GLOBAL PEDIATRIC HEARING HEALTH

IN SEARCH OF NOVEL SOLUTIONS TO CURRENT CHALLENGES

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OUTLINE

- **Global Childhood Hearing Health – Challenges**
  - *Prevalence*
  - *Access to care*
- **Exploring Novel Solutions**
  - *Remote diagnosis of ear disease in primary health care*
  - *Mobile hearing screening solution*

PREVALENCE OF CHILDHOOD HL

- Disabling HL *(>40dB for adults >30dB for children in better ear)* prevalence:
  - *120 mil in 1995*
  - *278 mil in 2005*
  - *360 mil in 2013**

      ** 5.3% of world population*

- **32** million of which are children
- Mild and greater – **160** million children

(WHO, 2006; WHO, 2013; Olusanya & Newton, 2007)

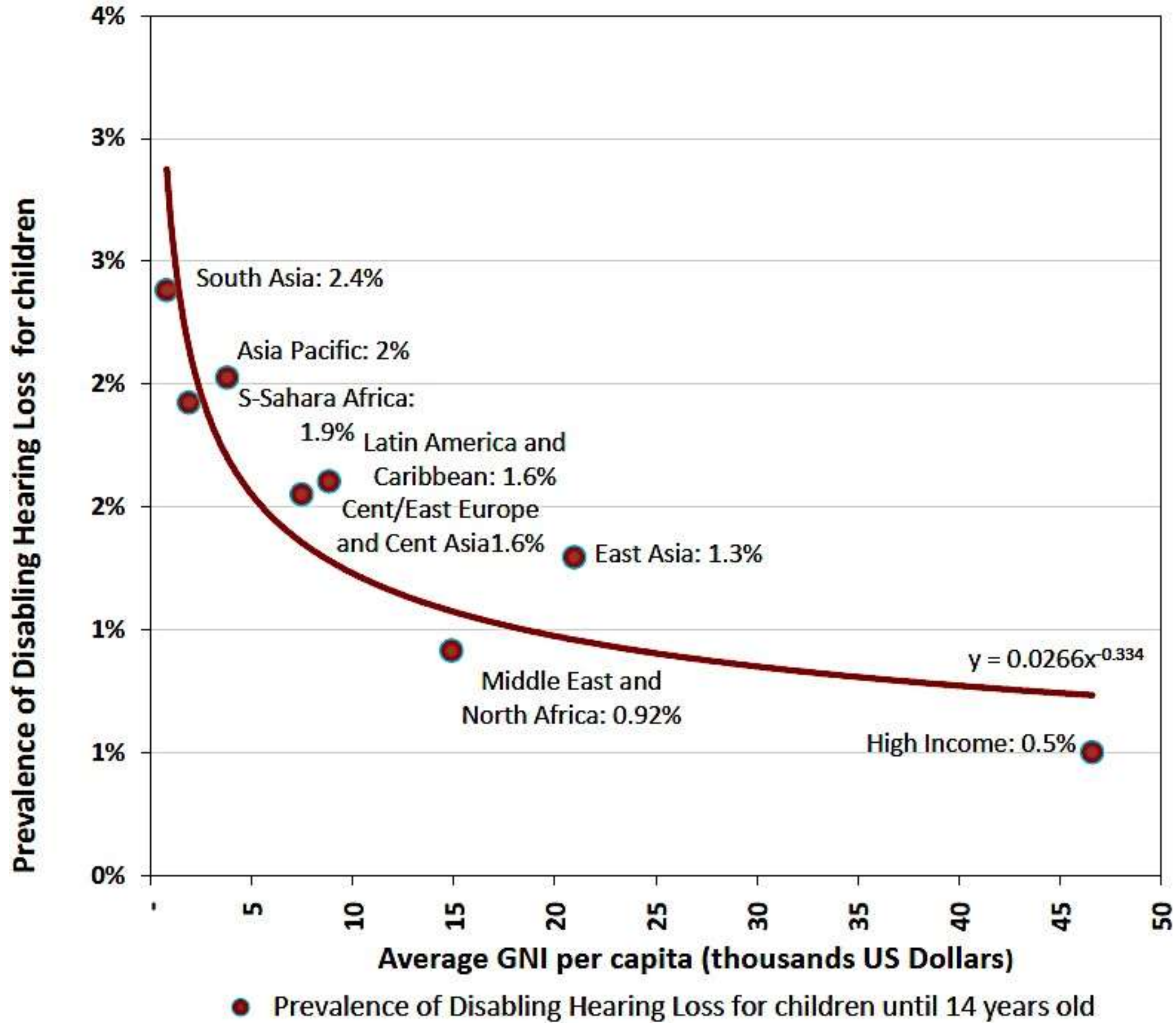
PREVALENCE OF CHILDHOOD HL

Regions	DHL in children (<15 yoa)	
	Millions	Prevalence %
High-income	0.8	0.5
Sub-Saharan Africa	6.8	1.9
Middle East & North Africa	1.2	0.9
South Asia	12.3	2.4
Asia Pacific	3.4	2.0
Latin America & Carribbean	2.6	1.6
East Asia	3.6	1.3
World	**31.9**	**1.7**

(WHO, 2013)

PREVALENCE OF CHILDHOOD HL

Prevalence decreases exponentially as GNI increases



(WHO, 2013)

PREVALENCE OF CHILDHOOD HL

- **120 million** annual births in developing world
- **798 000** - permanent bilateral HL (**25%** from SSA)
    - *Higher prevalence of **ANSD** – (**10.3** to **21.4%** of permanent HL's)*
- **53 150** - permanent bilateral HL in all developed countries (**Ratio 1:14**)

(Swanepoel, Johl & Pienaar, 2013; UNICEF, 2008; Olusanya & Newton, 2007; Olusanya et al. 2008; Smith et al. 2005)

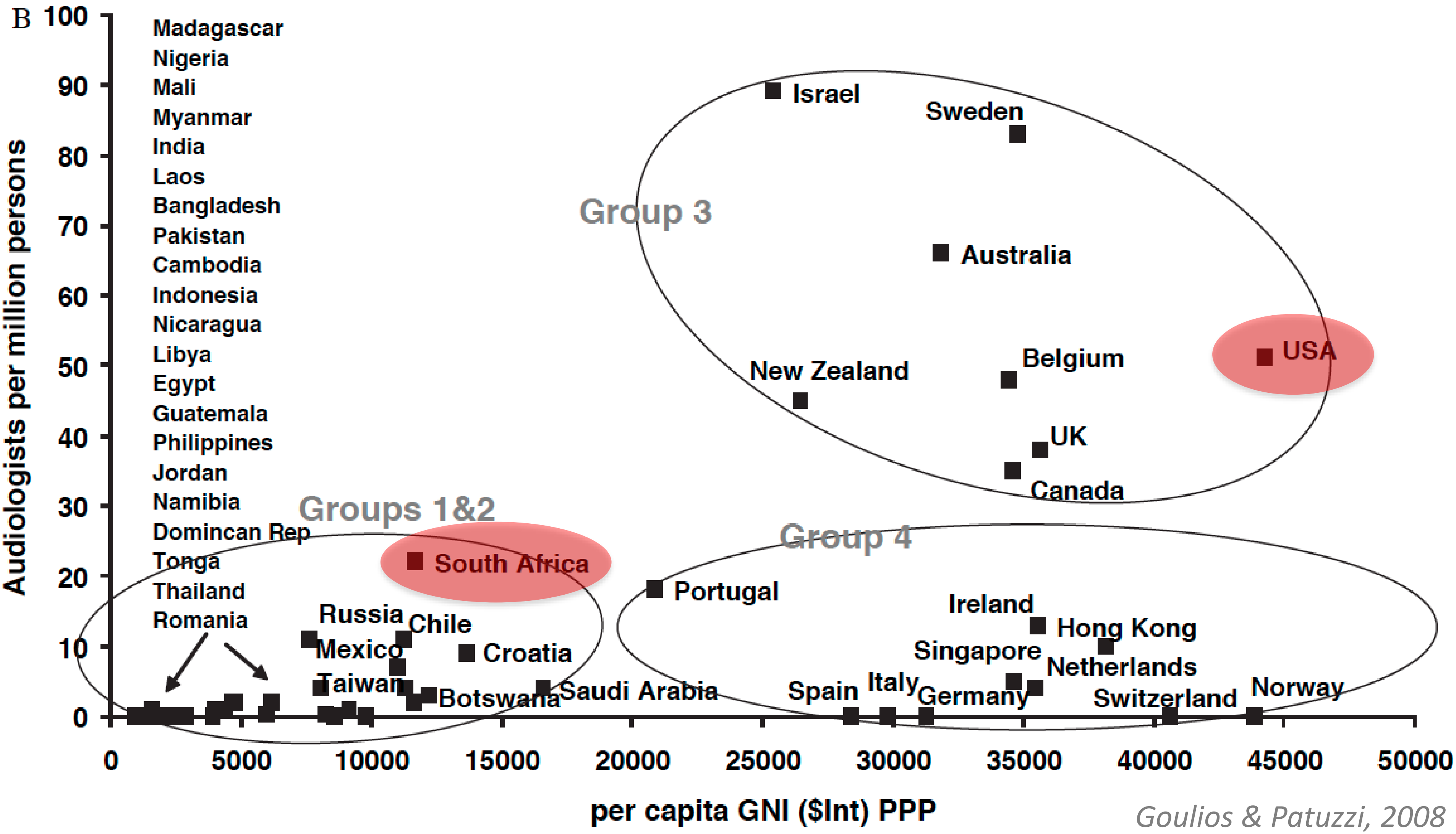
PREVALENCE OF CHILDHOOD HL

Global Situation

- Everyday **1 753** born with significant permanent SNHL:
  - **1 643** born in developing world (5/1000)
  - **110** born in developed countries (3/1000)
- **>90%** born in developing world

