727521 – EVOTION

DELIVERABLE No: D5.7

Auditory Training component and mobile auditory tests

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Executive Summary

Deliverable 5.7 presents the theoretical background and a detailed description of the auditory tests (i.e. pure tone audiometry, speech in babble and digit recall) and auditory training component of the EVOTION mobile application. As the tests and auditory training as well as their scientific background have been briefly presented in previous EVOTION Deliverables (i.e. D7.1, D7.2 and D5.2) the present Deliverable is complementary and reports additional information and details that were not previously reported. The user manual of the application and clinical instructions for the patients on how to perform the activities are also provided in the Annex. This Deliverable is presented as a Report instead of a Demonstrator and focuses more on the scientific aspects of the components because the technical implementation, design and technology of the EVOTION mobile application have already been demonstrated in D5.4.

1 Overview of components

The EVOTION mobile application includes the following components:

1. A self-administered Pure Tone Audiometry
2. A self-administered Speech in Babble test
3. A self-administered Digit Recall test
4. An Auditory Training programme
5. Hearing Aid controls
6. Self-reporting of noise exposure
7. Information material
8. Notifications

From these components, above numbers 1, 2, 3 and 4 are the focus of the present Deliverable.

Please note that a self-performed auditory test that would take electrophysiological measures of cochlear function was foreseen in the Description of Action (DOA). However and for the time being ear-moulds capable of electrophysiological measures (see https://cordis.europa.eu/result/rcn/194985_en.html) are not feasible for everyday use and therefore the activity to supplement self-performed auditory tests with automated tests has been abandoned.

2 Aim of the Deliverable

An overview of the EVOTION mobile application, its components and design has been given in Deliverable 5.4 'Mobile Application' (Dimakopoulos et al., 2017b). Additionally, a brief description of the tests and auditory training programme that were implemented has been given in Deliverables 7.1 'Study protocol and Ethics Approval Application Report' and 7.2 'Collection of non real-time HA user data' (Bamiou et al. 2017; Kikidis et al. 2018). The present Deliverable is complementary to previous work and deliverables and its purpose is to update and give details on the scientific background and the descriptions of the mobile application tests and auditory training component.

3 Mobile application tests (PTA, Speech in Babble, Digit Recall)

3.1 Rationale

The auditory tests in EVOTION aim to assess factors important for monitoring and understanding and listening capabilities of people with hearing loss. The basic hearing capabilities, the audiogram and the cognitive abilities, are the most important factors for understanding hearing capabilities (Lunner, 2003)

In order to monitor and verify actual TTS episodes, two tests were incorporated in the EVOTION mobile application:

- A self-administered pure tone audiometry (PTA) test to detect shifts in audiometric thresholds at 4 kHz
- A self-administered Speech in Babble test to detect changes in performance that may be related to TTS episodes.

In order to assess and monitor cognitive abilities and possible cognitive decline, a Digit Recall test was implemented via the mobile application as a measure of auditory working memory.

3.2 Pure Tone Audiometry (PTA)

The self-measured 4 kHz PTA test In EVOTION is an aided threshold: a probe signal (the tone) is emitted from the EVOTION mobile phone's loudspeaker and then travels through the air to the EVOTION Hearing Aid, where the level is measured, and the signal is amplified according the patient's audiogram. The EVOTION Mobile phone is controlling the volume [Sound Pressure Level (SPL)] of the probe tone and records patient interaction when the tone is audible and when it is not.

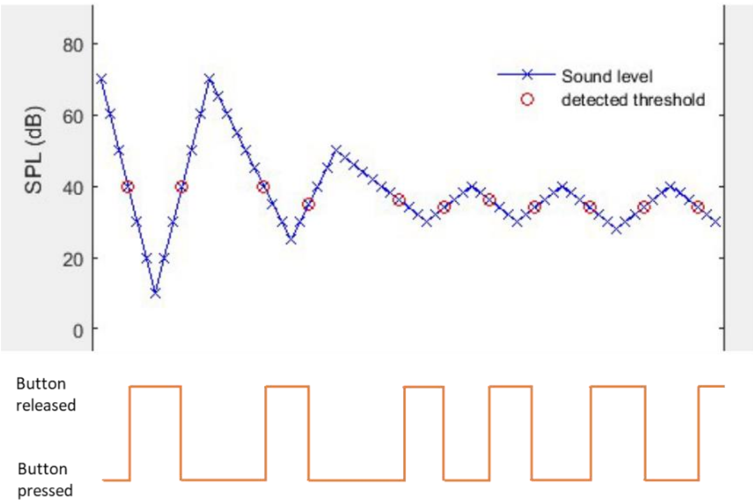

Figure 1: Békésy zigzag tracing and patient response

The test follows the Békésy measurement paradigm ("Békésy audiometry," 2012) where the probe signal is a 4 kHz tone with time-varying level controlled by the EVOTION mobile phone. Figure 1 shows one trial where the threshold was just below 40 dB SPL. Initially the tone started at an audible level, here 70 dB, then it dropped in steps of 10 dB. As it got below 40 dB the patient indicated that it was not audible (see red circle in Fig 1), and the mobile phone started to increase the level in 10 dB steps from 2 steps below the inaudible tone, 10 dB. As the level reached 40 dB again the patient responded that the tone was audible. From there on the step size is halved to 5 dB (later halved once more to 2.5 dB).

3.2.1 Threshold estimation

When $\widehat{N}$ detection thresholds have been recorded the threshold is calculated as follows

$$Threshold_{\widehat{N}} = mean(detection\ thresholds) = \frac{1}{\widehat{N}}\sum_{i=1}^{\widehat{N}} detection\ threshold_i$$

$$SD_{\widehat{N}} = \sqrt{\frac{1}{\widehat{N}}\sum_{i=1}^{\widehat{N}} (detection\ threshold_i - Threshold_{\widehat{N}})^2}$$

Detection thresholds further away from Threshold 1 than $2 \times SD_{\widehat{N}}$ are considered outliers and discarded, so the final Threshold is calculated from the N remaining detection thresholds.

$$Threshold = \frac{1}{N}\sum_{i=1}^{N} detection\ threshold_i$$

3.2.2 Test procedure

The mobile phone should be placed on a table in front of the patient. The patient wears both hearing aids during the test. Once the test starts, the app automatically changes the hearing aid program into “Program 4 (Low)” where the hearing aid provides the least amount of processing. The positions of the phone, the patient and hearing aids should be kept approximately the same during the measurement. The patient presses the on-screen button when s/he can hear the tone and release the button again when s/he cannot hear the tone anymore. The mobile app records the patient’s response and sends the results to the EVOTION server. When the test ends, the mobile app should restore the program and volume settings to those before the audiogram measurements.

