DEVELOPMENT AND TEST TRAIL OF COMPUTER BASED AUDITORY-COGNITIVE TRAINING MODULE FOR INDIVIDUALS WITH COCHLEAR HEARING LOSS

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Abstract

In spite of much technological advancement in the hearing aids, individuals with hearing impairment are not completely satisfied with the benefit from the hearing aids in the real-life listening needs. Hence, only fitting with a good hearing aid is does not complete the rehabilitation process. The earlier literature has shown relation between the working memory and speech perception. The purpose of the present project develop a software based auditory and cognitive training modules. Furthermore, it is also proposed to test the software module to determine whether the additional training in cognitive factors, specifically the working memory has influence on speech perception in noise. For this purpose an auditory and cognitive training software module was developed in collaboration with voice and speech systems, Bangalore. Auditory module of the software consisted of training paradigms in various difficult listening environments such as speech in noise, reverberation, rapid rate and vociding. Difficulty levels during the training varied adaptively. As the training progressed to higher levels speech was degraded using multiple distortions. Cognitive module consisted of skills to improve working memory such as training on forward, backward, ascending, descending, operation, reading spans. All the material were developed in Kannada, however, it may be easily adopted to any other language. Developed software was test run on 5 individuals with cochlear hearing loss. Outcome was measured using speech perception in noise, psychoacoustic skills, working memory measures and P300. Results showed that training resulted in significant improvements in performances even on tasks that were not directly trained. P300 amplitudes were significantly enhanced following training. Thus, the auditory cognitive training is proved to be effective in spite of individual variability.

Chapter 1

INTRODUCTION

Verbal communication often occurs in noisy backgrounds. The understanding of speech desires an appropriate acoustic communication context and an anatomical and physiological integrity of peripheral and central auditory systems. But, in the presence of noise, the likelihood of obtaining the acoustic information reduces. In other words, the speech consists of two components namely, the envelope and the temporal fine structure. The *envelope* refers to the slowly modulating aspect of the speech signal and the *temporal fine structure* (*TFS*) represents the swiftly modulating aspect of the signal that carries the envelope. In the presence of noise, the temporal fine structure cues are altered, thus affecting understanding of speech.

Effects of hearing loss on Speech perception in Noise:

As mentioned earlier, the presence of noise affects understanding of speech in every person. However, this issue is aggravated in patients with sensori-neural hearing loss due to their inability to extract the temporal fine structure of sounds in the presence of background noise. Thus, the speech perception in the presence of noise is affected in these individuals even when the audibility is matched with that of individuals with normal hearing. Nevertheless, their ability to use the envelope cues remains intact, thus preserving the understanding of speech in quiet (Lorenzi, Gilbert, Carn, Garnier, & Moore, 2006).

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Along with the above reasons, many studies have proposed that within a group of individuals with sensorineural hearing loss, there are variations in the ability to recognize speech in the presence of noise, even when their hearing loss is the identical (Preminger & Wiley, 1985; Plomp, 1986). A study by Crandell (1991) has shown that the speech recognition thresholds in noise could vary as much as 15 dB SPL between the individuals with identical hearing loss. Thus, there are individual variations in a person's susceptibility to noise even when controlled for hearing loss. This explains the reason behind the variation in the amount of benefit obtained from amplification between the individuals.

Effect of Cognition on Speech perception in noise:

It is well known that the understanding of speech in the presence of noise is a complex task. This requires listeners to attend to a primary target, while ignoring the competing signal. In order to do this, thebrain must convert the stream of acoustic energy into features and objects, seamlessly combine auditory and visual information, and prioritize processing of relevant stimuli. Along with this it retains the capability to react quickly to unexpected events. Also, the brain must memorize the immediate past, predict what is going to happen next and learn to categorize new features and objects. For instance, in a crowded cocktail party, one can selectively attend to a given conversation despite interference from multiple overlapping conversations, especially when seeing the lip movements of the speaker. Yet background noise and other conversations are automatically analyzed to some extent, as evidenced by attention being drawn to unexpected (i.e. unpredictable) events, such as one's name being brought up in a background conversation.

Conway, Cowan and Bunting (2001) and Coleflesh and Conway (2007) studied the relationship between the working memory capacity of the selective and divided attention dichotic listening tasks. Conway et al (2001) reported that individuals with lower working memory capacity performed poorly on selective attention dichotic listening tasks and were more sensitive to irrelevant messages compared to individuals with higher working memory capacity. Coleflesh and Conway (2007) reported that individuals with higher working memory capacity have the ability to control the focus of attention during the listening task depending on the task demands. Hence an extra cognitive effort especially working memory is required to recognize speech in noise. The listening difficulties observed in the elderly listeners could be due to age-related changes in the peripheral auditory system (Davis, 1994; Willot, 1991), changes in the central auditory system (Frisina & Frisina, 1997; Kim, Frisina, Mapes, Hickman, & Frisina, 2006) along some cognitive changes (CHABA, 1988; Pichora-Fuller, Schneider, & Daneman, 1995; Wingfield, Tun, & McCoy, 2005).

Hearing aid fitting:

The individuals with sensori-neural hearing impairment experience relatively little difficulty understanding one talker in a quiet listening environment, when provided with appropriate amplification in the speech range. However, they report difficulty understanding speech in noise and in multi-talker situations.

Over the last decades there have been significant advances in the design of hearing aids. The digital hearing aids with the incorporation of noise reduction

algorithms; improved microphone and receiver technology have enabled improvements in speech perception compared to the analog sound amplification devices. The Complex digital signal-processing algorithms now enable fittings that are vastly more variable than would have been possible with analogue technology. Although the recent digital technology has improved the ability to provide increased audibility and better SNRs, the individuals with hearing loss continue to struggle when listening in difficult environments (Hawkins & Yacullo, 1984; Valente et al., 1995).

In a large scale study 134 adults were evaluated over a 1-year period after the hearing aid fitting using a battery of outcome measures and tests for variables that might predict the success of older adults with hearing aids (Humes, 2003; Humes and Wilson, 2003). Structural equation modeling was used to determine the relationship between outcome measures and predictor variables. Three outcome measures were modeled: speech recognition, hearing aid usage, and subjective benefit and satisfaction. Not surprisingly, speech recognition performance was predictable from audibility and age. Subjective benefit and satisfaction was negatively related to judgment of sound quality and to loudness discomfort level. Hearing aid usage was positively related to duration of prior hearing aid experience and to number of years in the workforce, but it was negatively related to adjustment, speech recognition, and subjective benefit and satisfaction (*i.e.,* use was higher for those with more problems). The one predictor variable that was related to all three outcome measures was cognitive ability (verbal IQ), which was positively related to speech recognition and subjective benefit and satisfaction but negatively related

to hearing aid usage. Based on these findings, even though, the main personal factor guiding hearing aid fitting continues to be the basic audiometric profile of the individual, age and cognitive ability also influence fitting decisions and it seems that hearing aid usage is greater by those who may be less able to compensate (lower adjustment and lower cognitive ability).

Auditory and cognitive training:

Research has shown that it is difficult for the adult hearing aid users to understand speech especially in adverse listening conditions (Tun & Wingfield, 1999). Even after using hearing aid for many years, they perceive minimal benefit from amplification (Kochkin, 2005). The auditory rehabilitative efforts beyond amplification may provide the hearing aid users with added benefit to understand speech in noise. Auditory training is one type of rehabilitation that may augment listening abilities of individuals with hearing impairment.