(UNICEF, 2008; Olusanya & Newton, 2007; Olusanya et al. 2008; Smith et al. 2005)

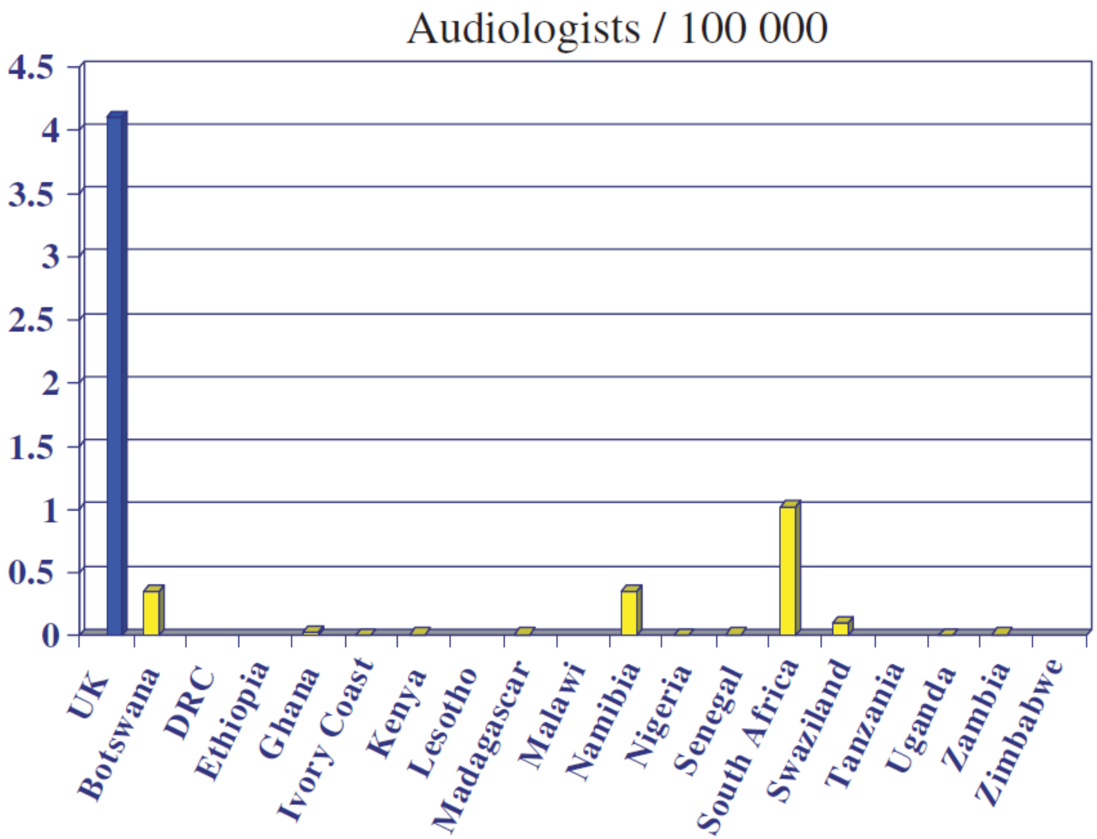
HEARING HEALTH CARE ACCESS



Goulios & Patuzzi, 2008

HEARING HEALTH CARE ACCESS

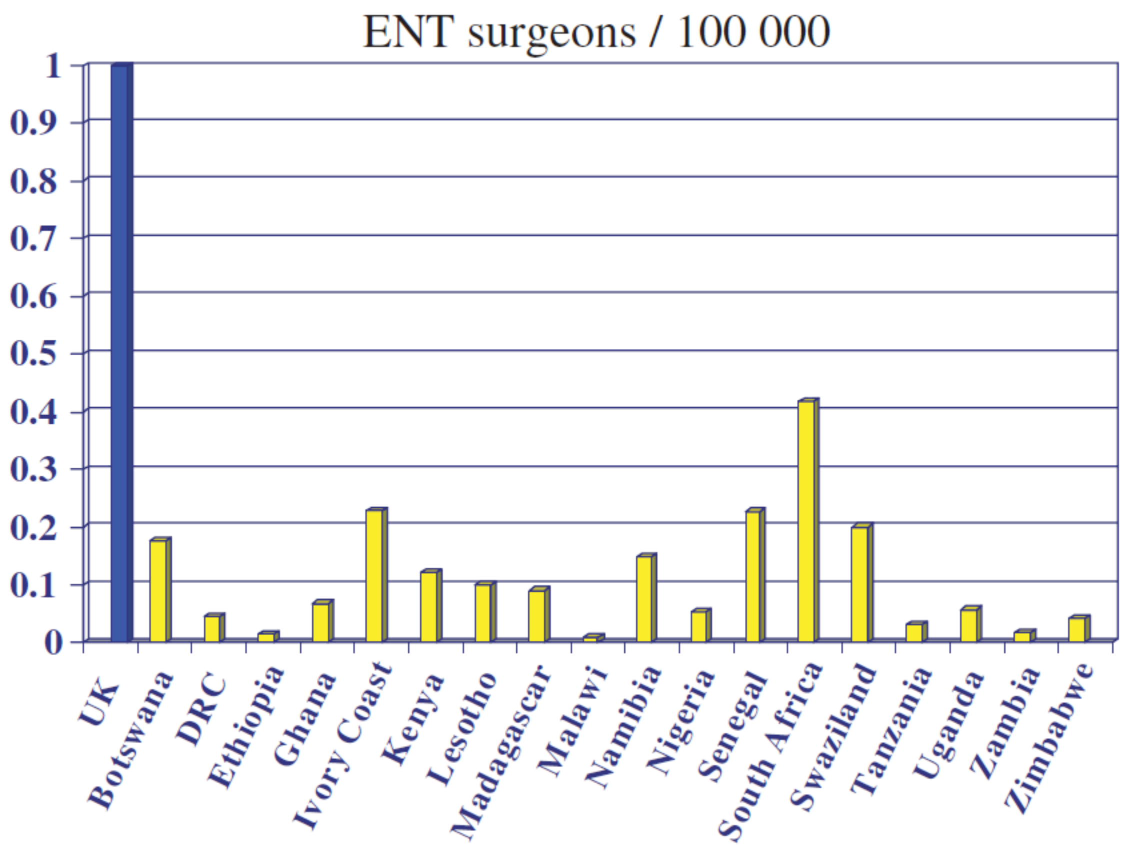
Survey of hearing health care services in SSA (Fagan & Jacobs, 2009)**:**



