



INTERNATIONAL MATRIX TESTS

Reliable speech audiometry in noise



International Matrix Tests

Reliable speech audiometry in noise

Speech communication is one of the most important aspects of the human auditory system. In everyday life, conversations usually occur in the presence of background noise. Hearing impaired listeners very often complain especially about problems with understanding speech in noisy situations. Therefore, the diagnostics and rehabilitation of hearing loss should include speech audiometry in noise.

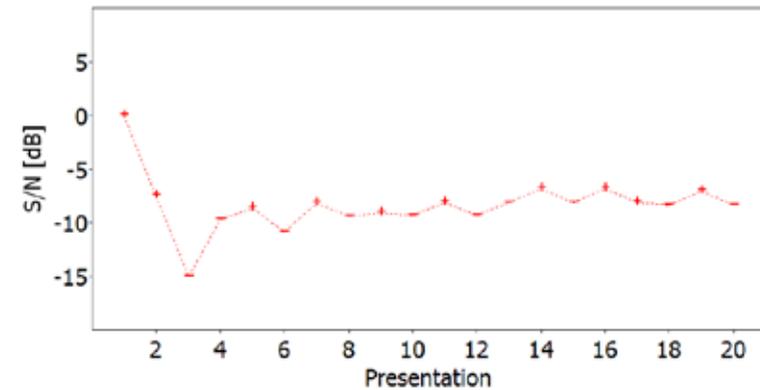
Matrix Tests resemble everyday situations (listening to complete sentences in noise) while being very accurate measurement tools. Therefore Matrix Tests can be used to test the performance of hearing devices in realistic situations and to show differences between various devices. Matrix Sentence Tests are adaptive speech in noise tests for determining the speech reception threshold (SRT) with a precision in the range of ± 1 dB. The sentences of Matrix Tests are composed with the same structure (e.g. in English from the categories: name, verb number, adjective and noun, like “Lucy kept nine green flowers”). Test lists are generated by crea-

ting seemingly random sentences from an inventory (a matrix) of fifty words, i.e. ten words per category. Despite the random composition, every sentence is syntactically correct. This way, up to 100,000 different sentences can be generated which makes it impossible to memorize them. Thus, after a short training, Matrix Tests can be repeatedly conducted with the same patient without affecting the test results.

The audiometrist does not even have to speak the language of the patient: Matrix Tests can be conducted in a closed test format, meaning that the patient sees the matrix of possible words on a computer screen and can select the words that he or she just heard. This means that Matrix Tests can be used anywhere in the world where speech audiometry in the respective language might be necessary. Because of the similar structure of all Matrix Tests, the results of different language versions can easily be compared.

Key Features of International Matrix Tests

- Relevant for daily life
- Quick and reliable threshold measurement
- Unlimited repeated measurements possible
- Suitable for any degree of hearing loss
- Wide language portfolio



Sample measurement trace illustrating the adaptive procedure for determining the speech reception threshold (SRT).

Application of Matrix Test

Matrix Tests are implemented in professional audiology software for use with patients (Oldenburg Measurement Applications, OMA). The software is compatible with several commercially available audiometers. Matrix tests are usually conducted with an adaptive procedure aiming for the 50% threshold of speech intelligibility in noise (the SRT). It is also possible to adapt to other thresholds between 20% and 80% speech intelligibility.

For the adaptive measurements, the noise level is kept constant at a level that is clearly audible to the patient (default is 65 dB). The first sentence is presented with a signal to noise ratio (SNR) of 0 dB. For the following presentations, the speech level is adapted according to the preceding response of the patient. This is done automatically by the software. If the patient correctly repeats three to five of the presented words, the speech level

of the next presentation is reduced. If the patient correctly repeats less than three words, the speech level of the next presentation is increased. The step sizes are variable. The adaptive procedure approaches the SRT which is determined using a maximum likelihood estimator.