A study by Olsen(2010) examined the behavioural effects of an auditory training program called Listening and Communication Enhancement (LACE™) in the Digital Video Display (DVD) format in new and experienced hearing aid users.Participants in the training groups completed twenty, 30 minute training lessons from the LACE™ DVD program at home over a period of 4-weeks. Trained group participants were evaluated at baseline, after 2-weeks of training and again after 4- weeks of training. Participants in the control group were evaluated at baseline and after 4-weeks of HA use. Findings of the study indicated that both new and experienced users improved their understanding of speech in noise after training and perception of communication function. Effect size calculations

suggested that a larger training effect was observed for new HA users compared to experienced HA users. New HA users also reported greater benefit from training compared to experienced users.

A meta-analysis of six articles (1970 to 2009) by Chisolm and Arnold (2012) revealed that there was a reliable improvement in speech recognition after auditory training in individuals with hearing loss. But the improvement was very small.   For training to be an effective intervention, the improvements observed during training require to generalize to listening in natural situation. Earlier studies have shown that the auditory and cognitive training is an effective intervention for individuals with hearing impairment. They have reported that generalization could be observed for both auditory as well as cognitive training. But, a combination of auditory and cognitive training has shown more benefits compared to auditory training alone. This is because, brain plasticity enables a hearing aid user to learn new mappings between sound inputs and stored knowledge since there is a connection between auditory and cognitive processing.

In India, many auditory training modules have been developed for children with hearing impairment for children with auditory processing disorders, for adults with auditory dys-synchrony (Chandraleka, 2000; Priya, 2007; Yathiraj, 2011; Kumar, 2013). These training modules focus primarily on auditory modality and little or no focus has been given to cognitive modality. Moreover, most of these training modules specifically aim at children with hearing impairment.

Need for the study:

In spite of much technological advancement in the hearing aids, individuals with hearing impairment are not completely satisfied with the benefit from the hearing aids in the real-life listening needs. Hence, only fitting with a good hearing aid is does not complete the rehabilitation process. The earlier literature has shown relation between the working memory and speech perception. The purpose of the present project develop a software based auditory and cognitive training modules. Furthermore, it is also proposed to pilot the software module to determine whether the additional training in cognitive factors, specifically the working memory has influence on speech perception in noise.

Aim

Aim of the current project was to develop a software based auditory cognitive training module for adults with hearing impairment and to test run the developed software on individuals with hearing impairment.

Objectives

1. To develop a auditory-cognitive training module for adults with cochlear hearing loss

2. To assess the influence of auditory-cognitive training material on auditory skills

3. To document the auditory neuro-physiological (ERPs) changes, if any, secondary to training

Chapter 2

METHOD

The method included two phases

Phase 1: Development of the auditory and the cognitive training modules

Phase 2: Test running of the developed software

Phase I: Development of auditory-cognitive training modules

Material preparation:

The materials for the auditory module included sentences, simple stories and paragraphs in Kannada language. The materials used for cognitive module included digits, shapes, Kannada words, mathematical problems, non-native alphabets and pictures of common lexical categories. Materials selected for training and testing were based on standard tests used to assess respective skills.

The Auditory module:

The materials for the auditory module included sentences, simple stories and paragraphs in Kannada language. A total of 500 four-word Kannada sentences were selected for preparation of training material. Out of the 500 sentences, 300 sentences were selected from sentence list developed by Geetha and Kumar (2012). Another 200 sentences were prepared by asking ten native Kannada speakers, to write regularly used four word sentences. The entire set of 500 sentences was given to fifteen native Kannada speakers to rate for

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familiarity and predictability. These 15 participants had normal hearing thresholds on pure tone audiometry in octave frequencies between 250 Hz to 8 kHz. Furthermore, all of them had clinically normal speech language skills as assessed informally by the research officer. For familiarity rating, a 3-point rating scale (unfamiliar/ familiar/ very familiar) was used. Here the individuals were asked to rate the given sentence as unfamiliar- if the sentence was not known, familiar-if the sentence was recognizable but not used regularly, very familiar- if the sentence was well known and used regularly. For rating predictability, they were provided with a 5-point rating scale with '1' as 'unpredictable' and '5' as 'predictable'. The individuals were asked to rate each sentence as unpredictable' if they were not able to predict the fourth word of the sentence by looking at the first three words, predictable, if they were able to predict the last three words by looking at the first word. Also they were asked to underline the predictable words along with the rating. The familiarity and predictability rating of all the sentences were analysed and the number of predictable words (underlined words) for each sentence was noted. The scores of predictability rating of all the subjects were averaged for each sentence. Based on the scores the sentences were divided in to two sets i.e. high predictable and low predictable sentences. The sentences having an average score of 3.5 or above were considered as highly predictable and those with a score less than 3.5 were considered as low predictable sentences. The sentences which were rated as familiar or very familiar by 80% of the individuals were separated from unfamiliar sentences and they were incorporated to in the stage-I of auditory training module. The unfamiliar sentences were incorporated to stage-II and stage-III of auditory training module.

For the stage-IV of the auditory module, stories and paragraphs were needed in order to increase the difficulty. The required stories and paragraphs were selected from Kannada news papers, magazines and school text books. The selected stories/ paragraphs were slightly modified if required. For each story or paragraph ten questions were prepared that could be answered if participants understands the story or paragraph. Before including those in training module stories were presented to ten native speakers of Kannada and it was ascertained that they could answer all the questions after listening to story/paragraphs. Material used in the testing phase was not used in the training phase. The above speech materials were mixed with noise, changed in terms of reverberation, time compression and vocoding automatically by the software during the auditory training.

Cognitive module:

The materials used for cognitive module included Kannada words, digits, shapes visual patterns, common pictures, Kannada sentences and simple mathematical problems. These materials are used to tap auditory, visual and visual-spatial working memory skills. Examples of the materials and presentation of stimulus s explained in the procedure section. Table 2.1 gives the working memory tasks implemented in the software along with their short descriptions.

Table 2.1. Working memory tasks implemented in software *(A=Auditory, V=Visual, S-Spatial , V-S=Visuo-Spatial).*

	Working memory tasks	Description
1	Forward span (A,V, S)	Presentation sequences of digits/shapes/highlighted blocks with increasing levels of difficulty (longer sequences being more difficult). It required subjects to repeat/arrange/indicate the sequence in the same order.
2	Backward span (A,V, S)	Presentation sequences of digits/shapes/highlighted blocks with increasing levels of difficulty (longer sequences being more difficult). It required subjects to repeat/arrange/indicate the sequence in the reverse order.
3	Ascending Span (A, VS)	Presentation sequences of digits/ polygonal shapes with increasing levels of difficulty (longer sequences being more difficult). It required subjects to repeat/arrange/indicate the sequence in the increasing order.
4	Descending span (A, VS)	Presentation sequences of digits/ polygonal shapes with increasing levels of difficulty (longer sequences being more difficult). It required subjects to repeat/arrange/indicate the sequence in the decreasing order.
5	Paired associate	Presentation of series of word pairs or shapes in

	learning (A, V, S)	each trial. At the end of each trial, only one item of each pair was presented and the subject was required to choose the other item of the pair from the items on display.
6	Running Span	Presentation of sequences of 10 to 20 digits/shapes in random order. Subjects were asked to recall the most recent N digits/shapes in the same order.
	Pattern recognition memory	Presentation of sequences of visual patterns one at a time. Participant needs to identify pattern which was already seen in the presented sequence in a pair of patterns.
7	Counting span	The counting span task involved counting the target shapes and remembering the count totals for later recall.
8	Math span	Presentation of sequences of 2-8 simple mathematical operations. The subject was required to solve each mathematical operation and remember the answer for later recall.
9	Operation span	Presentation of sequence of mathematical operation and a word. Subjects need to remember words
10	Reading span	Presentation of sequence of sentences along with Kannada letter. Participants need to recall the

		letter

A demo power point presentation (ppt) was created for each task in order to check the difficulty level and the content. In the demo ppt, 4 items were presented for each task. The demo ppt was presented to ten subjects who were under graduate and post graduate students. They were asked judge the difficulty of each task on a 5-point rating scale (1-very easy, 5-very difficult). Also, the subjects were allowed to write remarks and suggestions about the type of task. There were remarks and suggestions for some of the visual tasks. Considering the remarks and suggestions of the subjects, few modifications were made. After the modifications, the demo ppt of the modified tasks was given to the same 10 subjects for rating the difficulty. The scores given by all the participants were averaged for each task. Based on the average score, the tasks were divided into two sets, simple tasks and complex tasks. The tasks having a score less than or equal to 2.5 were considered as simple tasks and the tasks having score more than 2.5 were considered as complex tasks. Finally, the tasks were distributed as given in the table 2.2. Detail description of the tasks and its implementation in the software is provided in appendix I. Depending on the feasibility tasks were designed for training visuo-spatial or only visual skills.