Fagan & Jacobs, 2009

HEARING HEALTH CARE ACCESS

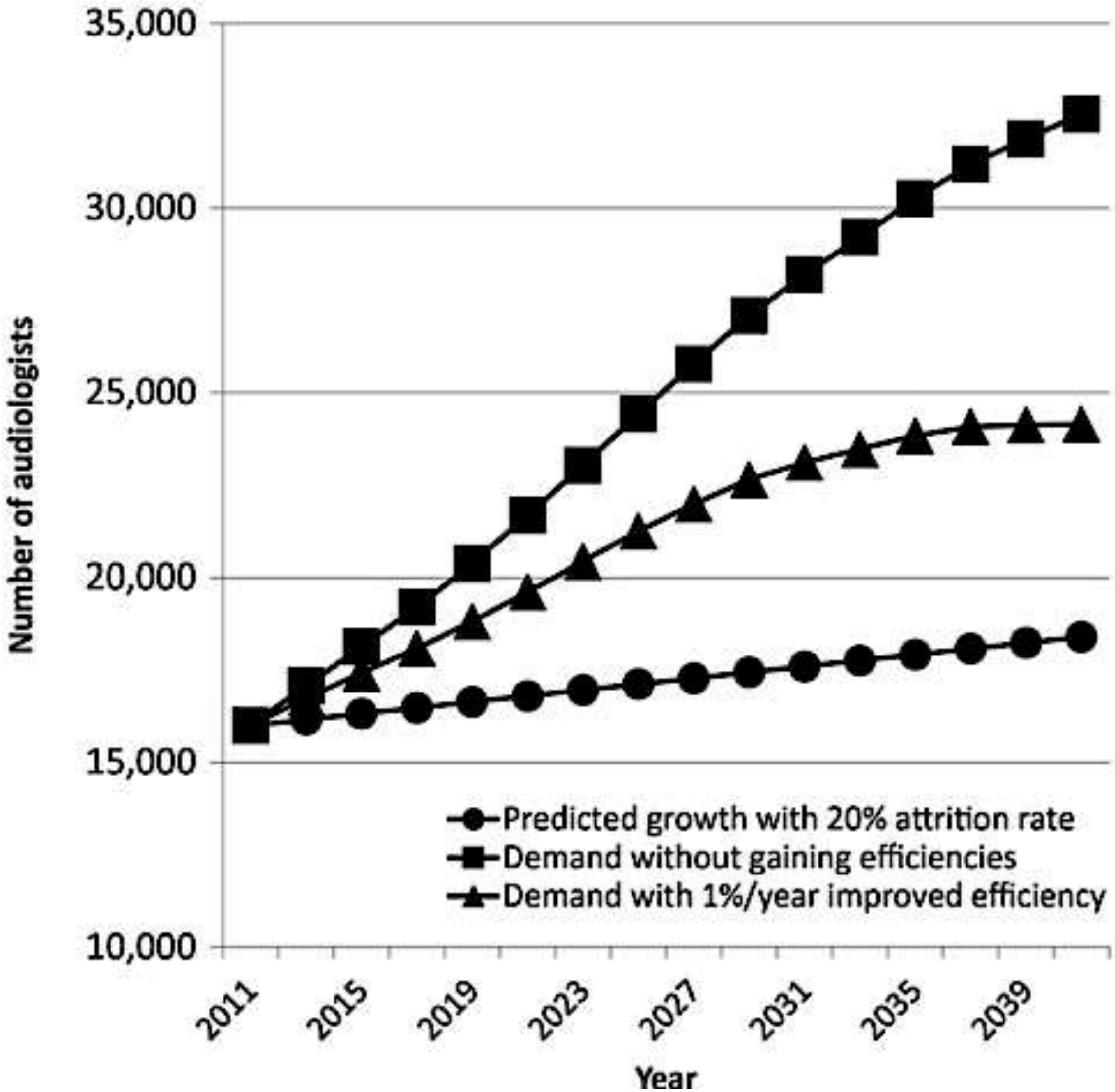
ENT distribution across SSA countries:



1: 250 000 – 7.1 mil

Goulios & Patuzzi, 2008, Fagan & Jacobs, 2009

HEARING HEALTH CARE ACCESS



Projected demand for audiology services over next 30 years (US)

Windmill & Freeman, 2013

HEARING HEALTH CARE ACCESS

Status of NHS screening globally

- At least **7** countries screen **>90%** of births
  - *Austria, Netherlands, Oman, Poland, Slovakia, UK, USA*
- At least **9** countries screen **30 – 89%** of births
  - *Australia, Belgium, Canada, Germany, Ireland, Philippines, Russia, Singapore, Taiwan*
- At least **46** countries evidence programs (pilot, limited)

(White, 2010; Olusanya, Swanepoel et al. 2007)

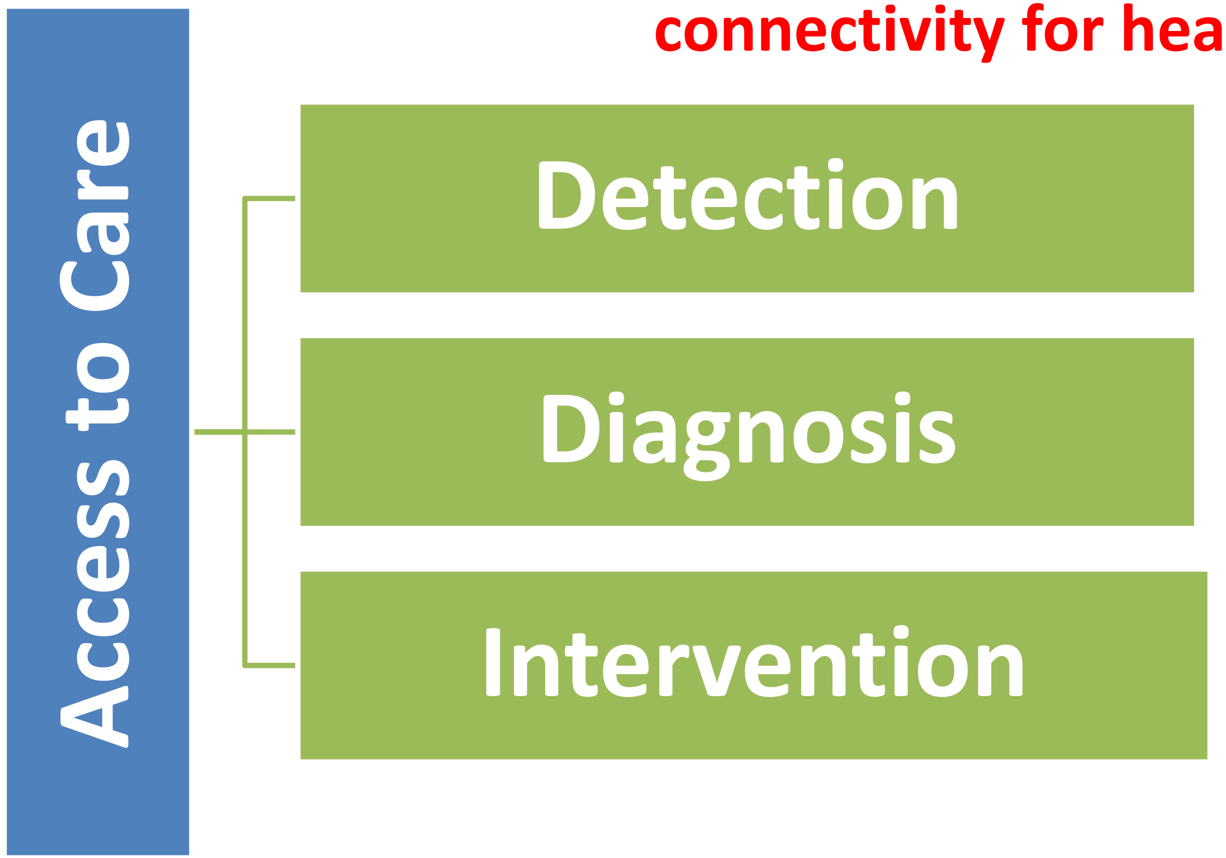
HEARING HEALTH CARE ACCESS

- Good coverage in some developed **countries**
- **Pilot programs** starting in many developing countries
- **BUT:** Globally **>90%** of babies born with HL have **no prospect** of early detection
- Detection primarily passive:
  - *Complications of OM*
  - *Speech & language delays*
  - *Unusual behavior*

- Exacerbate impact of HL - consigns to **seclusion, limited access** & **quality of life**