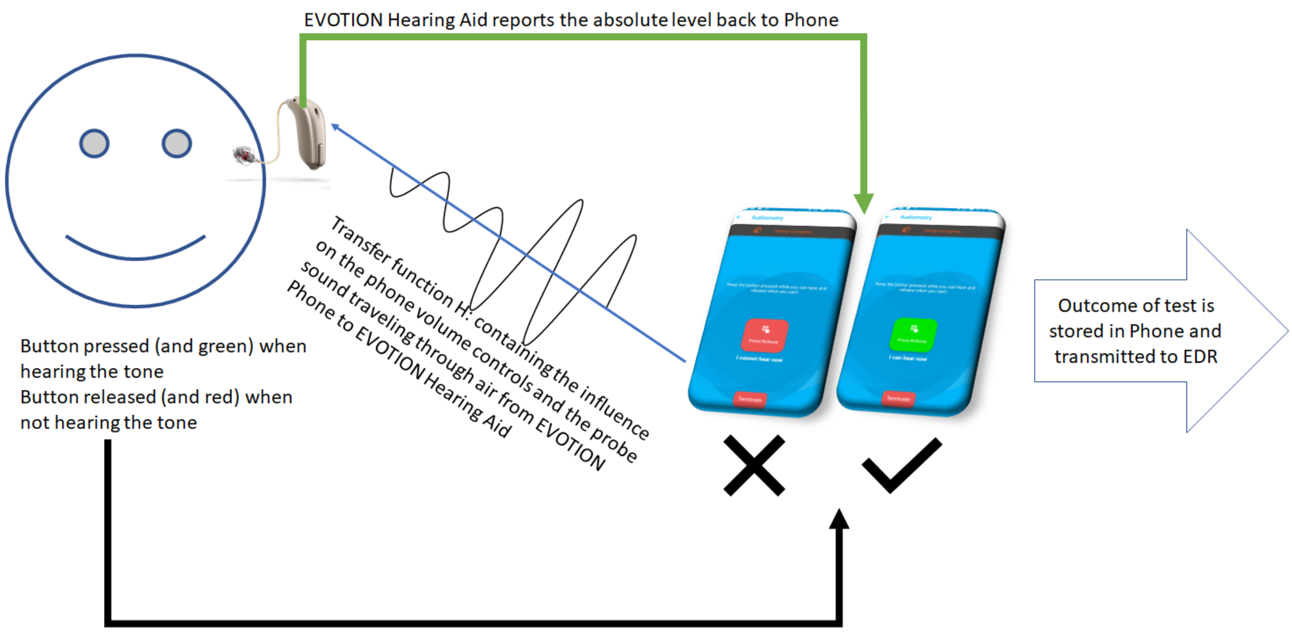

Figure 2: Illustration of EVOTION audiogram measurement

As shown in Figure 2, the pure tone sound is played over the phone's loudspeaker. The patient will need to press or release the on-screen button to give the response. Meanwhile the SPL estimations by the hearing aids will be recorded by the mobile app over BLE. Therefore, it is important that the app verifies that the phone is receiving data while the pure tone sound is playing.

3.2.3 Acoustical transfer function

The audiogram tone is played from the EVOTION app through the phone volume control over the phone's speaker and passes through the air, to get amplified by the hearing aid(s) worn by the patient. The attenuation of these three stages is contained in the linear transfer function H. Since it is a single frequency, the transfer function is calculated as $H = SPL_{\text{At Hearing Aid}} - SPL_{\text{In Phone before Volume Control}}$, where the different variables are explained below:

Variable	Description
$SPL_{\text{In Phone before Volume Control}}$	Sound Pressure Level in dB relative to full-scale digital signal inside the Mobile Phone before the Volume Control.
$SPL_{\text{At Hearing Aid}}$	Absolute Sound Pressure Level in dB measured by the Hearing Aid at the microphone position
$H = SPL_{\text{At Hearing Aid}} - SPL_{\text{In Phone before Volume Control}}$	Transfer function that transforms the relative SPL calculated before the Phone Volume Control to the Absolute SPL at the Hearing Aid Microphone.

Example: $SPL_{\text{In Phone before Volume Control}}$ = -30 dB, $SPL_{\text{At Hearing Aid}}$ = 24 dB, H=24 dB-(- 30 dB)=54 dB.
Since the transfer function is linear, the transfer function can be applied to the detection thresholds prior to the calculation of threshold or after the calculation of thresholds.
The transfer function is only valid for a single measurement, so the next time the patient measures the audiogram a new transfer function must be estimated through the calculation above.
Finally, the sound pressure level (dB SPL) is converted into hearing threshold by subtracting 12 dB corresponding to the Reference Equivalent Threshold Sound Pressure Level for supra-aural headphones (American National Standard Institute, 1996) as that reference matches the recording of level at the microphone position of the EVOTION Hearing Aids.

3.3 Speech in Babble (SiB) test

The test is largely based on the Speech-in-Babble (SiB) test (Bamiou et al., 2015; Spyridakou et al., 2012) that employs 8 lists of monosyllabic phonemically balanced meaningful English words as the speech stimulus presented with multi-talker babble as the masker. Each list contains 20-25 words. These are spoken by a female native Southern-English speaker. Each word is delivered with 500 milliseconds of babble masker at the beginning and the end of the word itself.

The listener is asked to choose (by typing in) the word they believe they heard in a multiple-choice scenario. The Signal to Noise Ratio (SNR, level of the target words vs noise) is fixed throughout the

test at 10dB and performance is measured with the % correct responses. The English words that were used were those of the SiB test.
Equivalent material was recorded in Greek specifically for the purposes of the project based on the phonemically balanced words by Trimmis et al [34]. Words in these lists are phonemically balanced, which means that they contain percentage of phonemes similar to the one recorded in the Greek language with analysis of a big sample of raw speech from various TV and radio shows. It is used in every day clinical practice in Greek hospitals.
It should be mentioned that these tests cannot replace those performed in audiological setting as they are likely to be less accurate in view of the lack of control over the acoustics of the environment.