Table 2.2: The distribution of the working memory tasks as simple and complex tasks (A=Auditory, V=Visual, S-Spatial , V-S=Visuo-Spatial).

Simple tasks	Complex tasks
Forward span: A, V, S	Running span: A, V-S
Backward span: A, V, S	Pattern recognition memory

Ascending span: A, V-S	Math Span
Descending span: A, V-S	Counting Span
Paired associate learning: A, V-S	Reading Span
	Operation Span

Recording:

The auditory stimuli for the auditory module (sentences) and cognitive module (words, digits, stories and paragraphs) were spoken by a 25 years old female, native Kannada speaker. The speaker was instructed to maintain neutral intonation, normal vocal intensity, pronunciation and tempo. These stimuli were digitally recorded with a sampling frequency of 44,100 Hz and 16 bit resolution into a computer with the Adobe Audition software version 3.0 and were edited using the same software. The microphone was kept at 6 inches distance from the mouth. The various levels and exercises implemented in the Auditory and Cognitive training modules are described below.

2.1.2 Development of the software

Two separate software-based training modules were developed for the structured training in auditory and cognitive domains: The **auditory training module** and the **cognitive training module**. Software was prepared in collaboration with Voice and Speech systems Bangalore. Auditory training module consisted of training on speech perception in degraded listening conditions. It was further divided into auditory module I and auditory module II. Both the auditory modules had a testing phase and a training phase. Auditory

module I consisted of stage I and stage II and Auditory module II consisted of stages III and IV. Cognitive training module consisted of training on working memory skills in auditory, visuals as well as visuo-spatial domains. This was also sub divided into cognitive module I and cognitive module II. There was a testing phase and a training phase in both the cognitive modules and additionally there was a pre- training phase in cognitive module II. Cognitive module I had simple working memory span task while cognitive module II had complex working memory spans. Currently the module was developed in Kannada. However, it can be used in any language with minor modifications.

Software design and scoring procedure

3.1.1 Features of auditory-cognitive module

The developed auditory-cognitive training module has the following features:

➢ It is user friendly and interactive.

➢ It is compatible with any of the commercially available 32 bit PCs.

➢ The training starts near the individual's skill threshold as baseline is obtained prior to initiation of training for each task.

➢ It is sufficiently difficult to maintain interest and attention while being sufficiently manageable to minimize fatigue.

➢ Training module incorporates an adaptive procedure, where difficulty levels of the items vary based on subjects' performance.

➢ It proceeds at the patient's optimal pace and.

➢ It provides reinforcement to the patient.

➢ The progress in each level/sub- level is saved and a graph is displayed at the end of each session.

➢ It makes the patient assume some degree of responsibility for the ultimate outcome objective.

3.1.2 Software design

A detail working instructions and manual for the software is provided in Appendix II. Brief, description of salient features is provided here.

1. As soon as the training module icon is clicked, a window for selection of user ID appears. The entire list of user Ids is shown and by clicking on the User ID the required one is selected. Figure 3.1 is the screen shot of user ID window.
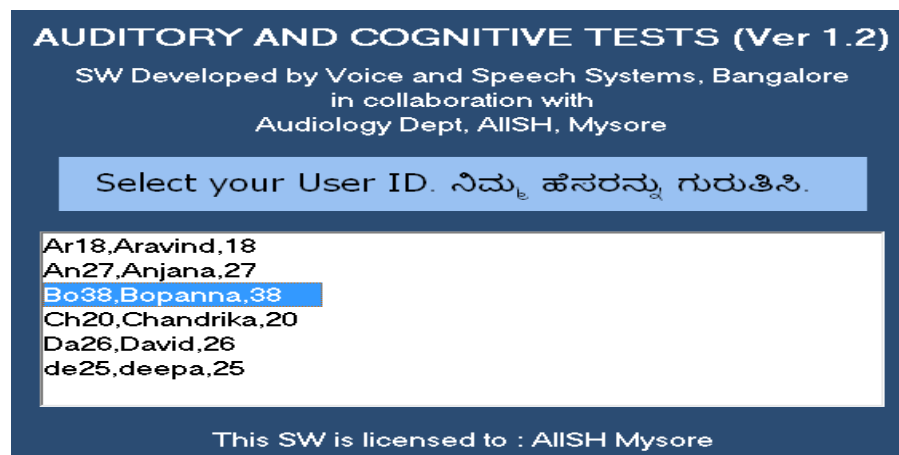
Figure 3.1: screen shot of the user ID window

2. Once user ID is selected, four modules and an audiogram sheet appear on the screen. The module for which key is connected is highlighted and the required (highlighted) module should be clicked. The auditory thresholds should be entered before clicking the required module. The screen shot of the display of four modules is given in figure 3.2.
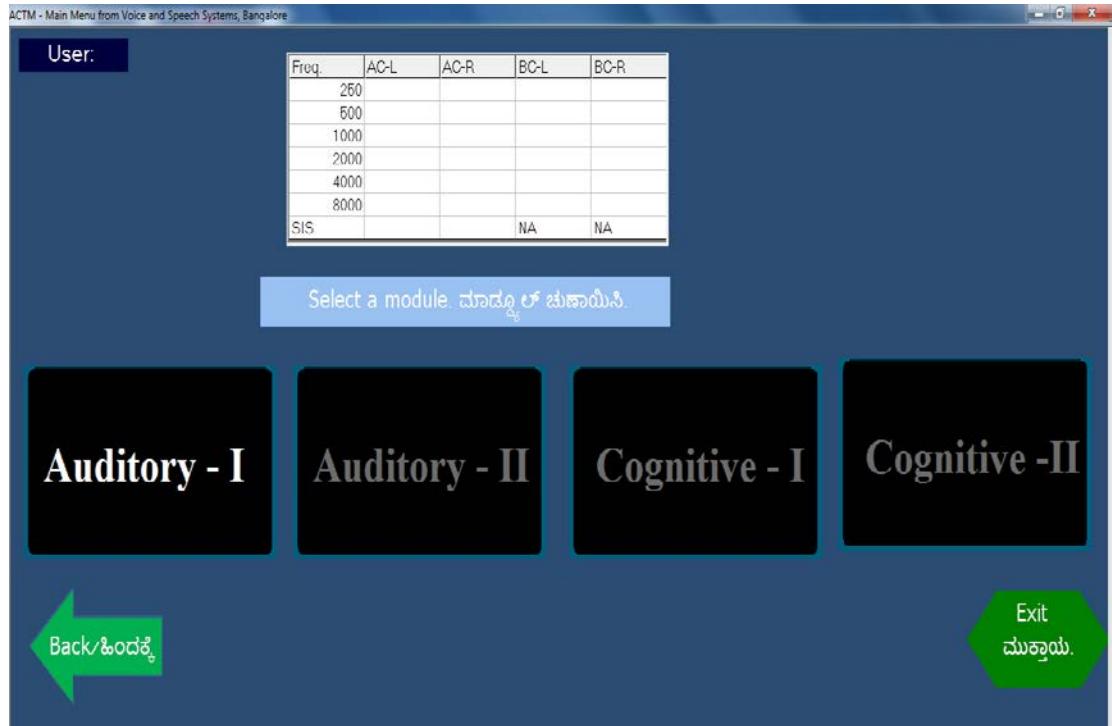
Figure 3.2: screen shot of the four modules and audiogram

3. Once the module is selected, the tasks included in that module are displayed and the subject has to select the required task for training. The screenshots of auditory module and cognitive module are shown below in figure 3.3 and 3.4.