EXPLORING NOVEL SOLUTIONS

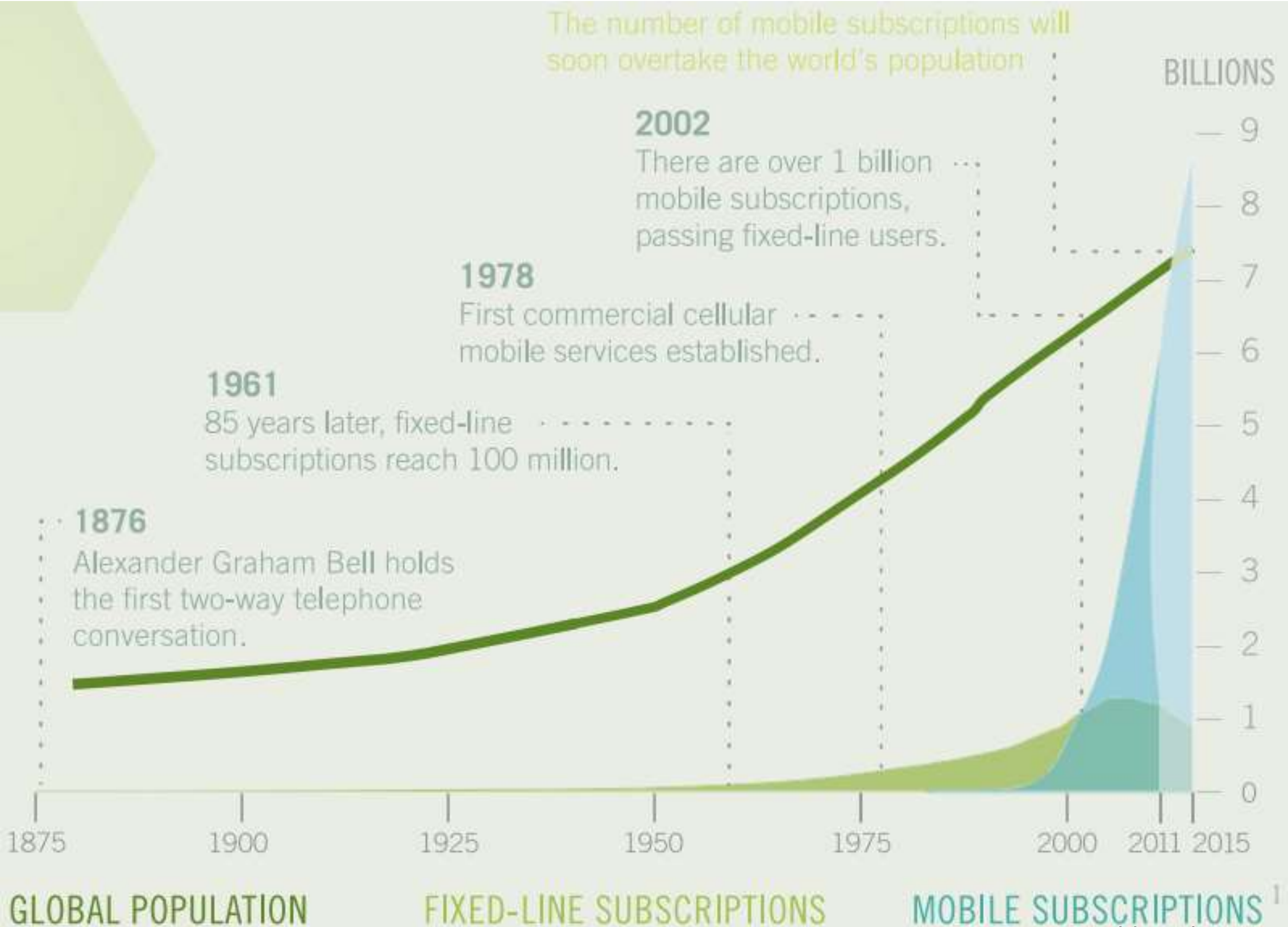
2. Mobile phone technology and connectivity for hearing screening



1. Remote ear diagnosis

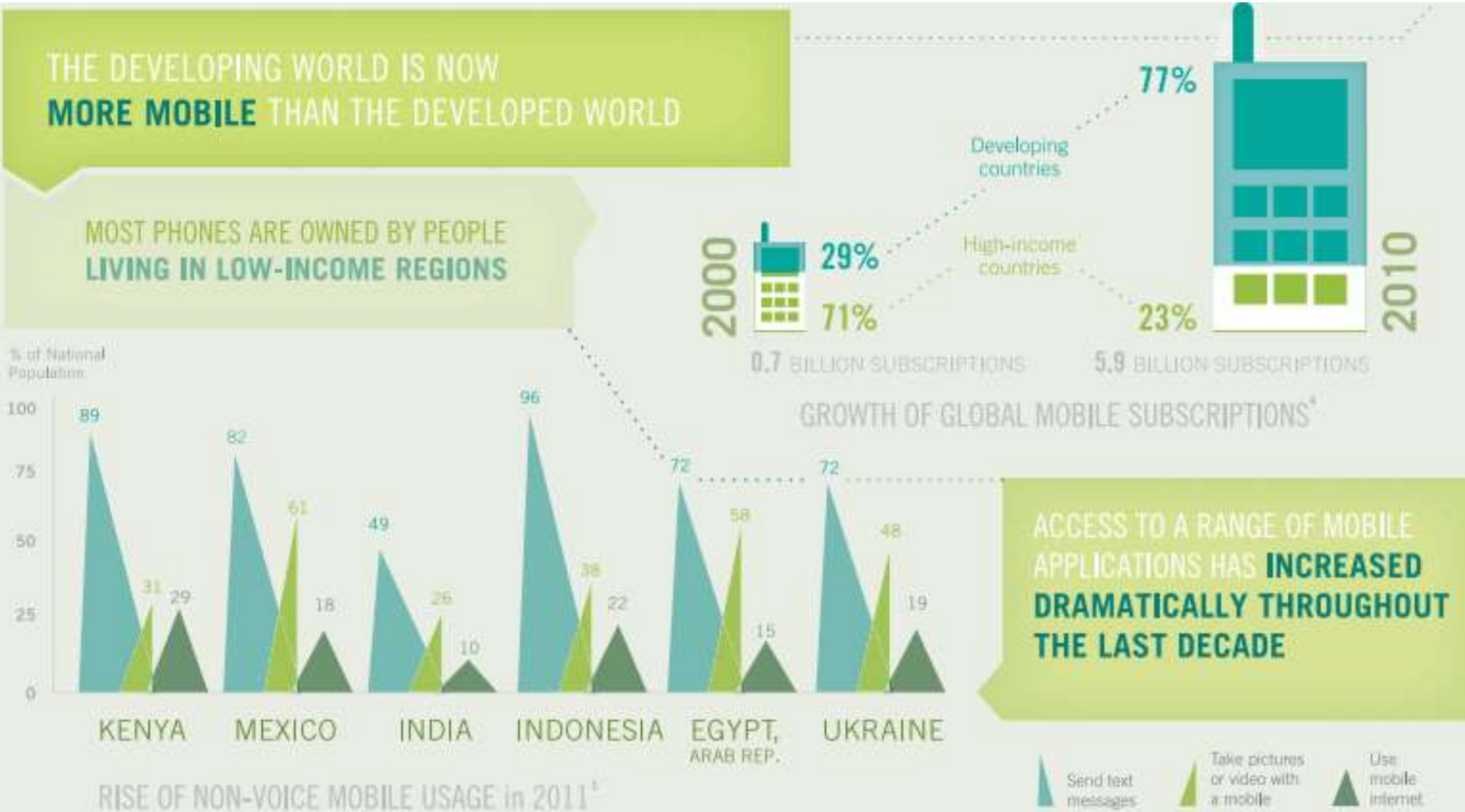
MOBILE REVOLUTION

CONNECTIVITY



World Bank, 2012

World Bank, 2012



World Bank, 2012

REMOTE DIAGNOSIS OF EAR DISEASE

Background

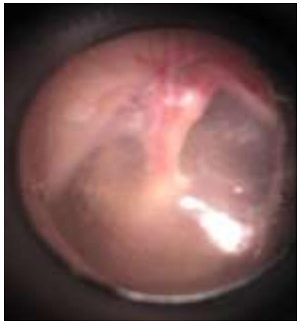
- Global burden from **chronic OM** affect **65 – 330 million**
- **Prevalence** of **COM** can be as high as **46%**
- **India** & **sub-Saharan Africa** account for most deaths from **OM**
- **COM** – 1) **risk** of **hearing loss** and 2) **life-threatening** complications (e.g. meningitis, brain abscesses)
- Largely **preventable** and **effective** medical management
- **Early detection** and treatment at primary health care can **reduce long-term morbidity** and **mortality**

BUT - **Poor access** to specialist personnel **limit diagnosis** and appropriate **treatment**

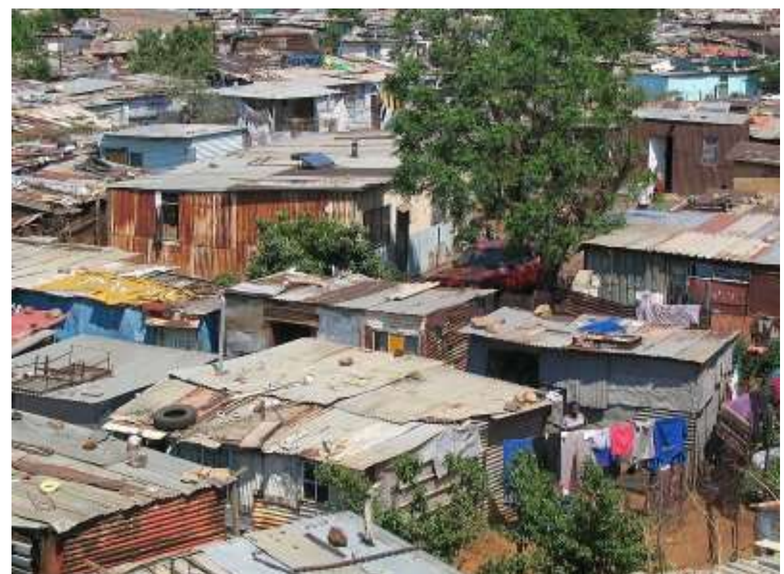
(WHO, 2013; Acuin, 2004)