Example of 1 of 8 English lists implemented in the test:

beak	Job	Soak
Bet	Lock	Stamp
Both	Mace	Track
Coin	Meal	Van
Crew	Mouth	wade
Debt	pull	
Flood	Reach	
Fun	Roar	
Hoot	Sand	
hug	Shall	

A summary of the Speech in Babble test can be seen here:

Material	50 monosyllabic words, Multi-talker babble noise
Procedure	SNR fixed at 10dB
Administration	Mobile app, self-administered
Outcome measure	% of correct responses

3.4 Digit Recall

The digit recall test that was implemented in EVOTION was based on the digit span subtest of the Wechsler Adult Intelligence Scale (WAIS) IV (Wechsler, 2008). Digits from 1 to 9 were recorded by a male native English speaker. Pairs of digit sequences are played, and the user has to type in the sequences in the correct order. There are 2 versions of the test, a forward and a backward version, where the listener has to type in the digits in the right or reverse order, respectively. On successful recall of at least one of the 2 sequences from each pair, the sequence increases by one digit (maximum 8 digits for forward and 7 for backward recall). Discontinuation occurs (i.e. the test ends) when both sequences are recalled incorrectly (i.e. at least one digit is incorrect).

Equivalent digits 1 to 9 were also recorded in Greek and were implemented for the Greek version of the test with the exact same design as above.

Example: Matrix of Digit recall forward version (please note: for the backward version the maximum number of digits is 7 and sequences are different)

Item/pair number	Trial number	Digit sequence	Trial score (0 or 1)	Item score (0, 1 or 2)
1	1	1 – 7		
	2	6 – 3		
2	1	5 – 8 - 2		
	2	6 – 9 - 4		
3	1	6 – 4 – 3 – 9		
	2	7 – 2 – 8 – 6		
4	1	4 – 2 – 7 – 3 - 1		
	2	7 – 5 – 8 – 3 – 6		
5	1	6 – 1 – 9 – 4 – 7 – 3		
	2	3 – 9 – 2 – 4 – 8 – 7		
6	1	5 – 9 – 1 – 7 – 4 – 2 – 8		
	2	4 – 1 – 7 – 9 – 3 – 8 – 6		
7	1	5 – 8 – 1 – 9 – 2 – 6 – 4 – 7		
	2	3 – 8 – 2 – 9 – 5 – 1 – 7 – 4		
8	1	2 – 7 – 5 – 8 – 6 – 2 – 5 – 8 – 4		
	2	7 – 1 – 3 – 9 – 4 – 2 – 5 – 6 – 8		
			Digits forward Total Score (Max = 16)	

A summary of the Digit Recall test can be seen below:

Material	Single digits 1-9 spoken by male native British English or Greek speaker
Procedure	Adaptive: sequence increases by one digit on successful recall of ½ trials of digit sequences
Administration	Mobile app, self-administered
Outcome measures	Final forward and final backward score

4 Auditory Training programme

4.1 Background

The scientific background underpinning the development of the Auditory Training tool has been briefly presented in Deliverable 2.1 'Stakeholders, Scenarios and Requirements' (Dimakopoulos et al. 2017a) and is reported in more detail here.

Auditory training (AT) involves repeated listening exercises designed to improve the function of the auditory system via reorganisation of the brain's neurons. This cortical reorganisation of the auditory brain is driven by auditory stimulation, which is thought to activate inactive neuronal connections and/or trigger formation of new and more efficient synaptic connections (Chermak and Musiek 2014; Musiek et al., 2002). The rationale behind auditory training is the expectation that a successfully learned auditory behaviour/skill within the training will be repeated and applied in a real-life context and in situations different to that of the training paradigm (i.e. generalization of learning or training benefit). In general, auditory training tasks aim to train several abilities simultaneously such as linguistic, cognitive, and perceptual skills. The characteristics of the trained tasks influence the transfer and specificity of learning (Amitay et al., 2014), and most AT regimes include more than one training tasks. The training dosage also affects AT outcome (Levi and Li, 2009) (Schäffler et al., 2004) (Murphy et al., 2015) (Halliday et al., 2012). The training material in existing AT programs includes predominantly speech material (such as phonemes, syllables, words as well as sentences) as well as non-speech sounds. AT targets both bottom-up sensory processing, i.e "analytic training" and top-down linguistic and other higher order functions, i.e. "synthetic training" (Sweetow and Palmer, 2005).

A number of studies have assessed efficacy of AT for both healthy young adults as well as older adults with normal hearing and have found improvements in speech in noise test performance and auditory memory test performance after computer based auditory training (CBAT) that aimed to provide both analytic and synthetic training and that incorporated several training exercises (Song et al., 2011). There is also indication that improvements from CBAT may generalise to untrained everyday problem solving (Strenziok et al., 2014; Fisher et al., 2009). Cognitive benefits of AT are of particular interest for the hearing impaired listeners since HA users depend more on their cognitive resources than normal hearing listeners in order to understand speech (Moradi et al., 2014), and thus experience mental fatigue that is not wholly alleviated by the use of sophisticated current HAs (Hornsby, 2013). Therefore, it would make sense that AT aiming to improve both the sensory representation of speech and the cognitive resources allocated to speech perception would make listening less effortful and more accurate in hearing impaired listeners. Hearing impaired adults show improvements in a range of indices after AT, such as speech recognition in noise or cognitive and self-reported hearing measures (Henshaw and Ferguson, 2013). Of interest, new hearing aid users appear to derive greater benefit by CBAT compared to experienced HA users, indicating that such training should be initiated as soon as a hearing aid is fitted (Olson et al., 2013).

Indeed, it has been suggested that ideally HA fitting should be supported by rehabilitation treatments such as AT (Musiek et al., 2002), as HA users depend more on their cognitive resources than normal hearing listeners in order to understand speech (Moradi et al., 2014). However, systematic reviews (Henshaw and Ferguson, 2013) and randomized clinical trials (Saunders et al.,

2016) have indicated poor evidence for the effects of AT for adult HA users, except for some evidence for psychosocial benefits (Hickson et al., 2007).

EVOTION aimed to develop a prototype auditory training mobile application that would (a) target auditory memory, (b) use a background of noise approximating real-life noisy listening situations and (c) be self-administered, accessible by the user any time on a smartphone, engaging and interactive. This app is being made available to the patients for a period of 12 months.