The patient usually listens to the sentences presented from the frontal loudspeaker or monaurally via audiometric, free-field equalized headphones. The sentences are presented along with the test-specific noise. In typical cases, the noise is only played back during the presentation of a sentence. If desired, the software also allows for continuous playback of the noise during the whole measurement. This can be of importance in case of measurements with hearing devices in order to ensure that the devices are in their optimal operating mode all the time.

Matrix Tests can be conducted with test lists of 20 or 30 sentences. The duration of a typical 20 item test list is about 4 minutes. For practical clinical applications, test lists of 20 sentences are usually sufficient. However, if a more reliable measurement of the SRT is desired, 30 item test lists can be used. The accuracy in threshold estimation of the 20 item test lists usually is on the order of 1 dB. Due to the training effect of Matrix Tests, a training session with two 20 item test lists is necessary.

The typical procedure that has been described so far is especially useful for diagnostics. If the SRT obtained in one fixed spatial configuration is compared to reference SRT distributions for normal hearing test subjects in the same configuration, the amount of hearing impairment related

to speech intelligibility in noise can be established. Small differences in SRT can mean considerable differences in speech intelligibility. This is due to the steep intelligibility function of Matrix Tests. An SRT difference of just 3 dB can mean a difference in speech intelligibility of up to 40% for normal hearing listeners.

In addition to diagnostics, the Matrix Test can also be used for comparing different situations for the same patient, e.g. aided vs. unaided, pre-op vs. post-op, different hearing devices or different settings of the same hearing device. In these cases the test is usually presented via loudspeaker. As the Matrix Test is a speech in noise test, speech and noise can also be presented from different directions. That way, a wider range of realistic situations can be assessed.

Typical use of Matrix Tests

- Standardized test instruction for each patient (see next page)
- Training with two test lists (first at constant, clearly above threshold SNR; then with adaptive procedure)
- Noise level: 65 dB (or higher if required to be audible)
- Start SNR for adaptive procedure: 0 dB SNR
- Target SRT: 50% speech reception threshold
- Spatial configuration for free field presentation: SoNo (i.e. speech and noise from the same loudspeaker from the front). Other configurations are possible.
- For diagnostics: monaural headphone measurement
- Aided measurements should be performed with continuous noise setting

Suggested test instructions for Matrix Tests

This is a test which assesses your ability to hear speech in noisy situations. For this purpose, you will be presented with a list of twenty sentences with background noise.

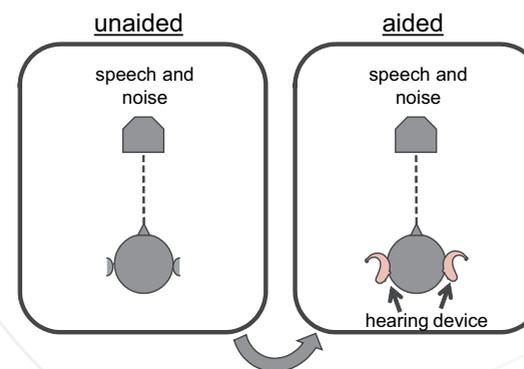
Each sentence consists of five words and always has the same structure: name, verb, numeral, adjective and noun, for example “Peter ordered three large desks”. The sentences are not necessarily meaningful.

Please repeat the sentence after each presentation. Each word counts as a point, so if you cannot get the entire sentence, repeat any word you hear. You may guess if you are uncertain.

There will be some sentences that are easy to understand and others where you might not understand any of the words. That is part of the test so do not get discouraged, just repeat what you can.

If the sentences are too loud at any point, please let me know.

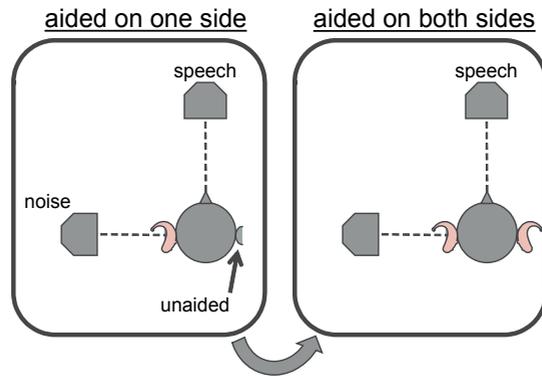
Do you have any questions?