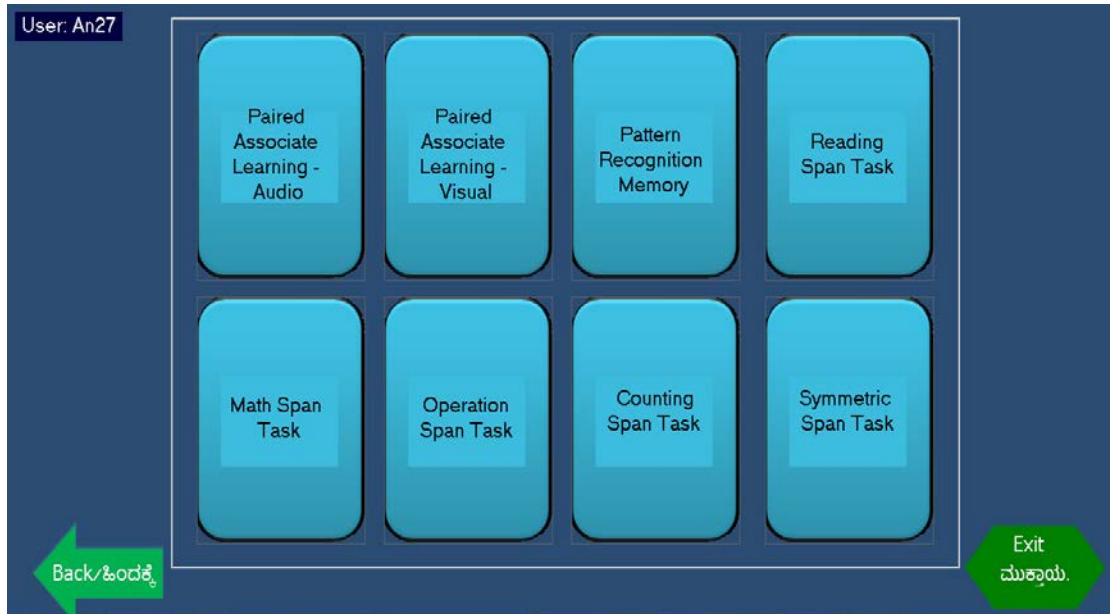

Figure 3.3: Screen shot of auditory module

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Figure 3.4: Screen shots of Cognitive module part I (upper row) and part II (lower row).

4. After selection of the task a window appears to choose training mode or testing mode. The software checks for base level and start level and recommends use of 'test mode' or 'training mode'. The 'test mode' will be recommended (figure 3.5, upper panel) if the base level is not available or else the 'training mode' will be recommended (figure 3.5, lower panel).

Figure 3.5: Screen shot of selection of 'mode'. Upper panel shows suggestion for use of 'test mode' and lower panel shows for 'training mode'.

5. After mode selection the subject is provided with the instructions and he/she should press the continue button once he/ she understands the instruction. An example of instruction window is shown in figure 3.6.
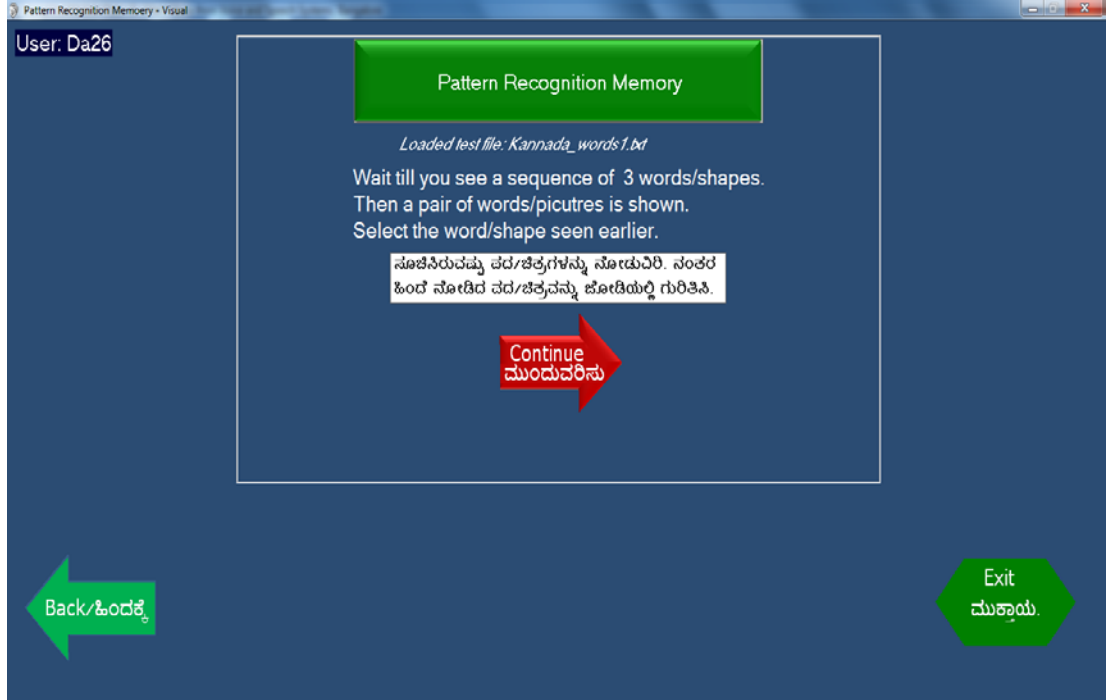

Figure 3.6: Screen shot of instruction window of pattern recognition memory

6. After the instruction, a window having details about the level and stage of the task appears. It consists of a 'run' button and once this button is clicked, the actual task starts. Also, it has an 'instruction' button, which will be displayed even during the training and the subject can get back to instructions whenever required. Figure 3.7 shows the details of the auditory task, 'run' button and 'instruction' button.

Figure 3.7: Screen shot having details of the task, instruction button and run button.
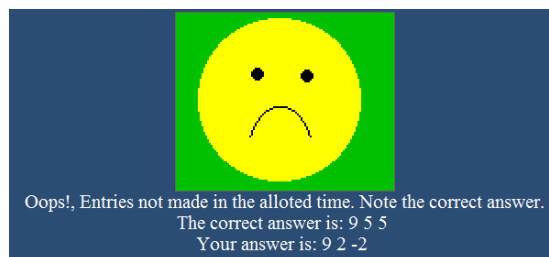
7. *Reinforcement and feedback:*

Reinforcement and feedback is provided only in training mode. For each trial of a given task, positive/ negative reinforcement is given along with a feedback about whether the response was correct or wrong.

In a given trial, if accuracy score =1, a positive reinforcement is given.
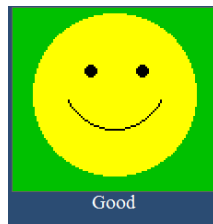
In a given trial, if accuracy =0, a negative reinforcement is given along with a feedback.

During each trial, the feedback about the time taken to respond is shown both graphically and in text mode. If the response time exceeds the allotted time, then it is considered as a failure. Negative reinforcement (as above) is given along with a feedback that the entries were not made in the allotted time.