Data that will be collected from this AT tool will be used to identify predictors of effective AT, assess whether AT is associated with improved HA use and benefit or delayed cognitive deterioration and eventually link this information onto appropriate management strategies (Public Health Policy Decision Model 4 'Prognosis and Delivery of Effective Auditory Training Rehabilitation', Deliverable 3.1).

Specifically, the EVOTION platform will collect information that will enable progress tracking and compliance (elements for effective AT (Chisolm et al., 2013), and their evaluation as determined by real life performance. As CBAT is going to be provided by a Hearing Aid device and a mobile application that will be available to the user round the clock and a log will be kept of training performance and progress tracking, compliance with such training, which is a key factor for CBAT benefits is expected to be improved (Chisolm et al., 2013). Early start of the CBAT after fitting of the EVOTION device will be facilitated, thus securing maximum benefits from such training. It is also anticipated that continuous monitoring of user experienced hearing/listening difficulties and CBAT progress tracking will help further define user auditory needs as well as his/her cognitive profile, and thus enable early identification of cognitive decline.

Within the context of EVOTION, a prototype auditory training mobile application was developed to identify predictors of effective Auditory Training (AT), assess whether AT is associated with improved HA use and benefit or delayed cognitive deterioration. The development of an Auditory Training component is therefore addressing some of key EVOTION objectives. Eventually, information collected from the EVOTION Auditory Training programme will be linked onto appropriate management strategies to support policy making.

4.2 Description

4.2.1 Design and material

The AT that was chosen to be implemented in EVOTION was briefly described in *Deliverable D7.2* and is presented in more detail here. The AT that was implemented in EVOTION was based on the Story in Noise, an existing auditory training program using words in phrases from connected narratives spoken by adult British female and male talkers and presented in background noise (Loo et al., 2016).

4.2.2 Materials

For EVOTION, two texts were implemented: 'Money for Sale'[1] and 'Snowball', which was adapted from a Sherlock Holmes story originally entitled Silver Blaze. Both texts were taken from books aimed at foreign learners of English and therefore had consistent complexity and controlled vocabulary and syntax (Bloese, 2005; Hardcastle, 1975; Revell, 2008). One female and one male talker of standard Southern British English were recorded for the Money for Sale and 2 males and 3 females in the Snowball. Each text was divided into phrases of 2-10 words. The number of phrases per text ranged from 1034 to 2641. The median phrase length for each text was five words. For each phrase, between one and four potential target words were selected. Target words were primarily content words, although function words were used in a small proportion of phrases. Similar sounding foil words were chosen for each target (see Figure 1 for an example). Foils typically shared at least two phonemes with the target and, as far as possible, were chosen so as to be plausible in the context of the narrative. For phrases in which there was only a single potential target word, a single foil word was chosen. In all other cases each potential target word had two foils. Phrases were presented with a background of multi-talker babble noise.

4.2.3 Task

The principle of the training is that listeners work through a connected story divided into phrases. The participants listen to consecutively presented phrases and after each phrase they see a display containing keywords along with a number of alternatives/foils. Each phrase has up to 4 possible target words. In order to increase the error rate, which is necessary for the implantation of adaptive training, more foils than targets are presented for each phrase. There are two foil words for each possible target word. One or two target words are chosen at random and displayed along with one of their foils. For the remaining possible target words only their two foils are displayed. The participants select from the display the words that they believed have been in the phrase. When a foil is selected the whole phrase is immediately replayed, with this process continuing until the one or two target words have been selected. At this point the phrase is displayed orthographically and played out once again. The training runs for a 30-minute session, subdivided into four blocks of 7.5 mins, which alternate between the male and the female talker and between different individuals. In the Snowball, where there are more than 2 talkers, each of them appears once within a 30 mins training session, rather than two talkers twice. The user is free to choose the talker (male or female) or the story they want to start with from the settings of the app as well. The noise level adapts according to the errors made over the preceding 10 phrases. The initial SNR is set to 10 dB (i.e. target sound 10dB higher than the noise). If the proportion of possible errors made is > 0.15 then the SNR for the next 10 phrases is increased by 3 dB, otherwise it is reduced by 3 dB. There are separate adaptive tracks for each talker (essential for the talkers we have as the male is considerably more difficult). At the start of each new block the SNR is set 3 dB higher than the SNR used at the end of the previous block with that talker.

4.2.4 Outcomes measures

Progress within AT will be evaluated by assessing the number of errors made over 10 phrases. If the number of errors, as a proportion of the possible errors that could have been made, is above a criterion value of 0.15, the SNR is increased for the next set of phrases, otherwise it is decreased.

[1] Hardcastle, M. (1975). Money for Sale (Heineman Educational Books Ltd., Portsmouth, NH)

Improvements in SNR will also be measured during the training. Compliance with AT will be assessed by how often and for how long participants engage with the training.
In EVOTION, correlations will be primarily examined between AT performance/compliance and the scores of the Speech in Babble and Digit Recall mobile tests, the MoCA cognitive assessment, GHABP scores and logged HA usage.
These analyses will inform decisions regarding Delivery of Effective Auditory Training Rehabilitation, as per the PHPDM 4 (D3.1).

A summary of the EVOTION Auditory Training mobile application can be seen here:

Words	2 stories divided into phrases with 1-4 target words and a set of alternatives
Talkers	3 male and 4 female switching every 7.5 minutes
Noise	Multi-talker babble noise
Procedure	Adaptive, starting at +10dB and increasing/decreasing at 3dB intervals
Administration	Self-administered, instruction to do 30'/day, 3 days a week for 5 weeks
Progress within AT	Improvement in SNR, Min/max/mean SNR, total number of errors avoided as a proportion of possible errors
Outcome measures	Main: Speech in Babble (SiB) mobile app score change, Other: digit span mobile test score change, reaction time, MoCA, GHABP, HUI
Compliance	Frequency and amount of AT
Hypothesis	Main: AT performance will improve in time, AT will improve SiB Secondary: AT will improve digit span and MoCA score, HA satisfaction, QOL

4.3 Auditory Training in Greek

UOA developed auditory training material in Greek for the purposes of EVOTION based on the above rules. Phrases were recorded and foils were produced. This is the first auditory training material in Greek language. Specifically, 3 texts from the literature were processed: Crazy Antonis (Τρελαντώνης, Π. Δέλτα), For Whom the Bell Tolls (E. Hemingway) and Perfume (Patrick Süskind). These were recorded unchanged and were divided into 300 sentences in total. For each sentence 1-4 words were chosen (regardless of their grammatical category) and for each of these two alternative choices was provided. These choices were r words that sound similar (same vowels or same initial/final syllable and with the syllabic structure retained in most cases) with the additional aim for these words to be semantically similar to avoid use of semantic context from the patient. Figure 4 below shows an example of the Greek AT material.