Typical test setup (1) : Benefit of hearing aid provision

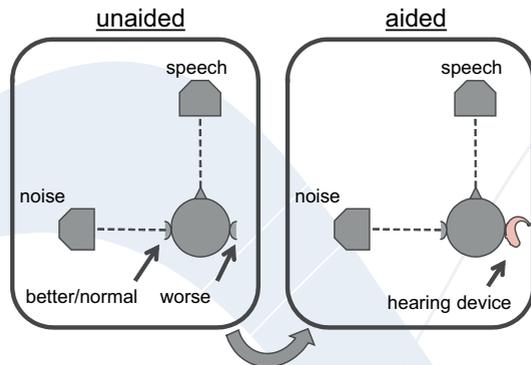
To check the result of hearing device provision in free field using the matrix test (after sufficient training), the speech reception threshold (SRT) measured binaurally with speech simulating noise has to be improved (i.e. reduced) by a significant amount in the same spatial configuration (e.g. SoNo).

The American English Matrix Test



Typical test setup (2): Benefit of a second hearing device

The proof of benefit of a second hearing aid can be done with the matrix test in noise (after sufficient training) by first measuring the speech reception threshold (SRT) with monaural hearing device provision (spatial configuration: speech from front, noise from 90° on the aided side). The benefit of a second hearing device is demonstrated if in the same spatial configuration with binaural hearing device provision an improvement (i.e. reduction) of the SRT by a significant amount is reached.



Typical test setup (3): Benefit of a single hearing device

The proof of benefit of a single hearing aid can be done with the matrix test in noise (after sufficient training) by first measuring the speech reception threshold (SRT) without hearing device provision (spatial configuration: speech from front, noise from 90° on the better side). The benefit of a hearing device is demonstrated if in the same spatial configuration with hearing device provision on the worse ear an improvement (i.e. reduction) of the SRT by a significant amount is reached.

Name	Verb	Number	Adjective	Noun	
Peter	got	three	large	desks	<i>Peter got three large desks.</i>
Kathy	sees	nine	small	chairs	<i>Kathy sees nine small chairs.</i>
Lucy	brought	seven	old	tables	<i>Lucy brought seven old tables.</i>
Alan	gives	eight	dark	toys	<i>Alan gives eight dark toys.</i>
Rachel	sold	four	heavy	spoons	<i>Rachel sold four heavy spoons.</i>
William	prefers	nineteen	green	windows	<i>William prefers nineteen green windows.</i>
Steven	has	two	cheap	sofas	<i>Steven has two cheap sofas.</i>
Thomas	kept	fifteen	pretty	rings	<i>Thomas kept fifteen pretty rings.</i>
Doris	ordered	twelve	red	flowers	<i>Doris ordered twelve red flowers.</i>
Nina	wants	sixty	white	houses	<i>Nina wants sixty white houses.</i>

Properties of the American English Matrix Test

Expected SRT range for normal hearing individuals: -8.6 ± 0.9 dB SNR (mean \pm standard deviation) for adaptive measurements

Slope of psychometric function: 13.3 %/dB

Reference: Zokoll MA, Warzybok A, Carroll R, Kreisman B, Allen P, Wagener KC, Kollmeier B (in preparation). Design, Optimization, and Evaluation of an American English Matrix Sentence Test in Noise.



The Arabic Matrix Test

Adjective	Noun	Number	Name	Verb	
جديدة	كتب	عدة	علي	يريد	Ali wants many new books.
بنية	اطباق	خمسة	نبيل	اشترى	Nabil bought five brown plates.
صغيرة	كراسي	عشرة	زين	يصنع	Zain makes ten small chairs.
كبيرة	كؤوس	أربعة	ناجي	ربح	Naji won four large cups.
خفيفة	قمصان	ستة	عمر	يفضل	Omar prefers six light shirts.
حمراء	خواتم	سبعة	هاشم	لون	Hisham colored seven red rings.
قديمة	بيوت	بضع	وائل	نال	Wael got a few old houses.
ثمينة	سكاكين	تسعة	بلال	ياخذ	Bilal takes nine precious knives.
زرقاء	أعلام	ثمانية	أمين	أخرج	Amin removes eight blue flags.
جميلة	ألواح	ثلاثة	فؤاد	يعطي	Fuad gives three beautiful boards.