8. *Output files*

The results of the 'Test Mode' and 'training mode' will be saved automatically into files and the names for these files are automatically assigned. In Test mode the scores will be stored only if the test is complete. Details regarding various output files that are generated is provided in Appendix II.

2.2 Phase II: Test trail of auditory-cognitive training modules

During the development phase of the software, after the development of each module it was test run on 10 normal hearing adults to make sure that the material used is appropriate and software is running as desired. After the development of auditory-cognitive training module, a pilot study was conducted to de-bug and field test the software. This phase involved short duration training on some auditory as well as cognitive skills and assessment prior to the commencement and after the termination of training.

2.2.1 Participants:

All the participants in the current study was assigned to either experimental or control group. The experimental group consisted of 10 participants and underwent training in auditory and cognitive domains. Of the

10 only 5 completed the training regime and hence the data is reported only 5. Control group consisted of five participants (3 males) and they did not undergo any training. Participants in the experimental group were naïve hearing aid users and each participant underwent structured auditory as well as cognitive training after the hearing aid fitment. The selected subjects were in the age range of 40-60 years (3 males) and all of them had mild to moderate bilateral acquired cochlear hearing loss. They had type 'A' tympanogram and all of them were binaural digital hearing aids users. They underwent a structured interview to rule out any gross neurological, cognitive or otological problems and an informed consent was taken from each participants before recruiting them for the study. With the interview only gross neurological and cognitive problems were ruled out. Cognitive training was given to participants even though they had normal cognitive skills see if the training on cognitive skills improves speech perception and other auditory abilities. All the participants were native speakers of Kannada. All of them had minimum of 10 years of formal schooling. Each participant was fitted with binaural digital hearing aids using the standardized clinical protocol followed at Department of Audiology, All India Institute of Speech and Hearing, Mysore. Fine-tuning of the hearing aids was carried out based on the feedback and requirements of the individual participants. Following the hearing aid fitment a detailed behavioural and electro-physiological assessment were done to obtain a baseline before initiating the training. Baseline auditory skills measured included speech perception in noise (SNR-50), auditory digit span, auditory sequencing span, operation span and reading span. The speech perception in noise and working memory skills were assessed before and

after the training. Electrophysiological assessment involved recording of cortical evoked potentials for speech stimulus.

Table 1. Demographic details of the participants

Experimental group	Age	Sex	PTA right ear (in dB)	PTA left ear
Participant 1	40	Male	45	42.5
Participant 2	45	Male	42.5	45
Participant 3	50	Male	55	40
Participant 4	55	Female	40	40
Participant 5	60	Female	35	42.5
Control group				
Participant 1	52	Male	40	52.5
Participant 2	40	Male	52.5	55
Participant 3	60	Male	55	40
Participant 4	57	Female	35	40
Participant 5	45	Female	45	50

2.2.2 Base line assessment of auditory and cognitive skills:

A baseline was obtained before starting training using 1 up 1 down procedure for all the tasks mentioned below. The lowest level where the subject gave 3 correct responses was considered as the baseline and training was started from one level just below obtained baseline.

Baseline auditory assessment

Speech in noise measurement. Speech perception in noise was evaluated using the Kannada speech in noise test (Methi et al. 2009). Seven equivalent lists from the original test were selected for the present study. Each list contained seven sentences mixed with the eight talker speech babble noise at different signal to noise ratios (SNRs). First sentence in each list was at +20 dB SNR, with SNR decreasing by 5 dB for each sentence and with the last sentence being presented at -10 dB SNR. Each sentence had 5 key words. These sentences were presented at 60 dB SPL using a personal computer (Dell Inspiron 15R) routed through a calibrated audiometer into a loudspeaker kept at a distance of 1m and 45^0 azimuth. The listener's task was to repeat the sentences presented and each correctly repeated key word was awarded one point for a total possible score of 35 points per list. Different lists were administered in pre and post training sessions.

Concurrent vowel identification. Five vowels /a/, /e/, /i/, /o/, /u/ were synthesized at the sampling rate of 44,100 Hz, using Klatt synthesizer. Each vowel was synthesized with a base F0 of 220 Hz. Base F0 of 220 Hz was chosen to simulate the F0 of a female speaker. All the five vowels were once again synthesized with different F0 which corresponded to 1, 2, and 4 semitones increase from base F0 (Eg:- 1 semitone increase from 220 Hz corresponds to 238.3 Hz). Each vowel had duration of 290 ms with 20 msec raised cosine onset/offset ramps. All the synthesized vowels were scaled to have similar amplitude. The formant characteristics of the vowels used for the concurrent

vowel identification task are given in table 2.3. These values were considered based on the normative study by Hillenbrand, Getty, Clark, and Wheeler (1995).

Table 2.3. *Format frequencies used for synthesis of different vowels*

Vowel	F1 (in Hz)	F2 (in Hz)	F3 (in Hz)
/a/	936	1551	2815
/i/	437	2760	3372
/u/	459	1105	2735
/o/	555	1035	2828
/e/	536	2530	3047

Identification task was carried out separately for each semitone F0 condition. The listeners were first familiarized with all the vowels in a single vowel identification task. In the familiarization task, the listeners heard five repetitions of all the vowels in base F0 and semitones varied conditions. Feedback was provided for each response. For the purpose of concurrent vowel identification, the vowels were paired with each other. Same vowels were not paired even though they had different F0. Vowel /a/ was kept constant and other vowels were variable which were considered as target stimuli. Vowels within the pair were presented simultaneously to one ear at a time. APEX 3 software was used to present the randomized stimulus (Francart, Wieringen, & Wouters, 2008). Concurrent vowel identification was done at four different conditions. In all the four conditions, vowel /a/ with a base F0 (220 Hz) was kept constant. Whereas, the variable vowels (/i/, /u/, /o/ and /e/) had F0 that were varied in semitone levels. In the first condition both the vowel /a/ and variable vowel were presented at base F0. This resulted in 0 semitone difference between the F0 of

two concurrently presented vowels. In second condition, F0 of the variable vowels were increased by 1 semitone (238.3 Hz). In third and forth condition, F0 of variable vowels were increased to 2 semitone levels (256.6 Hz) and 4 semitone levels (292.2 Hz) respectively. In all the conditions, F0 of vowel /a/ was maintained at 220 Hz.

Participants were seated in a quiet room in front of a computer monitor at a distance of 1.5 feet. The four variable vowels (/i/, /u/, /o/, /e/) appeared on the screen. Variable vowels and vowel /a/ with base F0 were presented through Sennheisser HD449 circumaural headphones at 80 dB SPL. Stimuli were presented monaurally to the participants' at their most comfortable level. The participants were instructed to click on the corresponding vowel button on the computer screen after hearing the stimuli. Each of the four variable vowels was presented 10 times in a randomized order. This resulted in a total of 40 of presentations in each of the semitone condition and a total of 160 presentations for all 4 semitone difference conditions. Participants were encouraged to guess if they were not sure. The results were tabulated in confusion matrices for analysis.

Temporal processing tasks.

All temporal processing tests except for the duration pattern test were carried out using mlp (maximum likelihood procedure) toolbox, which implements mlp in Matlab (Grassi &Soranzo, 2008). The maximum likelihood procedure employs a large number of candidate psychometric functions and after each trial calculates the probability (or likelihood) of obtaining the listener's response to all of the stimuli that have been presented given each psychometric function. The psychometric function yielding the highest

probability is used to determine the stimulus to be presented on the next trial. Within about 12 trials, the maximum likelihood procedure usually converges on a reasonably stable estimate of the most likely psychometric function, which then can be used to estimate thresholds. Stimuli were recorded at 44,100 Hz sampling rate. A two-interval alternate forced-choice method using an mlp was employed to track an 80% correct response criterion. 30 trials were used in the present study. During each trial, stimuli were presented in each of two intervals: One interval contained a reference stimulus, the other interval the variable stimulus. The participant indicated after each trial which interval contained the variable stimulus. This procedure was used in all temporal processing tests except for the duration pattern test. For all the tests stimuli were presented through Sennheisser HD449 circumaural headphones at 80 dB SPL.

