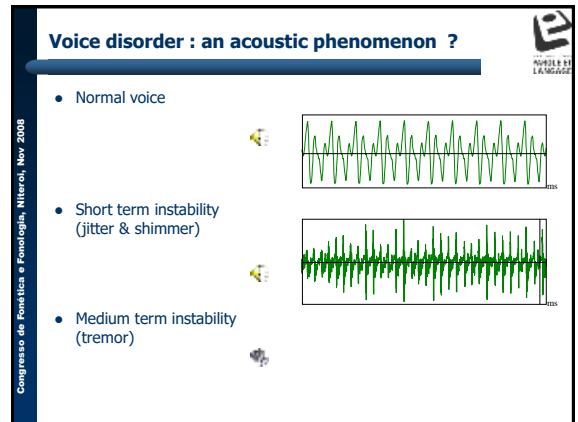
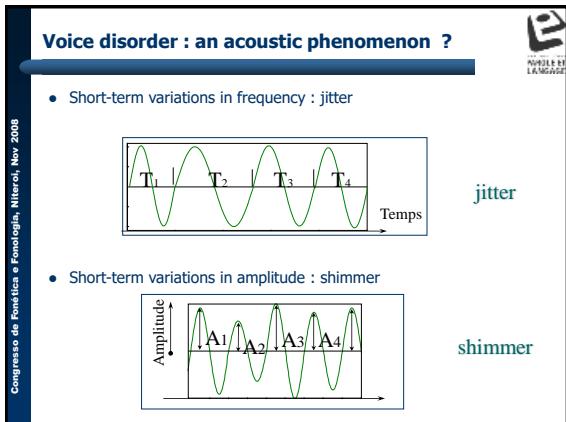
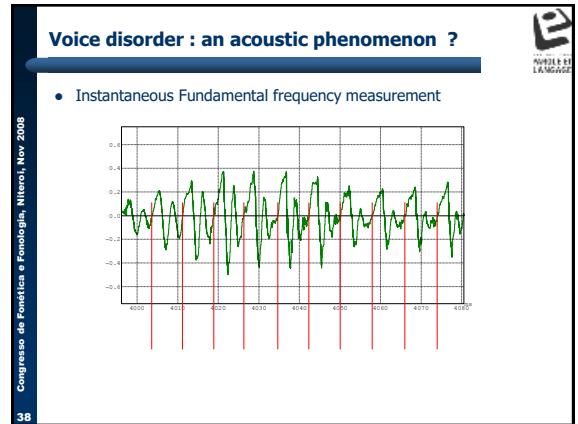
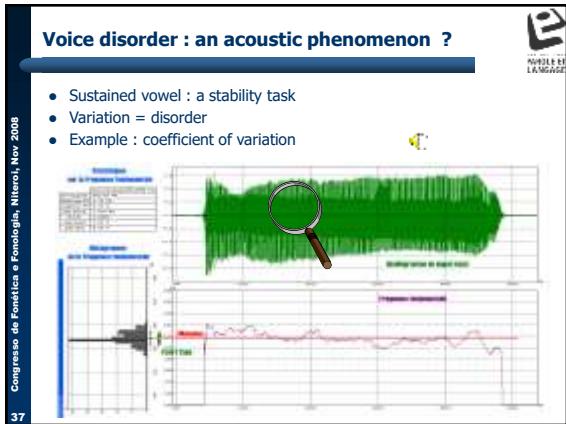
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**Voice disorder : an acoustic phenomenon ?**

- Acoustical perturbations of the glottal source

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**Voice disorder : an acoustic phenomenon ?**

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- Spectral analysis (Harmonic/noise ratio)

Normal harmonic energy      Poor harmonic energy

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**Voice assessment : an acoustic analysis ?**

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Groupe	année	Jury	Patients	Mesures	R <sup>2</sup>
Wolfe (Auburn)	95	22	60	Jitter, shimmer, SNR	45%
Wuyts (Antwerp)	00	-	387	DSI (I-low;Jitter;MPT;Fo-high)	64%
Eadie, Doyle (Washington)	05	12	36	LTAS, Noise energy	48%
Roy (Bloomsburg)	06	12	134	Cepstral and Spectral analysis, Pitch sigma	64%

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**Aerodynamic assessment**

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**Voice disorder : an aerodynamic phenomenon ?**

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**Voice disorder : an aerodynamic phenomenon ?**

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- Flowmeter and microphone

Dessin : A. McChaud

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**Voice disorder : an aerodynamic phenomenon ?**

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- Oral airflow and dysphonia severity (G Hirano : G0, G1, G2, G3)
- Male/ female

Severity (G)	M (Male)	F (Female)
G0	153	136
G1	191	168
G2	322	210
G3	446	305

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Yu P, Nicollas R, Garrel R, Ouaknine M, Giovanni A. Objective voice analysis in dysphonic patients. New data including non linear measurements *Folia Phoniatrica* (2007)

**Estimation of sub-glottal pressure**

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- Subglottal pressure can be estimated by intra-oral pressure using the airway interrupted method (Smitheran et Hixon)