Properties of the Arabic Matrix Test

Reference: Buschermöhle M, Zokoll MA, Abdulhaq N, Hochmuth S, Kollmeier B (in preparation). Development of a test procedure for speech audiometry in noise for Modern Standard Arabic: The Arabic Matrix Test

in association with



The Finnish Matrix Test

Name	Verb	Number	Adjective	Noun	
Elina	etsii	pari	halpaa	autoa	Elina searches a pair of cheap cars.
Harri	huomasi	kaksi	kallista	bussia	Harri notices two expensive buses.
Johanna	järjesti	kolme	keltaista	kelloa	Johanna arranged three yellow watches.
Kerttu	lainasi	neljä	pientä	kenkää	Kerttu borrowed four small shoes.
Mikko	näkee	viisi	punaista	kirjaa	Mikko sees five red books.
Juhani	ostaa	kuusi	sinistä	kuppia	Juhani buys six blue cups.
Olga	pyysi	seitsemän	suurta	mattoa	Olga asked seven big carpets.
Petteri	tahtoo	kahdeksan	tuttua	pöytää	Petteri wants eight familiar tables.
Sofia	tarvitsi	yhdeksän	uutta	rengasta	Sofia needed nine new wheels.
Ville	valitsee	kymmenen	vanhaa	sukkaa	Ville chooses ten old socks.

Properties of the Finnish Matrix Test

Expected SRT range for normal hearing individuals: -9.7 ± 0.7 dB SNR (mean \pm standard deviation) for adaptive measurements

Slope of psychometric function: 16.7 %/dB

Speech rate: 226 ± 19 syllables per minute

Reference: Dietz A, Buschermöhle M, Aarnisalo AA, Vanhanen A, Hyryrynen T, Aaltonen O, Löppönen H, Zokoll MA, Kollmeier B (2014). The development and evaluation of the Finnish Matrix Sentence Test for speech intelligibility assessment. Acta Oto-Laryngol.



The French Matrix Test

Name	Verb	Number	Noun	Adjective	
Jean-Luc	ramasse	trois	classeurs	jaunes	<i>Jean-Luc picked up three yellow folders.</i>
Emile	voudrait	deux	livres	rouges	<i>Emile wants two red books.</i>
Agnès	attrape	quinze	crayons	verts	<i>Agnes caught fifteen green pencils.</i>
Julien	dessine	huit	piquets	bruns	<i>Julien draws eight brown posts.</i>
Etienne	demande	douze	vélos	bleus	<i>Etienne wants twelve blue bikes.</i>
Michel	ramène	onze	jetons	mauves	<i>Michel brings eleven purple tokens.</i>
Eugène	reprend	neuf	ballons	roses	<i>Eugene takes nine pink balloons.</i>
Félix	achète	six	anneaux	blancs	<i>Felix buys six white rings.</i>
Charlotte	propose	cinq	rubans	gris	<i>Charlotte offers five gray ribbons.</i>
Sophie	déplace	sept	pions	noirs	<i>Sophie displaces seven black pawns.</i>



Properties of the French Matrix Test

Expected SRT range for normal hearing individuals: -6.0 ± 0.6 dB SNR (mean \pm standard deviation) for measurements at constant level

Slope of psychometric function: 14.0 %/dB

Reference: Jansen S, Luts H, Wagener KC, Kollmeier B, Del Rio M, Dauman R, James C, Fraysse B, Vormès E, Frachet, B, Wouters J, van Wieringen A (2012). Comparison of three types of French speech-in-noise tests: A multi-center study. *Int. J. Audiol.* 51(3) 164-173