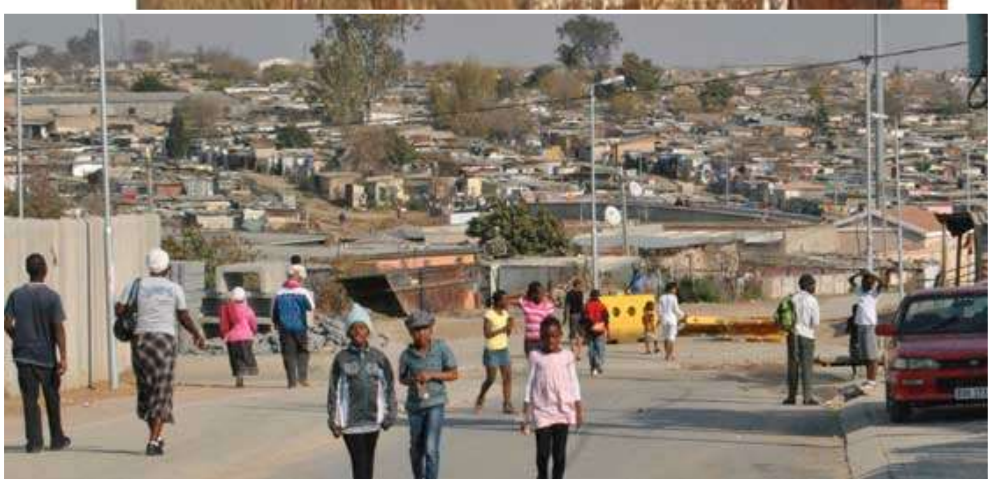
REMOTE DIAGNOSIS OF EAR DISEASE

- **Aim:** To evaluate the **effectiveness** and **accuracy** of **video-otoscopy** recordings by a trained **non-professional** for remote **diagnosis** of **ear disease** in children
- **Design:** Within-subject comparative design
- **Subjects:** **140** unselected children (**2 – 15** yoa; mean 6.4 $\pm$3.5 yoa; 44.3% female) attending a PHC
- **Context:**



REMOTE DIAGNOSIS OF EAR DISEASE





REMOTE DIAGNOSIS OF EAR DISEASE

REMOTE DIAGNOSIS OF EAR DISEASE

Equipment and procedures:

Dropbox

REMOTE DIAGNOSIS OF EAR DISEASE

Concordance of otomicroscopy and remote video-otoscopy

	Onsite diagnosis n = 272 ears	Remote diagnosis n = 269 ears	
	Otologist (%)	Otologist (%)	
		Review 1	Review 2
Normal	75.8	58.4	62.1
Otitis media:	16.5	16.7	14.5
AOM	*0.7*	*0.0*	*0.7*
CSOM	*4.8*	*6.7*	*6.3*
SOM	*11.0*	*10.0*	*7.5*
Undetermined	7.7	24.9	23.4

R1 Kappa = 0.702

R2 Kappa = 0.740

Substantial agreement

Sens / Spec = 78% / 95%

Intra-rater diagnosis Kappa – 0.773

REMOTE DIAGNOSIS OF EAR DISEASE

CONCLUSIONS

- A non-professional, with no health care training, can **be trained to acquire** adequate video otoscopic recordings for remote otologic diagnosis
- Remote diagnosis accuracy is similar to inter- and intra-rater agreement previously reported
- Accompanied **with audiometric data** it can be a valuable **diagnostic tool** to underserved populations
- **Video recordings** improved diagnostic utility above images
- More experience may improve quality of recordings

MOBILE HEARING SCREENING SOLUTION

School-based screening

First opportunity for screening in sub-Saharan Africa

Screen for **barriers to learning** – educationally significant HL

South Africa - 2012 policy requiring screening of **1.2 mil children** entering school annually

Integrated School Health Policy

Health
Basic Education

CHALLENGES WITH SCREENING?

1. Expense; 2. Training; 3. Time; 4. Noise; 5. Electricity; 6. Data capturing; 7. Data surveillance

MOBILE HEARING SCREENING SOLUTION

- **Aim:** To determine if an Android-based **smartphone** can be used as a **calibrated screening audiometer** with real-time **noise monitoring** for school-based screening using **semi-automated** test sequences
- **Design:** 3 phase study
  1. **Calibration accuracy** of pure tones across smartphones using commercial headphones
  2. Accuracy of smartphone **microphone calibration** for noise monitoring
  3. **Screening outcomes** of smartphone based semi-automated compared to conventional hearing screening

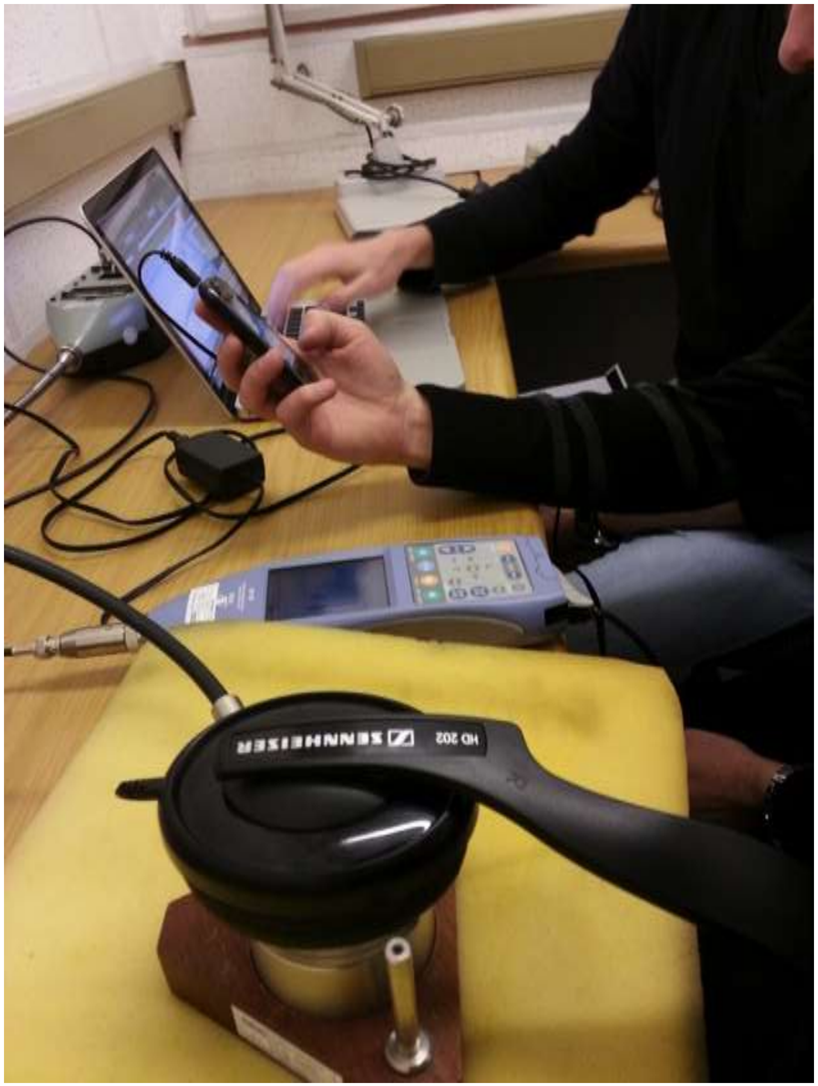
MOBILE HEARING SCREENING SOLUTION

Android application developed:

- **Transforming** smartphone to screening device using commercial headsets
- **Calibration functionality** for pure tone signals
- **Pre-programmed** screening protocols & **automated** test sequences
- **Microphone** SLM **calibration functionality** to monitor environment
- **Data capturing** and **sharing** features integrated

MOBILE HEARING SCREENING SOLUTION

PHASE 1 – PURE TONE CALIBRATION



Evaluate calibration of four Samsung S5301 **smartphones** (Android v4.0.4)