5 Implementation and manuals

The Auditory training components have been technically implemented and included in the EVOTION mobile application under app's activities section of the app using a user-friendly graphical user interface. As the Auditory training components are part of the EVOTION mobile app, the design and the technologies that were followed have been presented in D5.4 Mobile Application. Even though the mobile app components were administered to participants, patient feedback or potential for use of these tools in other clinical settings are out of the scope of this deliverable, relevant sections of the mobile app user manual and a quick clinical guide for the tests and auditory training are both included in the Appendix.

Snowball

label	wave	end	sentence	kw1	kw2	kw3	kw4	blank	fw1	fw2	fw3	fw4	blank	dfw1
SB0001	SB0001	1	"I need to go down there Watson."	need	go	down	there		read	know	round	where		near
SB0002	SB0002	0	"I simply must" said Sherlock Holmes	simply	must				singly	just				quickly
SB0003	SB0003	0	at the breakfast table	breakfast	table				breathless	stable				steadfast
SB0004	SB0004	1	on Thursday morning.	Thursday	morning				firstly	warning				thirsty
SB0005	SB0005	1	"Go where?" I asked.	go	where	asked			know	there	passed			so
SB0006	SB0006	0	"To Dartmoor"	Dartmoor					Dartford					
SB0007	SB0007	1	"To Kingsbury."	Kingsbury					Finsbury					
SB0008	SB0008	1	"Yes of course" I said.	Yes	course	said			guessed	horse	sighed			yet
SB0009	SB0009	0	"Well everybody in the country"	well	everybody	country			hell	anybody	county			tell
SB0010	SB0010	0	"is talking about"	talking	about				walking	without				taking
SB0011	SB0011	1	"the case down there."	case	down				place	round				race
SB0012	SB0012	0	I always know	always	know				almost	go				away
SB0013	SB0013	1	when Holmes is interested in a case.	when	interested	case			one	interrupted	chase			men
SB0014	SB0014	0	He reads all the newspapers	reads	all	newspapers			needs	calls	neighbours			feeds
SB0015	SB0015	0	he walks up and down the room	walks	down	room			looks	round	gloom			talks
SB0016	SB0016	1	and doesn't speak for hours.	doesn't	speak	hours			mustn't	squeak	showers			wasn't
SB0017	SB0017	1	He did all those things yesterday.	did	those	things	yesterday		had	knows	thinks	everyday		hid
SB0018	SB0018	0	He didn't answer	didn't	answer				hadn't	after				isn't
SB0019	SB0019	1	any of my questions.	any	my	questions			many	mine	sessions			plenty
SB0020	SB0020	0	But I knew it was because	knew	because				drew	course				do
SB0021	SB0021	1	of the mystery at Kingsbury.	mystery	Kingsbury				history	instantly				misery
SB0022	SB0022	1	The morning papers were on the table.	morning	papers	table			warming	painters	stable			evening
SB0023	SB0023	1	They were full of questions.	full	questions				call	mentions				filled
SB0024	SB0024	1	What's happening at Kingsbury?	what's	happening				lots	happily				once
SB0025	SB0025	1	Where is Snowball?	where	Snowball				there	noble				care
SB0026	SB0026	1	Who killed John Straker?	killed	John	Straker			called	Don	Baker			grilled
SB0027	SB0027	1	What are the police doing?	what	police	doing			want	please	ruined			watch
SB0028	SB0028	0	Can they find the horse	can	find	horse			man	mind	house			ran
SB0029	SB0029	1	before the big race next week?	before	race	next	week		because	case	wrecked	leak		beyond
SB0030	SB0030	0	Snowball was a well known racehorse	Snowball	known	racehorse			Snowden	shown	course			trouble

Figure 3 Example of the 'Snowball' story implemented in the EVOTION AT mobile application component. The story is divided into phrases (each line is a different phrase). Each phrase has 1-4 keywords (kw1-kw4) and for each keyword there are 1 or more foils (fw or dfw).