The German Matrix Test

Name	Verb	Number	Adjective	Noun	
Peter	bekommt	drei	große	Blumen	<i>Peter gets three big flowers.</i>
Kerstin	sieht	neun	kleine	Tassen	<i>Kerstin sees nine small cups.</i>
Tanja	kauft	sieben	alte	Autos	<i>Tanja buys seven old cars.</i>
Ulrich	gibt	acht	nasse	Bilder	<i>Ulrich gives eight wet pictures.</i>
Britta	schenkt	vier	schwere	Dosen	<i>Britta presents four heavy cans.</i>
Wolfgang	verleiht	fünf	grüne	Sessel	<i>Wolfgang lends five green armchairs.</i>
Stefan	hat	zwei	teure	Messer	<i>Stefan has two expensive knives.</i>
Thomas	gewann	achtzehn	schöne	Schuhe	<i>Thomas won eighteen beautiful shoes.</i>
Doris	nahm	zwölf	rote	Steine	<i>Doris took twelve red stones.</i>
Nina	malte	elf	weiße	Ringe	<i>Nina paints eleven white rings.</i>

Properties of the German Matrix Test

Expected SRT range for normal hearing individuals: -7.1 ± 1.1 dB SNR (mean \pm standard deviation) for measurements at constant level

Slope of psychometric function: 17.1 %/dB

Speech rate: 233 ± 27 syllables per minute

Reference: Wagener KC, Brand T, Kollmeier B (1999). Entwicklung und Evaluation eines Satztests für die deutsche Sprache Teil III: Evaluation des Oldenburger Satztests. *Z. Audiol.* 38(3):86-95



The Italian Matrix Test

Name	Verb	Number	Noun	Adjective	
Andrea	cerca	due	bottiglie	azzurre	<i>Andrea searches two blue bottles.</i>
Anna	compra	quattro	macchine	belle	<i>Anna buys four beautiful cars.</i>
Chiara	dipinge	cinque	matite	bianche	<i>Chiara paints five white pencils.</i>
Luca	manda	sette	palle	grandi	<i>Luca sends seven big balls.</i>
Marco	possiede	otto	pietre	nere	<i>Marco has eight black stones.</i>
Maria	prende	nove	porte	normali	<i>Maria takes nine normal doors.</i>
Matteo	regala	dieci	scatole	nuove	<i>Matteo gives ten new boxes.</i>
Sara	trascina	venti	sedie	piccole	<i>Sara pulls twenty small chairs.</i>
Simone	vede	poche	tavole	rosse	<i>Simon sees a few red tables.</i>
Sofia	vuole	molte	tazze	utili	<i>Sofia wants many useful cups.</i>



Properties of the Italian Matrix Test

Expected SRT range for normal hearing individuals: -6.7 ± 0.7 dB SNR (mean \pm standard deviation) for adaptive measurements

Slope of psychometric function: 14.3 %/dB

Reference: Hochmuth S, Zokoll MA, Carroll R, Kollmeier B (2013). Matrix Sentence Tests in Noise for the Italian language. Abstracts of the 11th EFAS Congress Budapest

The Polish Matrix Test

Name	Verb	Number	Adjective	Noun	
Tomasz	nosi	pięć	dobrych	piłek	<i>Thomas carries five good balls.</i>
Paweł	woli	sześć	tanich	gazet	<i>Paul prefers six cheap papers.</i>
Adam	widzi	siedem	drogich	soków	<i>Adam sees seven expensive juices.</i>
Maciej	bierze	osiem	pięknych	dzwonów	<i>Matthew takes eight beautiful bells.</i>
Michał	daje	dziewięć	nowych	opon	<i>Michael gives nine new tyres.</i>
Anna	ma	dużo	starych	stołów	<i>Anne has a lot of old tables.</i>
Ewa	robi	sto	białych	klocków	<i>Eve makes hundred white bricks.</i>
Maria	kupi	tysiąc	żółtych	toreb	<i>Mary will buy thousand yellow bags.</i>
Zofia	wygra	wiele	czarnych	okien	<i>Sophie will win many black windows.</i>
Julia	sprzeda	kilka	dziwnych	koszy	<i>Julia will sell several strange boxes.</i>