Commercial **Sennheiser** (HD202) headsets

Standard artificial ear B&K Type 4152 coupler

Rion NA-28, Intergrating Sound Level Meter and 1/3 Octave Band Analyser

PHASE 1 – PURE TONE CALIBRATION

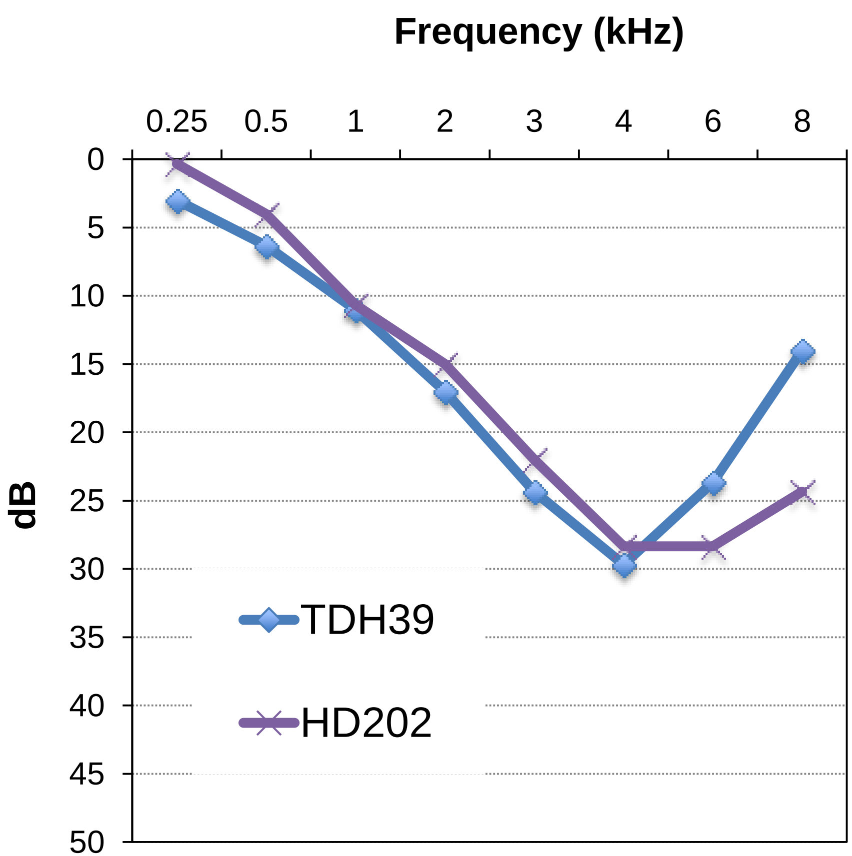
Pure tone calibration difference from specified standards across 4 phones and headsets (ANSI 3.6)

	Calibration levels								
	20 dB HL			30 dB HL			40 dB HL		
	1 kHz	2 kHz	4 kHz	1 kHz	2 kHz	4 kHz	1 kHz	2 kHz	4 kHz
Average Difference	0.9	0.5	-0.6	-0.7	-0.7	-0.4	-0.5	-0.6	-0.1
SD	0.1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.3
Max diff (abs)	1.0	0.8	0.8	1	0.9	0.7	0.8	0.8	0.4

≤ 1 dB

calibration error

PHASE 2 – NOISE MONITORING



Phase 2a: **Attenuation** of **headphones** to assess MPANL's

15 normal hearing subjects

Free-field thresholds testing with and without transducers

PHASE 2 – NOISE MONITORING

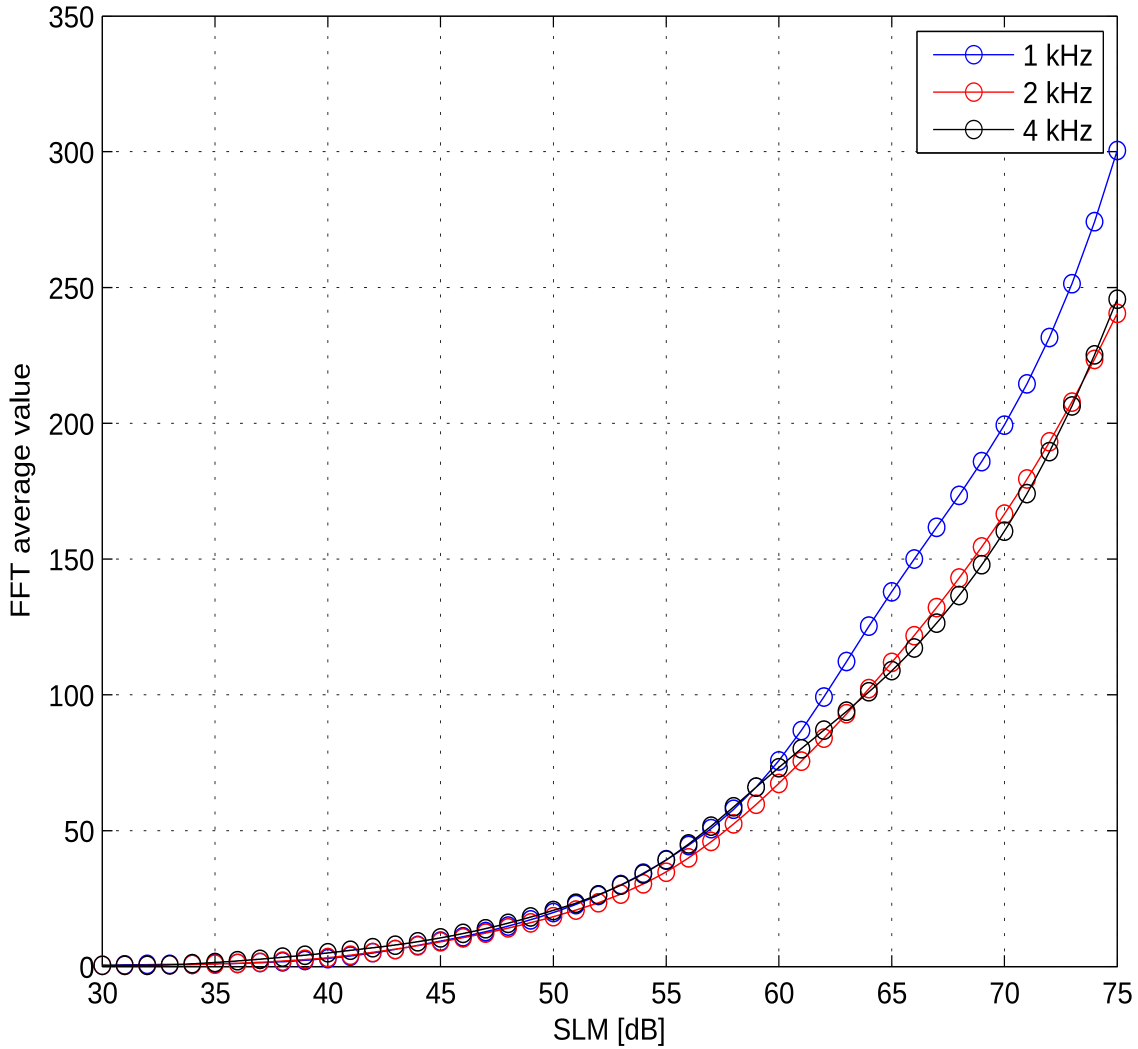
Phase 2b: **5 microphones** to determine **reference levels** corresponding to Type 1 SLM

NBN intensity presented from **30 to 70 dB SPL** in 5 dB increments (**0° azimuth,** 1m from speaker, 87.5cm above floor).

Corresponding **smartphone amplitude** readings recorded.