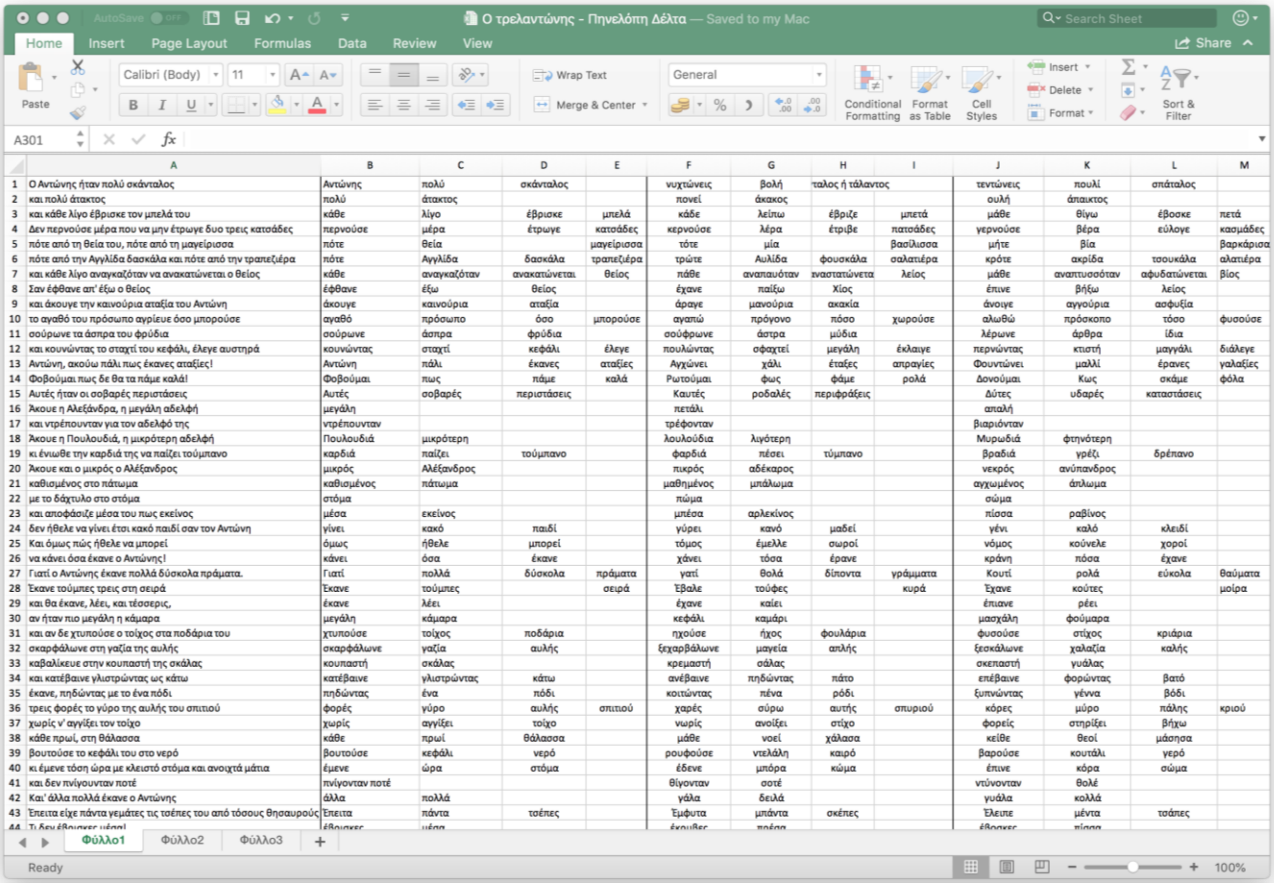

Figure 4 Example of one of the stories implemented in Greek (i.e. 'O Trelantonis', Pinelopi Delta) based on the original design and English material. As in Figure 1, the story is divided into phrases (1 to 44 in the above figure), target words have been selected for each phrase and foils for each target word

6 Conclusion

As part of the EVOTION project three prototype mobile tests (speech in babble, digit recall and an audiometry test) and a prototype auditory training program were developed with the primary aim to collect big data to support public health policy making for hearing loss but also with a view to patient treatment. D5.7 reported additional theoretical background and details about the design of the components that were not included in previous deliverables. Relevant sections of the user manual and a dedicated patient guide were also appended. Data collected from these tests and auditory training will be analyzed according to the public health policy models described in D3.1 'Public Health Policy Decision Models (PHPDM) v1' (Katrakazas et al. 2017).

References

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Annex 1: Mobile app user manual ('Activities' sections only)

2.6 Do an activity

You can navigate to the Activities page from the Home screen by pressing the "Activities" button (as shown in section A of Figure 15).

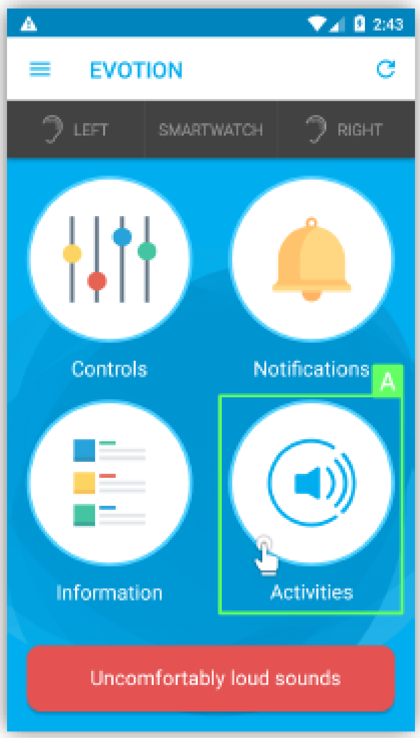

Figure 15: Use case 6 - Activities button

Figure 16: Use case 6 - Activities page

Inside the Activities page, you can take one or more of the available tests: Pure Tone Audiometry, Digit Recall or Speech in Babble (as shown in sections A to C of Figure 16). When pressing one of the buttons that corresponds to a test for the first time, you will be guided on how to take the respective test. You can always go back to these instructions by clicking the "View Tutorial" button at the bottom right of each test's front page.

2.7 Do Auditory Training

Auditory Training helps you practice your ability to understand words and sentences in background noise. In this specific Auditory Training programme, you will hear connected stories taken from books and we hope that you will find it entertaining as well as useful.

Figure 17: Use case 7 – Auditory Training Button

You can find the "Auditory Training" button in the Activities page, as shown in Section A of the above Figure. Instructions will appear automatically the first time you run the training but you can always find them by clicking the "View Tutorial" button at the bottom right of the Auditory Training front page.

2.8 Report a loud event

It is really important for us to record and understand your exposure to noise in your daily life. Every time you hear a sound that is uncomfortably loud for you, please press the button "*Uncomfortably*

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loud sounds" at the bottom of Home and Controls screen (as shown in section A of Figure 18: Use case 8 –).