Gap Detection Thresholds. The subject's ability to detect a temporal gap in the center of a 750 ms broadband noise was measured. The noise was 0.5 ms cosine ramps at the beginning and end of the gap. In a two-interval alternate forced-choice task, the standard stimulus was always a 750 ms broadband noise with no gap, whereas the variable stimulus contained the gap.

Modulation Detection Thresholds. Temporal modulation refers to a recurring change (in frequency or amplitude) in a signal over time. A 500 msec Gaussian noise was sinusoidally amplitude modulated at modulation frequencies, 8 Hz, 20 Hz, and 60 Hz and at 200 Hz. Noises had two 10-msec raised cosine ramps at onset and offset. Subject had to detect the modulation and tell which interval had the modulated noise. Modulated and un-modulated stimuli were equated for total root mean square power. Depth of the modulated signal was varied

according to the subject's response up to an 80% criterion level. The modulation detection thresholds were expressed in dB by using the following relationship:

Modulation detection thresholds in dB = 20 log10 m

Where m=modulation detection threshold in percentage

Duration pattern test. A 1000 Hz pure tone was generated at 44,100 sampling frequency with two different durations (i.e. short 250 ms and long 500 ms), using Audacity software (ver. 1.3). By combining these two durations in three-tone patterns six different tone patterns were generated (Short Short Long; Short Long Short; Long Long Short; Long Short Short; Short Long Long; Long Short Long). Inter-stimulus interval was 250 ms within the pattern and 6 s between two different patterns. Following practice trials, 30 test items were administered. Participants were asked to verbally repeat the sequence. Each correctly repeated sequence was awarded one point for a total possible score of 30.

Base line working memory assessment

The procedures used to measure working memory capacity included simple working memory tasks and complex working memory tasks. For all the tests stimuli were presented through Sennheisser HD449 circumaural headphones at 80 dB SPL

Simple Working memory tasks. The simple working memory tasks included following:

➢ Auditory forward span

- ➢ Auditory backward span

- ➢ Auditory ascending span

- ➢ Auditory descending span

Forward and backward span. Here, the sequences of digits were presented auditorly and subjects were instructed to type the keys on the keyboard or click on the numbers displayed in the same order or in reverse order as presented. There was an inter stimulus interval of 1 second. Adaptive staircase technique was used to track the above mentioned spans. If the response is correct software increased the difficulty by 1 level and if the response is wrong difficulty level was decreased. This up-down was carried out on 6 runs and average of last four runs were considered for estimation of base line and was considered as the forward/backward span of the participant.

Ascending and descending span. Here, sequences of digits were presented auditorily and digits from 0 to 9 were displayed on the screen. The subjects were instructed to arrange the digits presented in ascending or descending order and then type the keys on the keyboard or click on the numbers displayed on the screen. Adaptive staircase technique was used to track the above mentioned spans. If the response is correct software increased the difficulty by 1 level and if the response is wrong difficulty level was decreased. This up-down was carried out on 6 runs and average of last four runs were considered for estimation of base line and was considered as the ascending/descending span of the participant.

Complex working memory tasks. The complex working memory tasks included the following:

> ➤ Operation span task

> ➤ Reading span task

Operation span and reading span. The operation span task and reading span task which were adapted from the versions used by Kane, Hambrick, Tuholski, Wilhelm, Payne, and Engle (2004). Guidelines recommended by Conway et al. (2001) were followed during administration and scoring. To be consistent with the Conway et al. terminology, each task consisted of "items" that varied in difficulty, which was manipulated by varying the number of "elements" per item. This terminology was consistent with psychometric lingo where a test (or task) consists of items that vary in difficulty. Both the tasks consisted of 12 items and the number of elements per item varied from 2 to 5, with three items at each level of difficulty.

Operation span task. In the operation span task, each element consisted of a mathematical operation and a word (e.g., IS [8*5] -25 = 21 ? SNOW). The participant's task was to read the math problem aloud, say "yes" or "no" to indicate whether the given answer was correct or incorrect and then say the word. After all the elements in an item were presented the participant was required to write the words in correct serial order. The difficulty of the items were be randomized such that the numbers of elements were unpredictable at the outset of an item.

Reading Span task. In the reading span task, each element consisted of a sentence, followed by a letter (e.g., Suresh was stopped by the policeman because he did not use helmet? R). The participant's task was to say the sentence aloud, respond "yes" or "no" to indicate whether the sentence made sense or not and then say the letter. As with operation span, after all the elements in an item were presented, the participant was required to write the letters in correct serial order and the difficulty of the items was randomized such that the number of elements are unpredictable at the outset of an item. Proportion scores were computed for each item by dividing the number of correctly recalled stimuli by the total number of stimuli in that item (e.g., if the participant correctly recalled two of four words, then the score for that item would be 0.5). The total proportion score was calculated as the average of the item proportion scores multiplied by 100 to yield a scale of 0–100.

Electrophysiological measures

Electrophysiological assessment involved recording of cortical potentials. A 64 Channel Compumedics Neuroscan (Compumedics-Neuroscan, Charlotte, NC, USA) EEG equipment with Synamps^2 amplifier was used to record auditory cognitive potentials. A Stim^2 system by Compumedics Neuroscan was used for stimulus presentation.

Stimuli:

The stimuli used for eliciting the P300 responses included three syllables */ba/, /da/.* Syllable /ba/ was used as frequent stimuli and the syllables /da/ was used as infrequent stimuli with a frequent to infrequent ratio of 4:1. These

syllables were spoken by an adult native speaker of Kannada. The spoken syllables were recorded using Adobe audition software (ver. 5) using 44100 Hz sampling frequency. The duration of each syllable was 170ms and the inter stimulus interval was 2000ms. These syllables were chooses as they represent place of articulation distinction and previous studies have shown that cochlear hearing loss individuals have problems in distinguishing place cues.

Recording of P300. The Audio CPT module of the Stim[2] system (Compumedics-Neuroscan, Charlotte, NC, USA) was used to present stimuli in pseudorandom order for recording P300 responses. P300 was recorded during a choice reaction time task.

The stimulus and acquisition parameters used to record the cortical responses are given in Table 2.4. Three syllables (/ba/, da/) were psuedoandomly presented at 60 dB SL through insert phones with a ratio of 4:1. The subjects were asked to respond to /da/ syllable by pressing the buttons on the response box. (button 1 for the /da/ and button 2 for /ga/). The response buttons were disposed on a specially made keyboard on which each finger tip rested naturally on the corresponding button. The responses were averaged for a total of 250 stimuli presented in a pseudorandom order. Additionally, Auditory long latency responses were recorded in the conventional repetitive paradigm to the deviant stimuli. This was done in order to rule out the exogenous factors of the stimuli contributing to the P300 waveform. The EEG was acquired using ACQUIRE 4.5 (Compumedics-Neuroscan, Charlotte, NC, USA) and was analysed offline in EDIT 4.5 (Compumedics-Neuroscan, Charlotte, NC, USA).