Properties of the Polish Matrix Test

Expected SRT range for normal hearing individuals: -8.0 ± 1.3 dB SNR (mean \pm standard deviation) for adaptive measurements

Slope of psychometric function: 21.8 %/dB

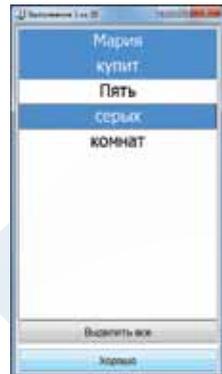
Reference: Ozimek E, Warzybok A, Kutzner D (2010). Polish sentence matrix test for speech intelligibility measurement in noise, Int. J. Audiol. 49:444-454

Note:

The adaptive procedure of the Polish Matrix Test employs sentence scoring.

The Russian Matrix Test

Name	Verb	Number	Adjective	Noun	
Саша	ищет	Пять	больших	фильмов	<i>Sascha searches five big films.</i>
Павел	хочет	девять	главных	улиц	<i>Paul wants nine important streets.</i>
Пётр	видит	десять	старых	книг	<i>Peter sees ten old books..</i>
Коля	даёт	мало	нужных	шаров	<i>Kolya gives some necessary balls.</i>
Иван	делает	много	чужих	газет	<i>Ivan makes many foreign newspapers.</i>
Юрий	любит	семь	целых	рядов	<i>Yurij likes seven whole rows.</i>
Анна	найдёт	сто	разных	комнат	<i>Anna will find hundred different rooms.</i>
Лена	помнит	восемь	серых	часов	<i>Lena will remember eight gray clocks.</i>
Яна	берёт	шесть	лучших	залов	<i>Jana takes six better halls.</i>
Мария	купит	двести	красных	марок	<i>Maria will buy two hundred red stamps.</i>



Properties of the Russian Matrix Test

Expected SRT range for normal hearing individuals: -8.8 ± 0.8 dB SNR (mean \pm standard deviation) for adaptive measurements

Slope of psychometric function: 14.0 %/dB

Reference: Boboshko M, Warzybok A, Zokoll MA, Maltseva N (2013) RUMatrix test: construction, evaluation and clinical validation. *Otorhinolaryngologia Hungarica*. Vol. 59, N 2.-P. 49 (Abstracts of the 11th EFAS Congress Budapest).

The Spanish Matrix Test

Name	Verb	Number	Noun	Adjective	
Claudia	tiene	dos	libros	grandes	<i>Claudia has two big books.</i>
Carmen	hace	tres	barcos	viejos	<i>Carmen makes three old ships.</i>
Elena	toma	doce	platos	nuevos	<i>Elena takes twelve new plates.</i>
Teresa	busca	siete	regalos	pequeños	<i>Teresa searches seven small gifts.</i>
Josefa	quiere	seis	guantes	enormes	<i>Josefa wants six huge gloves.</i>
José	compra	diez	zapatos	azules	<i>José buys ten blue shoes.</i>
Antonio	pinta	cuatro	juegos	bellos	<i>Antonio draws four beautiful games.</i>
Carlos	mira	veinte	dados	lindos	<i>Carlos sees twenty nice dice.</i>
Pedro	pierde	ocho	sillones	baratos	<i>Pedro loses eight cheap armchairs.</i>
Manuel	vende	mil	anillos	negros	<i>Manuel sells thousand black rings.</i>

Properties of the Spanish Matrix Test

Expected SRT range for normal hearing individuals: -6.2 ± 0.8 dB SNR (mean \pm standard deviation) for adaptive measurements

Slope of psychometric function: 13.1 %/dB

Reference: Hochmuth S, Brand T, Zokoll MA, Zenker Castro F, Wardenga N, Kollmeier B (2012). A Spanish matrix sentence test for assessing speech reception thresholds in noise. *Int. J. Audiol.* 51(7) 536-544