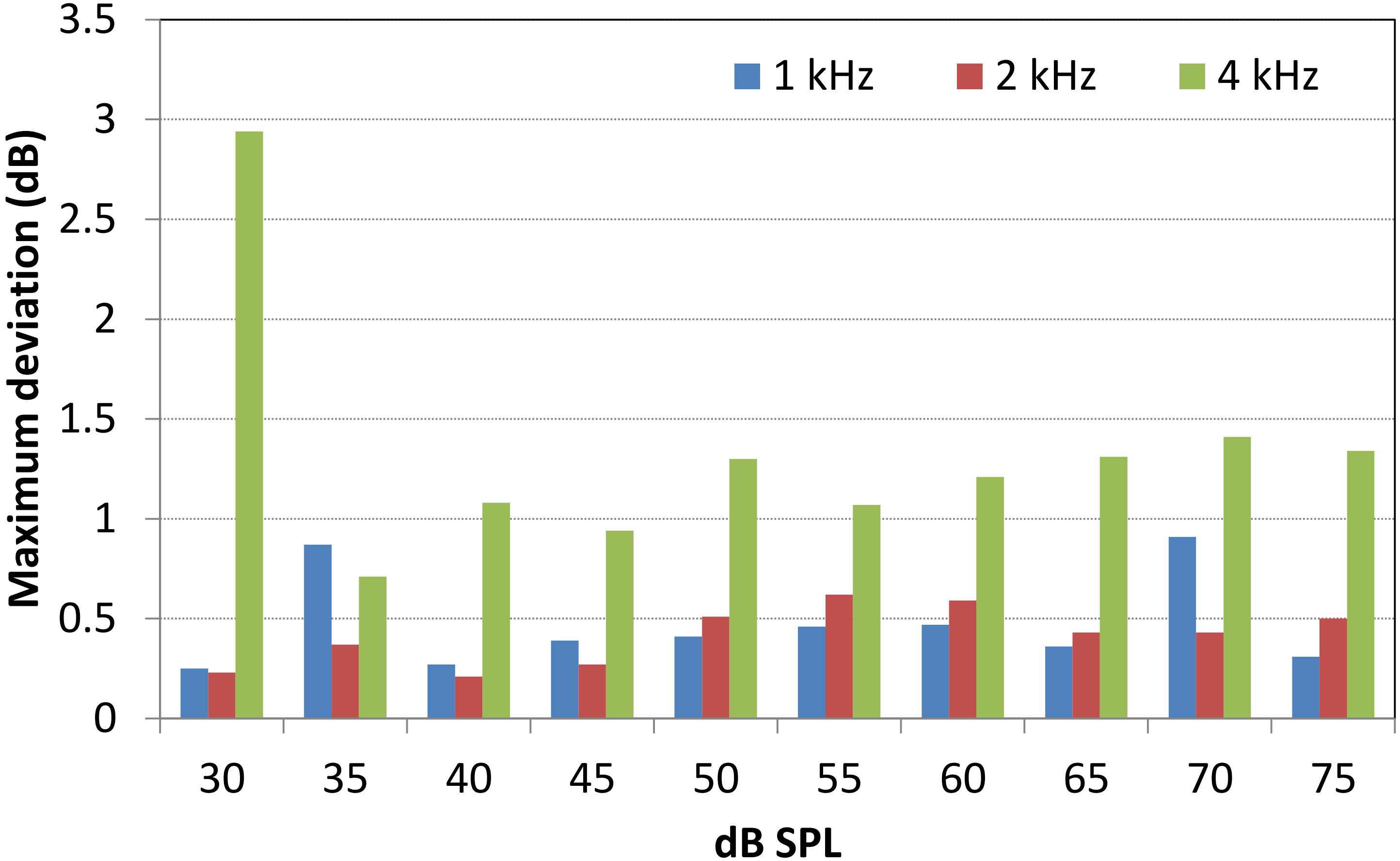
Average calibration map determined and **variability** between microphones investigated.

PHASE 2 – NOISE MONITORING

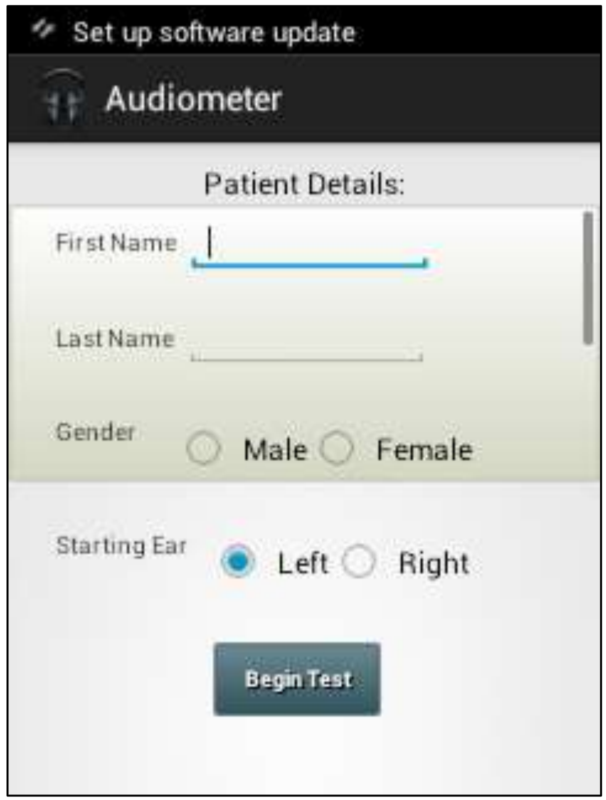


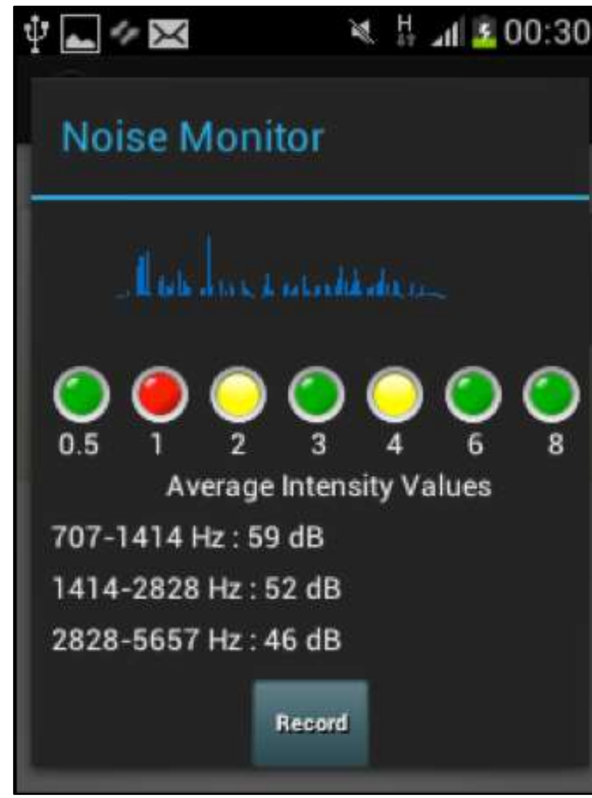
PHASE 2 – NOISE MONITORING

Maximum deviation across **5 smartphone microphones** compared to reference sound intensity