Table 2.4: Stimulus and acquisition parameters used to elicit the Cortical Responses

Stimulus Parameters	
Stimuli	/ba/, /da/
Frequent to infrequent ratio	4:1 (pseudorandom)
Ear	Binaural
Duration of stimuli	170 ms
Intensity	60 dB SL
Inter-stimulus Interval	2000 ms
Polarity	Rarefaction
Total Number of sweeps per recording	250
Acquisition Parameters	
Analysis time	1700 ms (-200 to 1500 ms)
Electrode locations	Fz,Cz and Pz referenced to Right mastoid along with Ocular channels.
Sampling frequency	20000 Hz
Amplification	10 times
Filter setting	DC to 80 Hz online 0.1-30 Hz offline
Artifact rejection	200 µV (offline only)
Electrode montage	Vertical
Response	Button press 1 for /da/

The electrode placement was done according to the international 10-10 EEG placement system (Chatrian, Lettich, & Nelson, 1985). Electroencephalograms (EEG) were recorded from three midline sites, Fz, Cz, and Pz, referenced to right mastoid usiong AgCl electrodes. An additional bipolar eye channel was placed with the non-inverting and inverting electrodes placed above and below the left eye respectively. The layout of the electrodes used is shown in Figure 2.1.
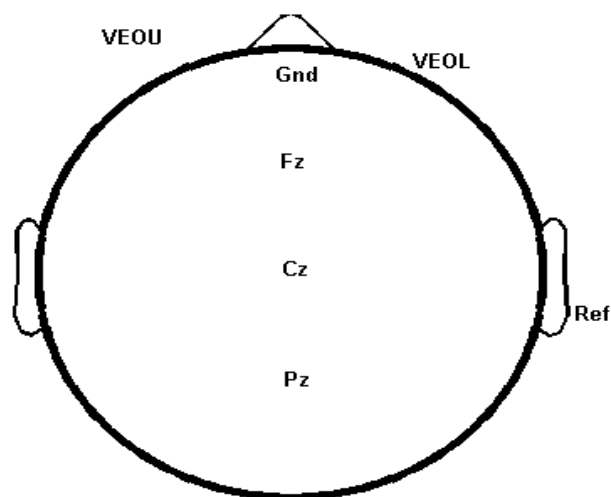
Figure 2.1: The layout of electrode sites used for the recording of cortical auditory evoked responses.

The EEG epochs was corrected for DC offsets and bandpass filtered from 0.1 Hz to 30 Hz with a zero phase FIR filter with 12 dB per octave slopes. The contamination of the EEG responses by the eye blinks/movements were removed using the ocular artefact reduction algorithm in the Edit 4.4. The EEG

epochs were then averaged separately for each stimulus. The averaged ERPs were baseline corrected for a 100-ms pre-stimulus baseline. The P300 component was designated as the largest positive deflection which peaked between 250 and 600 ms after the N1-P2-N2 complex in the infrequent waveform. The peak latency and baseline-to-peak amplitude of P300 was measured for each averaged ERP.

Auditory-cognitive training

To test trial the software, training was provided for the following tasks:

- Speech perception in noise

- Forward span: Auditory, Visual, Spatial

- Backward span: Auditory, Visual, Spatial

- Ascending span: Auditory, Visuo-Spatial

- Descending span: Auditory, Visuo-Spatial

- Running span: Auditory

The training for the aforementioned tasks was started within a week of hearing aid fitment. Before starting with the training, a baseline was obtained for each task and for each subject using the procedure mentioned in above section. Training was started from one level just below the obtained baseline. The subjects attended the training for 5 consecutive sessions and each session lasted for 120 minutes. Training was carried out in a quiet well illuminated environment. Training stimuli were presented at comfortable listening levels through a loud speaker. During training sessions participants wore their hearing aids and sat comfortable on a chair.. In training sessions subjects performed the tasks similar to that to testing (baseline) sessions but they were given feedback

about their responses. If the answers were incorrect, correct answers were displayed. The order of tasks for training was randomised and for each task training was given for 30 minutes. Training was provided for five days. Participants in the control group did not undergo any training

Chapter 3

RESULTS

Using the material and design described in method section a software for auditory and cognitive training was developed. Using this software ten individuals with cochlear hearing loss underwent auditory-cognitive training. Training included speech in noise, forward, backward, ascending, descending and running span training. Of the ten individuals only 5 completed training and hence results of only 5 individuals are reported. 5 individuals in control group did not undergo any training. For operation and reading span, training was not given but they were tested to check whether there was any transfer effect. Also the responses of electrophysiological tests such as P300 and FFR were recorded before and after the training. All the tests were repeated after a gap of one month on five individuals who served as control. The results of behavioural and electrophysiogical test/ training are explained below. Individual data of all the participants is provided in Appendix III.

Behavioural tests

Working memory skills.

Figure 3.1 shows the working memory scores of individual participants in pre and post training conditions. Figure 3.2 shows mean working memory scores assessed using various tests in experimental group and in control group. From the figures it can be seen that working memory skills were better in post training condition in experimental group. This difference was not seen in control group. Wilcoxon Sign rank test revealed that post training working memory scores are significantly better compared to pre-training scores on all the working memory tests. But, there was no significant difference between the two evaluations in the control group. It should be noted that there was improvement in reading and operation span though these skills were not trained. Table 3.1 provides the Z values and significance levels.
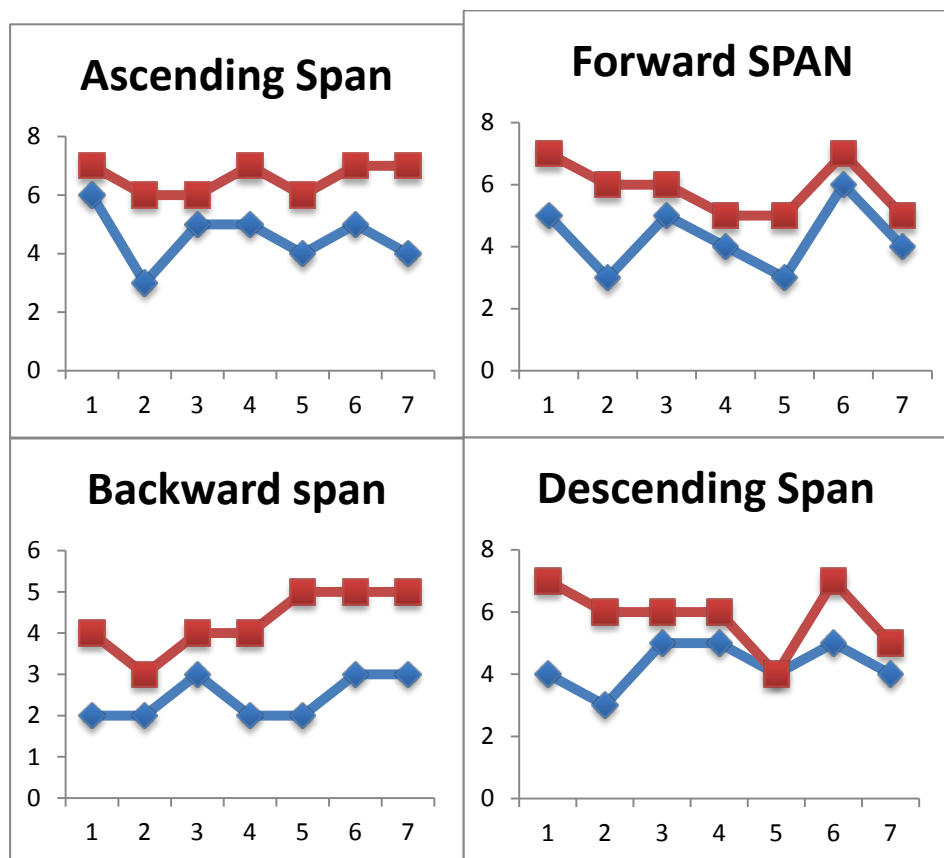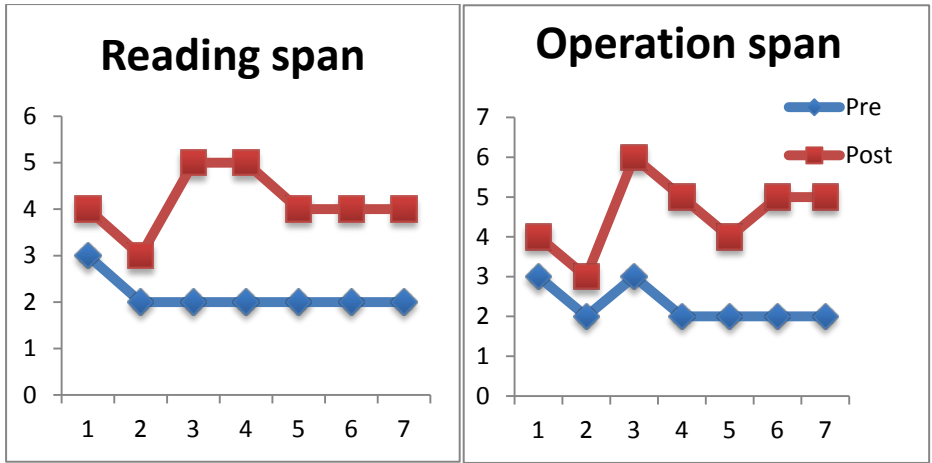
Figure3.1 Pre-training and post training working memory scores of individual participants. X-axis represents participants in the experimental group.
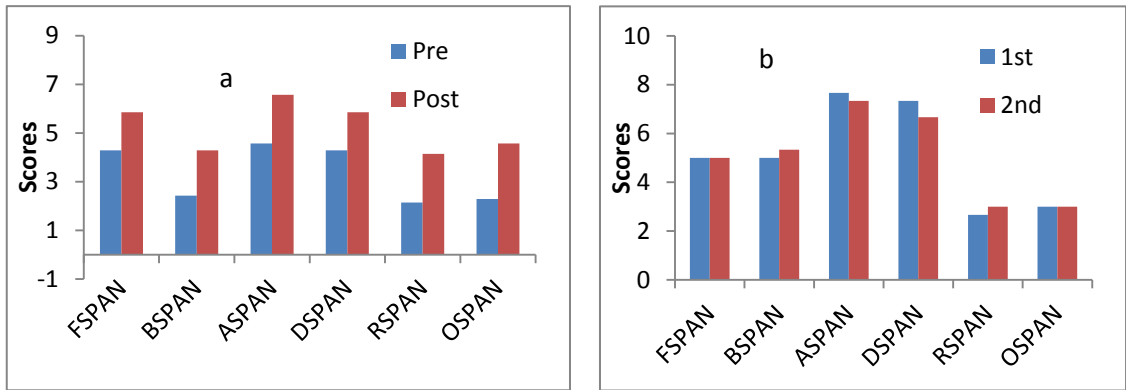
Figure 3.2. Baseline scores and training scores across sessions in various working memory tasks in experimental (a) and control (b) group. (FSPAN=Forward span, BSPAN = Backward Span, ASPAN= Ascending Span, DSPAN= Descending Span, RSPAN=Reading Span, OSPAN=Operation Span)