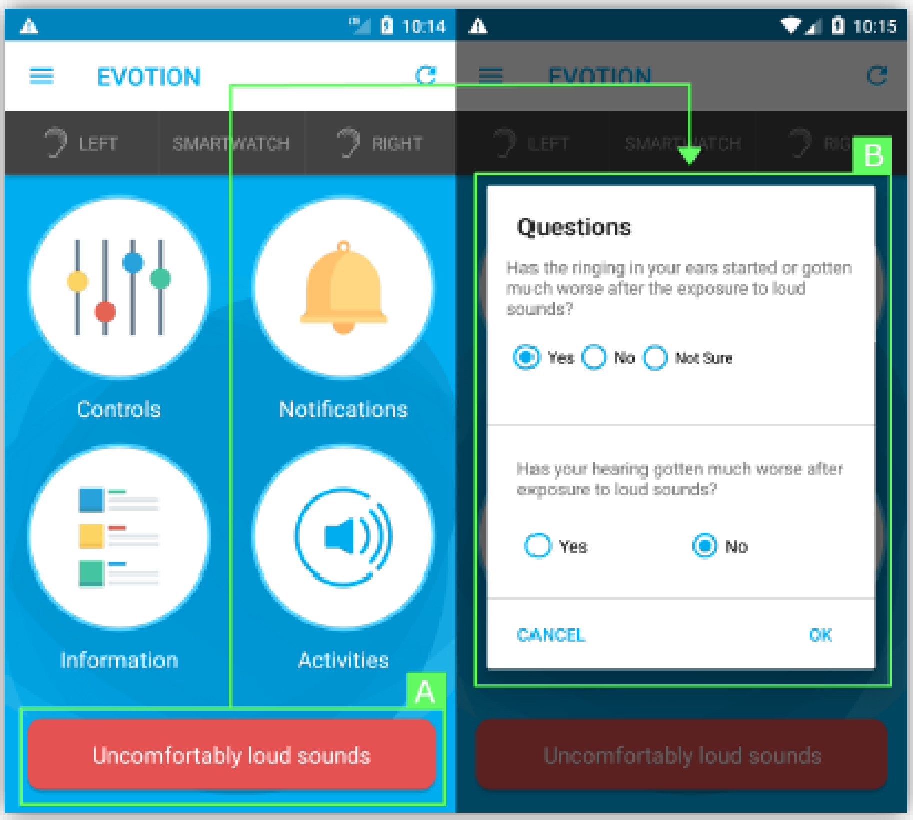


Figure 18: Use case 8 – Uncomfortably Loud Sounds

You can press this button as many times as you like. After pressing the button you will be asked 2 questions to help us understand better what happens after your exposure to noise (as shown in section B of Figure 18: Use case 8 –). Depending on your answers to these questions, you may be prompted to do an Audiometry and/or Speech in Babble test. Please do this by following the instructions in section 2.6 above.

3 Frequently asked questions (FAQ)

3.1 Why the Hearing Aids and the Wearable Sensor cannot connect to the EVOTION mobile app?

If you experiencing problems with the connection towards the peripheral devices such as that the peripheral devices are not able to connect with the EVOTION mobile application, you should check

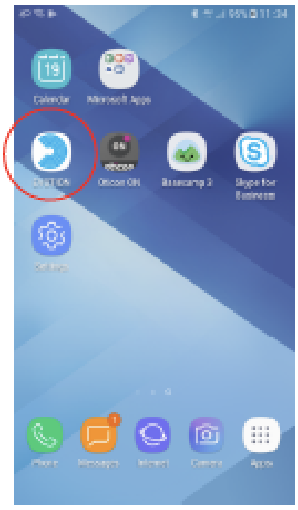
Annex 2: Mobile app clinical quick guide

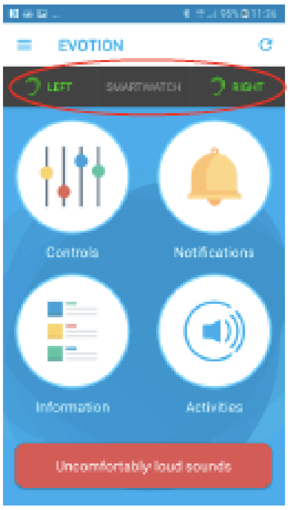
EVOTION QUICK GUIDE

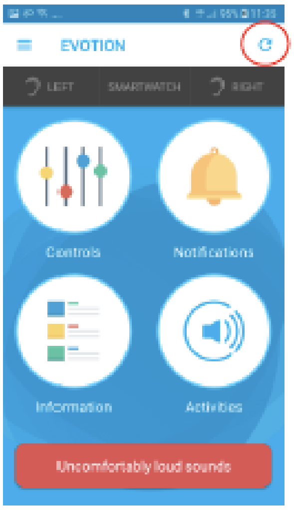
These instructions will help you quickly get started using your EVOTION hearing aids with the mobile application.

IMPORTANT: Please try to keep your mobile phone with you at all times when wearing the hearing aids (e.g. in your pocket, bag or on the table right in front of you).

FIRST TIME USE







Start the EVOTION App

This has already been installed for you.

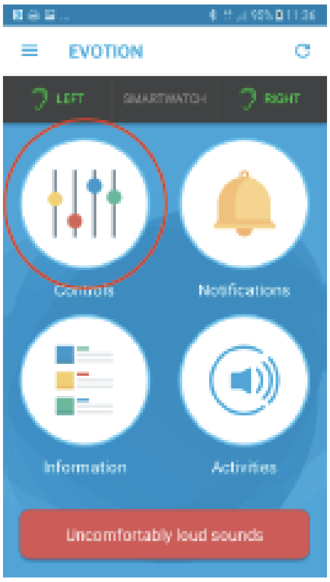
Connect Hearing Aids

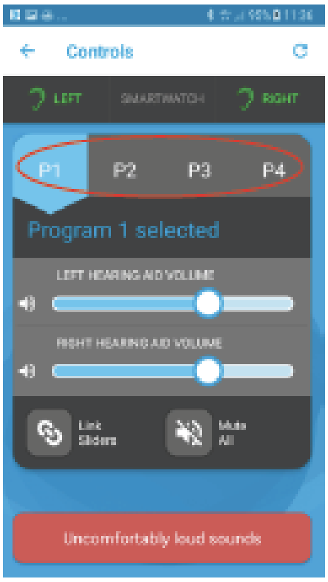
This is automatic and the icons turn green. Note: If you have only one hearing aid check the light shows the correct side.

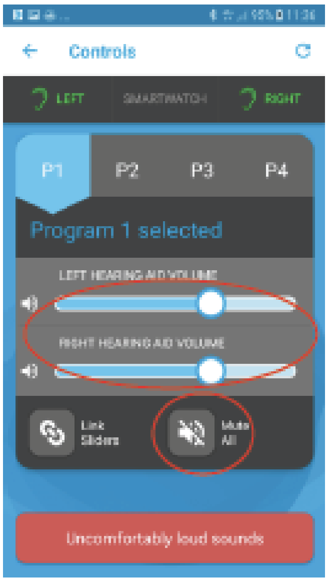
If the Lights Do Not Turn Green

Refresh the connection
If this fails change the hearing aid batteries.

SELECT PROGRAM / PROGRAM SETTINGS / VOLUME & MUTE







Select Controls

You can control the programs, volume and mute the hearign aids.

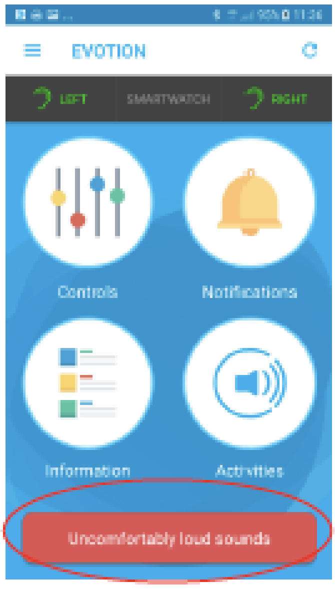
Change Programs

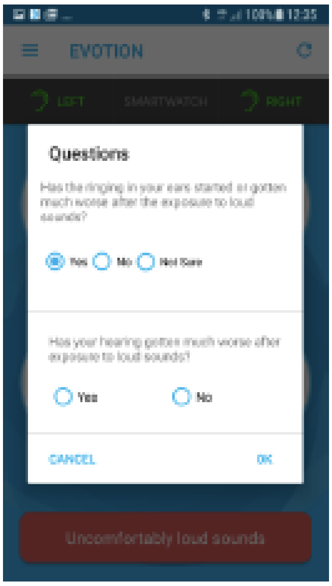
Pressing P1, P2, P3, P4 change the program in the hearing aids.