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**Validation 1997 : Belgium**

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- Good correlation between PIO and PSG

Demolin D., Giovanni A., Hassid S., Heim C., Lecluy V., Sequeut A. (1997). "Direct and indirect measurements of subglottic pressure". Proc. Larynx 97, Marseille, p.69-72

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**Validation 2007 : Timone, Marseille**

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**Voice disorder : an aerodynamic phenomenon ?**

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- SG pressure and dysphonia severity (G Hirano : G0, G1, G2, G3)
- Male/ female

Severity (G)	M (Pre-Surg SG pressure)	F (Pre-Surg SG pressure)
G0	6.7	6.7
G1	9.7	7.7
G2	10.8	9.9
G3	14.2	11.2

Yu P, Nicollas R, Garrel R, Ouaknine M, Giovanni A. Objective voice analysis in dysphonic patients. New data including non linear measurements *Folia Phoniatrica* (2007)

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**Validation of instrumental assessment**

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**Perceptual and instrumental assessment**

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Yu P, Garrel R, Nicollas R, Ouaknine M, Giovanni A., "Objective voice analysis in dysphonic patients. New data including non linear measurements", *Folia Phoniatrica et Logopaedica*, 59:20-30, 2007

- 308 F dysphonic and controls
- 141 M dysphonic and controls
- Perceptual analysis by an expert jury (4 experts)
  - Modified Visual Analogic Scale GRBAS (0,1,2,3)
- Objective analysis combining acoustic and aerodynamic measurements
  - Vocal range, Fo, jitter, Lyapunov, Signal-to-noise ratio, MPT, OAF, ESGP

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### Pneumophony Performances

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- Maximum phonation time
- Frequency Range

Group	M	F
G0	24	13.6
G1	13.4	10.5
G2	9.3	7.6
G3	4.7	5.3

Group	M	F
G0	294	410
G1	215	316
G2	141	199
G3	141	168

### Aerodynamic measures

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- Oral airflow
- Estimated sub-glottic pressure

Group	M	F
G0	153	136
G1	191	168
G2	222	210
G3	446	305

Group	M	F
G0	6.7	6.7
G1	9.7	7.7
G2	10.8	9.9
G3	14.2	11.2

### « Standards » acoustic parameters

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- HNR
- Jitter

Group	M	F
G0	21.7	23.1
G1	15.5	19.2
G2	15.1	15
G3	7	10.1

Group	M	F
G0	0.55	0.49
G1	1.02	0.6
G2	2.02	1.13
G3	10.58	4.51

### Phase portrait of vocal signal

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### Quantifying a phase portrait

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- Lyapunov exponents
- Fractal dimensions
- Autocorrelation

Giovanni A, Ouaknine M, Triglia JM. Determination of the largest Lyapunov exponents of vocal signal: application to unilateral laryngeal paralysis. *J Voice* 1999;13: 341-354

### Lyapunov exponents

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Group	M	F
G0	156	117
G1	217	133
G2	323	249
G3	950	622

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## Clinical interest of objective voice analysis

	Obj Group 0	Obj Group 1	Ob Group 2	Obj Group 3	% correct
Grade 0	<b>45</b>	4	0	0	92%
Grade 1	5	<b>72</b>	6	0	87%
Grade 2	2	19	<b>104</b>	16	74%
Grade 3	0	0	6	<b>29</b>	85%
Total	52	95	116	45	81%

	Obj Group 0	Obj Group 1	Ob Group 2	Obj Group 3	% correct
Grade 0	<b>22</b>	1	0	0	96%
Grade 1	2	<b>22</b>	2	0	84%
Grade 2	0	10	<b>42</b>	5	74%
Grade 3	0	0	1	<b>32</b>	97%
Total	24	26	22	12	84%

**Male**

**Female**

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## New patients

- 44 new patients
  - Same discriminant analysis algorithm
- 5 discordant cases (85% concordant)

#	Perc	Obj	Rang	MPT	OAF	ESGP	SR-I Kho	Lyo	Fo	Patho
10	1	0	205	15.5	172	5.3	20.2	104	275	Nodules
12	1	0	182	15.0	80	5.9	17.5	138	219	Laryngitis
13	1	2	188	8.0	180	9.6	9.0	284	169	Poly
17	2	1	213	7.4	166	8.4	20.9	116	240	Cyst
21	2	1	129	7.0	249	9.0	10.0	184	198	Laryngitis

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## State of the art

- Dysphonia severity can be correctly predicted by instruments for 4/5 patients
  - Frequency range
  - MPT
  - Jitter
  - Lyapunov
  - Signal-to-noise ratio
  - OAF
  - ESGP

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## Postural assessment

Preliminary results :

C. Bouché, A. Lagier, A. Ghio,  
T. Legou, M. Vaugoyau, C.  
Assaiante, A. Giovanni

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## Voice disorder : a behavioral phenomenon ?