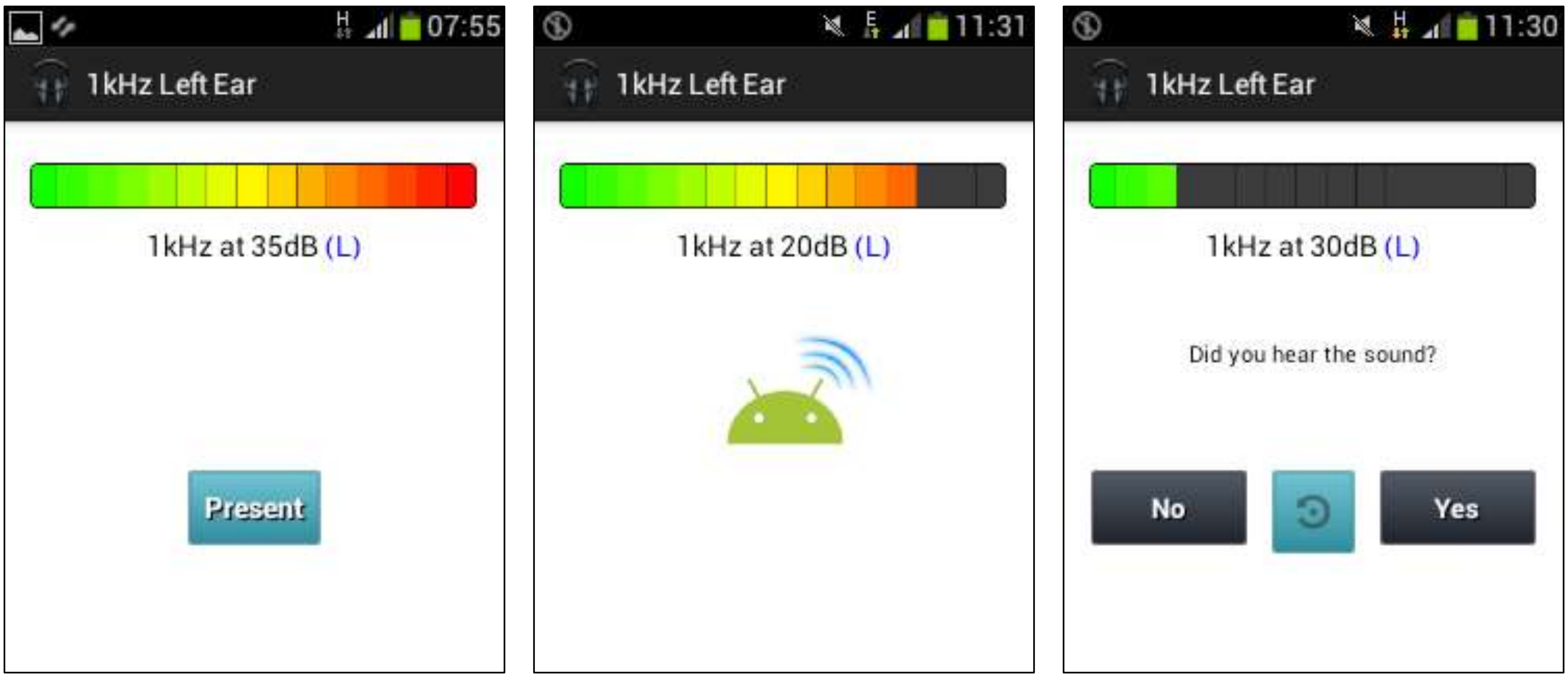
DEVICE FEATURES





University of Pretoria Patent

DEVICE FEATURES



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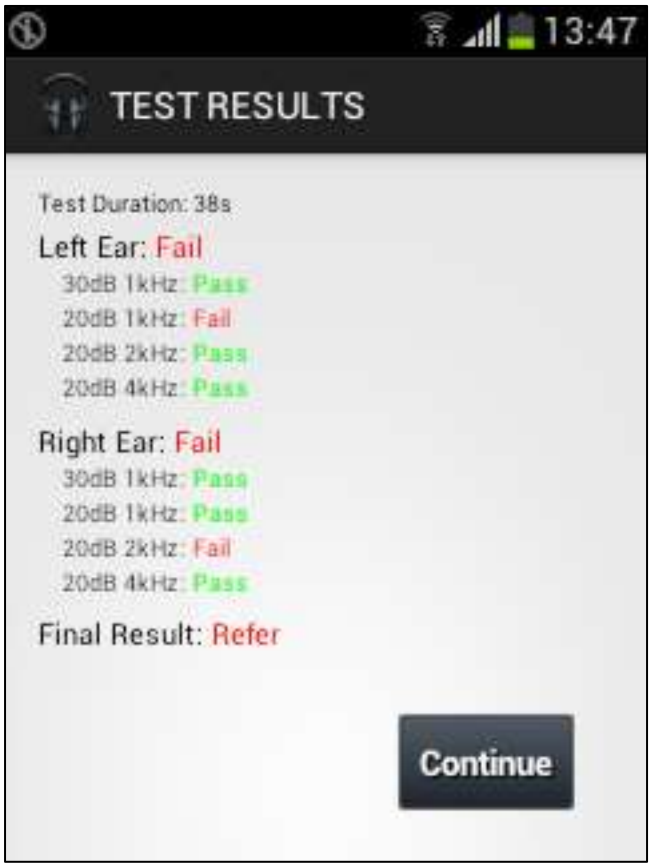
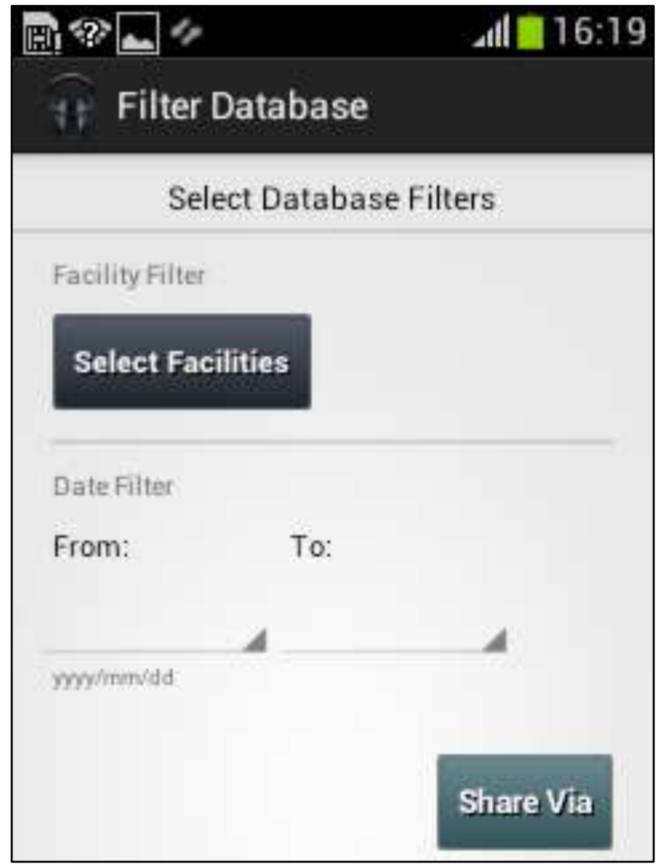


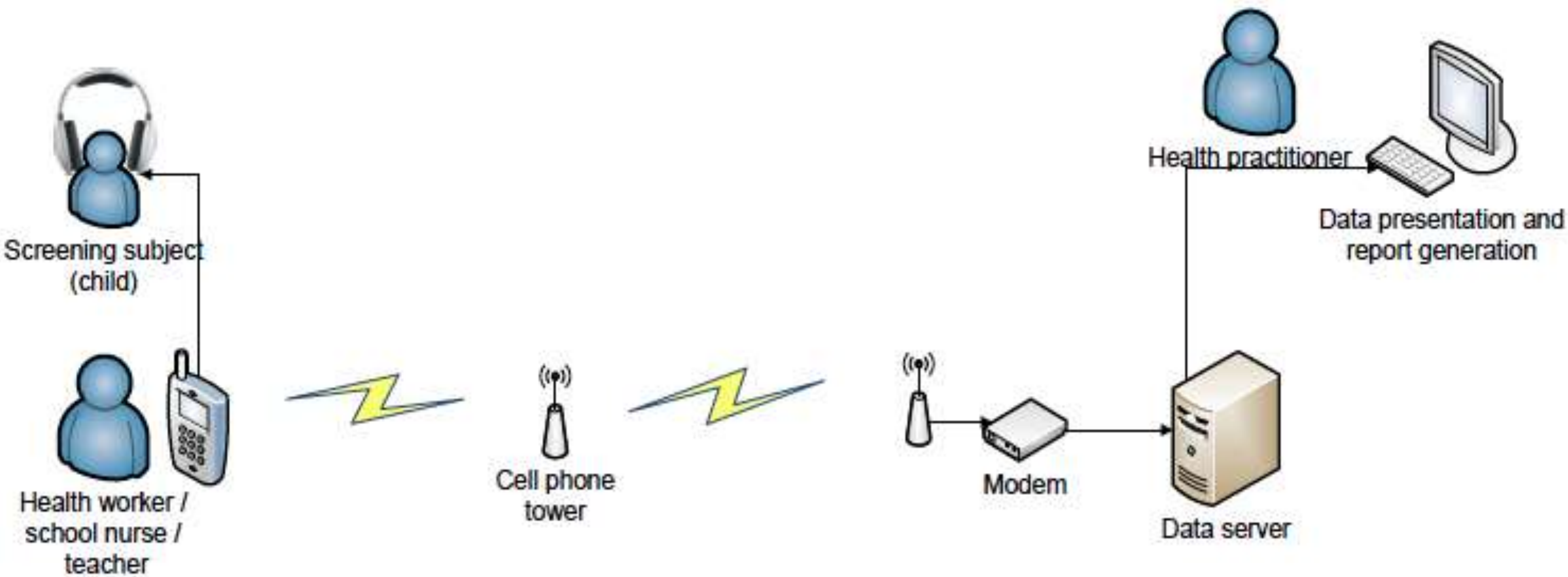


University of Pretoria Patent

PHASE 3 – CLINICAL VALIDATION

- **Screening audiometry** – 1, 2 and 4 kHz at 25 dB
- **Conventional** and **smartphone**-based screening
- **Same-day counterbalanced**
- **136** children (5 – 9 yoa; Ave 6.7 +/- 0.7)

PHASE 3 – CLINICAL VALIDATION



PHASE 3 – CLINICAL VALIDATION

		Conventional screening		
		Pass	Refer	Total
Mobile phone screening	Pass	92.6% (252)	3.7% (10)	96.3% (262)
	Refer	2.6% (7)	1.1% (3)	3.7% (10)
	TOTAL	95.2% (259)	4.8% (13)	

		Conventional screening		
		Pass	Refer	Total
Mobile phone screening	Pass	93.4% (121)	4.4% (6)	97.8% (127)
	Refer	4.4% (6)	2.2% (3)	6.6% (9)
	TOTAL	97.8% (127)	6.6% (9)	

Smartphone screen: **26.3** seconds (6.4 SD; Range 19 – 49)

PHASE 3 – CLINICAL VALIDATION

2014 Clinical Trials

School-based

- School screening of 2000 - 3000 children with conventional and smartphone based screening
- Diagnostic follow-up to establish sensitivity / specificity

Community Health Care Worker project

- Roll-out to 500 CHW


1. Expense; 2. Training; 3. Time;
4. Noise; 5. Electricity;
6. Data capturing; 7. Data surveillance

CONCLUSIONS

- Rapidly changing world
- **Hearing loss** prevalent with inadequate human resources to meet **demands**
- Continued **growth** in **technology** and **connectivity** will change the way in which we deliver services. E.g.
  – *Remote ear diagnosis*
  – *Cost-effective solutions for reliable hearing screening*
- Promise of **reaching** more patients, and especially those in **underserved** areas, **more effectively** (time and cost)

Because "children [with hearing loss] are equally entitled to an exciting and brilliant future"

QUESTIONS?