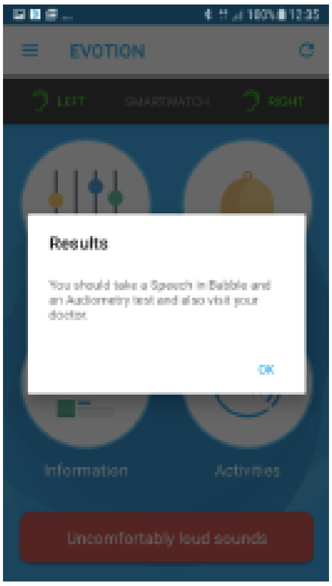
Change Volume and Mute

Use the left and right slider to increase or decrease the volume of the heairng aids. Press 'mute all' to mute the hearing aids.

UNCOMFORTABLY LOUD SOUNDS







Select Uncomfortable Loud Sounds

If you think you have been exposed to an uncomfortably loud sound press the button.

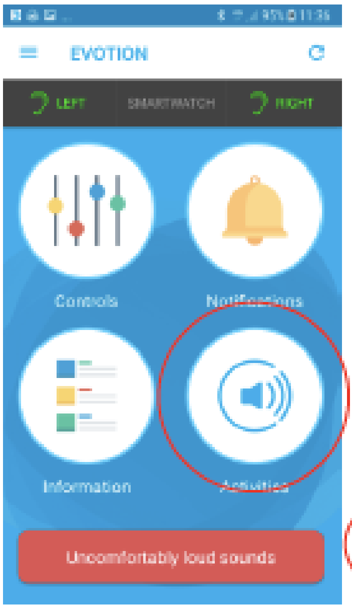
Answer Two Questions

Select your responses and press ok.

Results

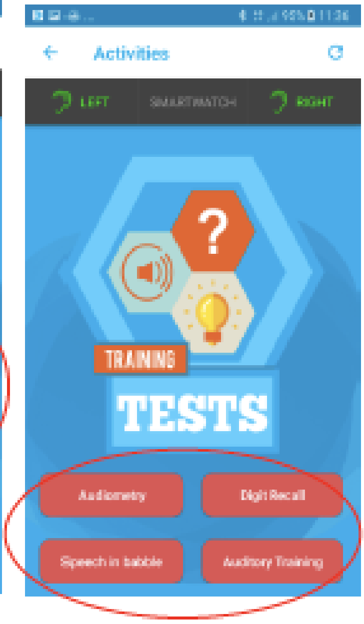
You may be prompted to take some additional tests within the mobile app.

TESTING YOURSELF



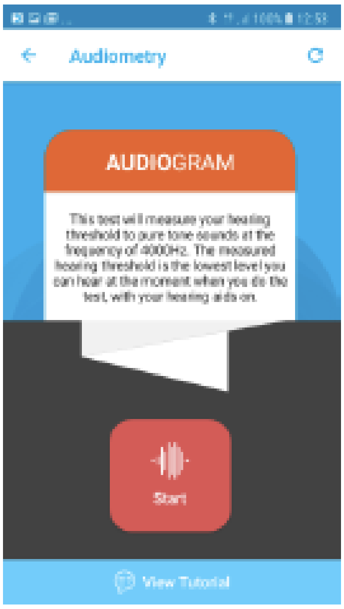
Select Activities

Press the 'Activities' button to access the tests and the Auditory Training.



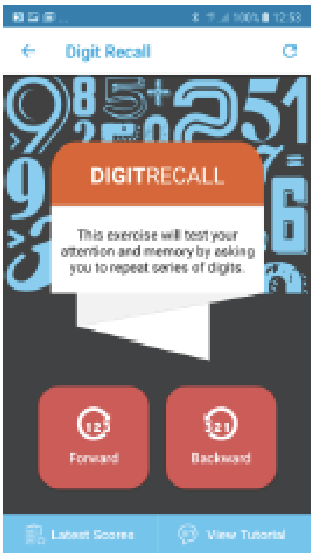
Choose An Activity

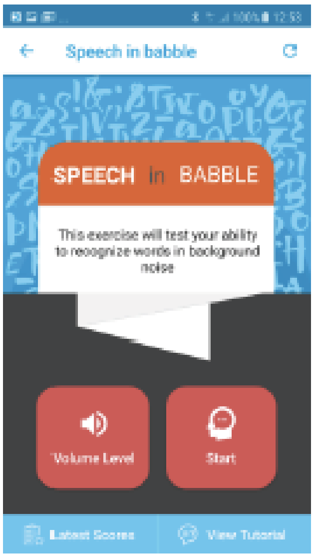
Select which of the test you would like to complete or the Auditory Training.

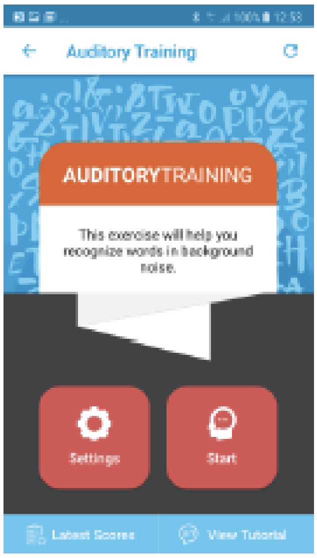


Audiometry

Do this test if you have been exposed to an uncomfortably loud sound or if you feel your hearing has changed.







Digit Recall

Complete 'Forward' and 'Backward' parts twice: do it once within the **first week** after receiving the mobile phone and again **4 weeks** later.

Speech in Babble

Complete the test twice: do it once within the **first week** after receiving the mobile phone and again **4 weeks** later.

Auditory Training

Do the training **30 minutes** a **day** for at **least 3 days** a **week** for the first **5 weeks** after receiving the mobile phone.