- Vocal effort :
  - Laryngeal hyper adduction (1)
  - Increase in Sub glottal pressure
- Respiratory modifications
  - Increase in thoracic movements
- Loose verticality (2),  
Head advanced (3)  
Global increase in muscular tensions

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## Voice disorder : a behavioral phenomenon ?

- Experiments :
  - Posturography
  - Movement tracker

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Communication TASK

**Posture analysis**

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- 19 marks
- 5 cameras infra-red
- System 3D SMART®

**Voice analysis**

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- Voice, SPL intensity
- Electroglossography
  - ✓ Fo
  - ✓ Closed quotient
- Système EVA®

**Synchronization**

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**Postural modifications**

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**Voice disorder : a behavioral phenomenon ?**

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- Clinical use
  - ✓ Detecting risky behavioral
  - ✓ Posture as a marker
  - ✓ Postural Therapy

Hergé: le trésor de Rackham le Rouge, Casterman

**And now ?**

## Continuous speech

- Dysphonia is not equally spread
  - Segmental pattern emphasizes (ex: voiced/unvoiced)
  - Accentuation can emphasize

- Phonetic analysis is needed
- Important corpus to process => semi-automatic analysis

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## Automatic Speaker recognition techniques

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## Adaptation to voice classification

- Perceptual assessment : G0, G1, G2, G3 (20 speakers x 4 grades)
- Parametrization with acoustic parameters on connected speech
- Training step : modelling with all the speaker of the grade

- Well adapted to classification task
- Similar to perceptual assessment : bottom-up, global

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## Recent results : Automatic Phonetic analysis

Voiceless consonants are the best candidate to assess dysphonia ?

	Grade 0	Grade 1	Grade 2	Grade 3	Total
Classes phonétiques	% TCC (n=20)	% TCC (n=20)	% TCC (n=20)	% TCC (n=20)	% TCC (n=80)
<b>Consonants</b>	<b>88.0 (16)</b>	<b>50.0 (10)</b>	<b>50.0 (10)</b>	<b>85.0 (17)</b>	<b>64.25 (53)</b>
- sourde	88.0 (16)	40.0 (8)	40.0 (8)	78.0 (16)	64.25 (53)
- sonore	88.0 (16)	60.0 (12)	75.0 (10)	75.0 (15)	68.25 (53)
<b>Vowels</b>	<b>50.0 (10)</b>	<b>35.0 (7)</b>	<b>40.0 (8)</b>	<b>70.0 (14)</b>	<b>48.75 (39)</b>
<b>Nasals</b>	<b>50.0 (10)</b>	<b>35.0 (7)</b>	<b>50.0 (10)</b>	<b>45.0 (9)</b>	<b>45.00 (36)</b>
<b>Fricatives</b>	<b>88.0 (16)</b>	<b>40.0 (8)</b>	<b>50.0 (10)</b>	<b>85.0 (17)</b>	<b>63.75 (51)</b>
<b>liquides</b>	<b>88.0 (16)</b>	<b>40.0 (8)</b>	<b>40.0 (8)</b>	<b>80.0 (17)</b>	<b>62.50 (50)</b>
<b>Occlusives</b>	<b>65.0 (13)</b>	<b>65.0 (13)</b>	<b>50.0 (10)</b>	<b>70.0 (14)</b>	<b>62.50 (50)</b>
- sourde	75.0 (15)	70.0 (14)	50.0 (10)	70.0 (14)	68.25 (53)
<b>Vowels</b>	<b>70.0 (14)</b>	<b>55.0 (11)</b>	<b>40.0 (8)</b>	<b>60.0 (12)</b>	<b>56.25 (46)</b>
<b>Oral</b>	<b>55.0 (11)</b>	<b>60.0 (12)</b>	<b>40.0 (8)</b>	<b>60.0 (12)</b>	<b>55.75 (43)</b>
<b>Tous phonèmes</b>	<b>85.0 (17)</b>	<b>55.0 (11)</b>	<b>50.0 (10)</b>	<b>70.0 (14)</b>	<b>65.00 (52)</b>

G. Pouchoulin, C. Fredouille, J.-F. Bonastre, A. Ghio, A. Giovanni (2008). Analyse Phonétique dans le Domaine Fréquentiel pour la Classification des Voix Dysphoniques. Journ. Etudes sur la Parole.

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## The importance of transitions between phonemes

The automatic system includes transitions into the consonant:  
These parts are the discriminant ones

Sur le phonème /s/      Sur le phonème /t/

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## Expertise is needed

A large blue graphic element on the left side of the slide.

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**When instrument is better than perception**

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**NÔTELH LANGUAGE**

**When instrument increase knowledge on physiology**

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**NÔTELH LANGUAGE**

**But a photographer is needed....**

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**NÔTELH LANGUAGE**

*« Measurements can be no better than the knowledge and skills of the clinician who chooses and obtains them »*  
*Ron Baker*

Congresso de Fonética e Fonoaudiologia, Niterói, Nov 2008  
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**NÔTELH LANGUAGE**

**Muito obrigado**

Congresso de Fonética e Fonoaudiologia, Niterói, Nov 2008  
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**NÔTELH LANGUAGE**