The Turkish Matrix Test

Name	Number	Adjective	Noun	Verb	
Gönül	yedi	mavi	sepet	haketti	<i>Gönül earns seven blue baskets.</i>
Zuhal	bir	yeni	kilim	verdi	<i>Zuhal gives one new carpet.</i>
Fırat	sekiz	beyaz	yatak	satmış	<i>Fırat sells eight white beds.</i>
Hikmet	üç	küçük	çatal	getirdi	<i>Hikmet brings three small forks.</i>
Tuncay	altı	yeşil	cımbız	bulmuş	<i>Tuncay finds six green tweezers.</i>
Nurşen	beş	temiz	gömlek	çizdi	<i>Nurşen draws five clean shirts.</i>
Poyraz	dokuz	renkli	balon	fırlatmış	<i>Poyraz throws nine colorful balloons.</i>
Seyhan	on	bordo	minder	gördü	<i>Seyhan sees ten brown cushions.</i>
Meltem	iki	güzel	terlik	kazanmış	<i>Meltem wins two beautiful slippers.</i>
Dilek	dört	siyah	fincan	yolladı	<i>Dilek sends four black cups.</i>



Properties of the Turkish Matrix Test

Expected SRT range for normal hearing individuals: -7.2 ± 0.8 dB SNR (mean \pm standard deviation) for adaptive measurements

Slope of psychometric function: 14.7 %/dB

Reference: Zokoll MA, Hochmuth S, Fidan D, Wagener KC, Ergenç, Kollmeier B (2012). Speech intelligibility tests for the Turkish language. In: Proceedings of the 15th annual meeting of the German Audiological Society (DGA). ISBN 978-3-9813141-2-0

International Matrix Tests

Available as Medical Device



In Development



Oldenburg Measurement Applications

Trendsetting methods in audiology must be implemented with computer technology if meaningful results and time-saving procedures are desired. The “Oldenburg Measurement Applications“ (OMA) software was developed with the aim to offer audiologists an instrument with which they can conveniently conduct new methods in hearing diagnostics using a flexible and modular system, no matter if their workplace is a clinic, a research facility or in the hearing acoustics branch. The offer ranges from classical speech tests to loudness scaling and modern speech audiometry methods implemented in quiet or noise. In cooperation with the University of Oldenburg and the Hörzentrum Oldenburg, the Center of Competence HörTech

guarantees competent implementation as well as continuous development of these methods on the basis of current research findings. The medical device version of OMA is available for a number of professional speech audiometers.

The Oldenburg Measurement Applications were introduced in 2007 as (optional) part of particular audiometry systems (and thus part of a medical device). In March 2010, the „Oldenburg Measurement Applications“ even became an own medical device (due to changes in the directive 92/43/EEC for medical devices).



The following modules are available:

- Adaptive Categorical Loudness Scaling (ACALOS/KLS)
- Oldenburg Sentence Test (OLSA)
- Göttingen Sentence Test (GÖSA)
- Oldenburg Children Rhyme Test (OLKI)
- Rhyme Test according to von Wallenberg & Kollmeier (WAKO)
- Oldenburg Sentence Test for Children (OLKISA)
- International Matrix Tests in various languages as listed on page 17



The Center of Competence HörTech, a non-profit organization located in Northern Germany and owned in part by the University of Oldenburg and led by Prof. Dr. Dr. Birger Kollmeier as scientific director, has a long standing expertise in the field of developing speech audiometric test procedures in various languages. More than twenty speech tests have been developed here, and many of them are in widespread use all over the world.

The aims of this non-profit organisation are to support science and research and to develop new methods and expertise concerning hearing. The institute has its origins in a national contest of the German Federal Ministry of Education and Research. Since then, it has come to enjoy international appreciation. Its efforts in basic research, which are widely renowned, have contributed to improvements in hearing aid technology. HörTech is based in the „House of Hearing“ in Oldenburg.

HörTech gGmbH

Dr. Michael Buschermöhle
Marie-Curie-Straße 2
D-26129 Oldenburg

Phone: +49 441 21 72-210

Fax: +49 441 21 72-250

E-Mail: m.buschermoehle@hoertech.de



HörTech

Kompetenzzentrum für
Hörgeräte-Systemtechnik