Table 3.1. z scores and p values for various working memory skills

		Experimental	Control
FSPAN	z	2.4	0.2
	p	0.016	1
BSPAN	z	2.4	1
	p	0.016	0.3

ASPAN	z	2.3	1
	p	0.017	0.3
DSPAN	z	2.2	0.3
	p	0.026	1.01
RSPAN	z	2.3	1
	p	0.017	0.3
OSPAN	z	2.4	0.4
	p	0.016	1.0

3.2.1.6 Auditory measures:

Figure 3.3 shows mean scores of different psychoacoustic and speech perception tests before and after training in experimental group. Figure 3.4 shows same for control group in first and second evaluations. From the Figure 3.3 it can be inferred that most of the auditory measures improved following training in experimental group and this improvement was not seen in the control group. Wilcoxon Sign Rank test revealed significant differences between pre-training and post-training scores in duration pattern test, gap detection test and in speech in noise test. Wilcoxon's signed rank test was performed to see the significance of difference between two evaluations. z value and p values are shown in table 3.2. It should be noted that in the auditory domain training was provided only for speech in noise perception. However, improvement could be observed in gap detection thresholds, duration pattern scores, frequency resolution, and speech in noise which were not trained.
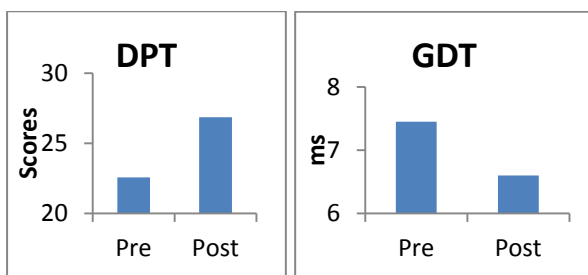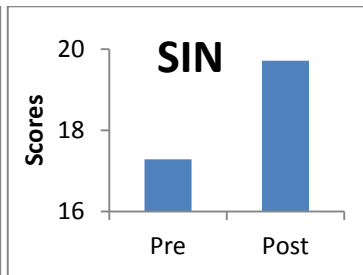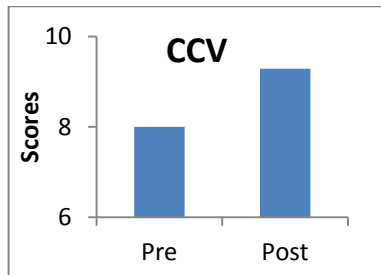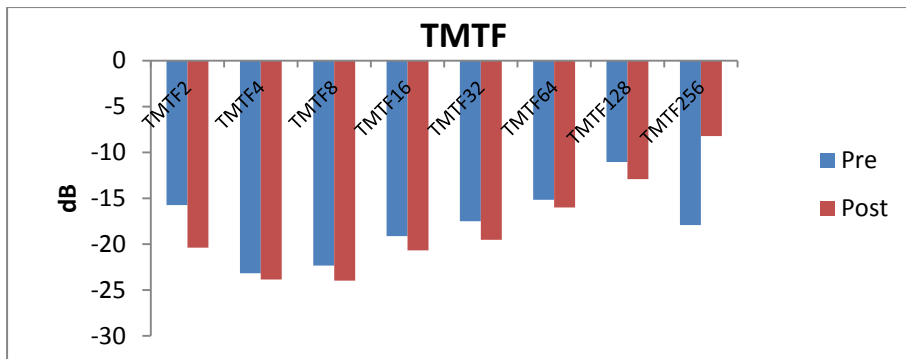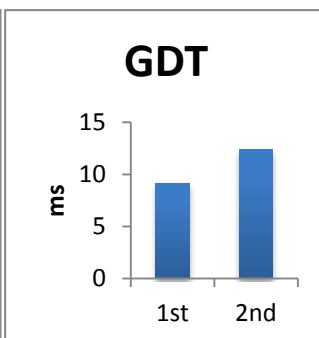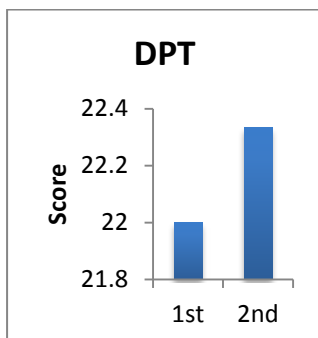
Figure.3.3.Scores of various auditory measures before and after training in experimental group. (DPT=Duration pattern test, GDT=Gap detection test, TMTF=Temporal modulation transfer function, CCV=Concurrent vowel identification, SIN=Speech on noise)
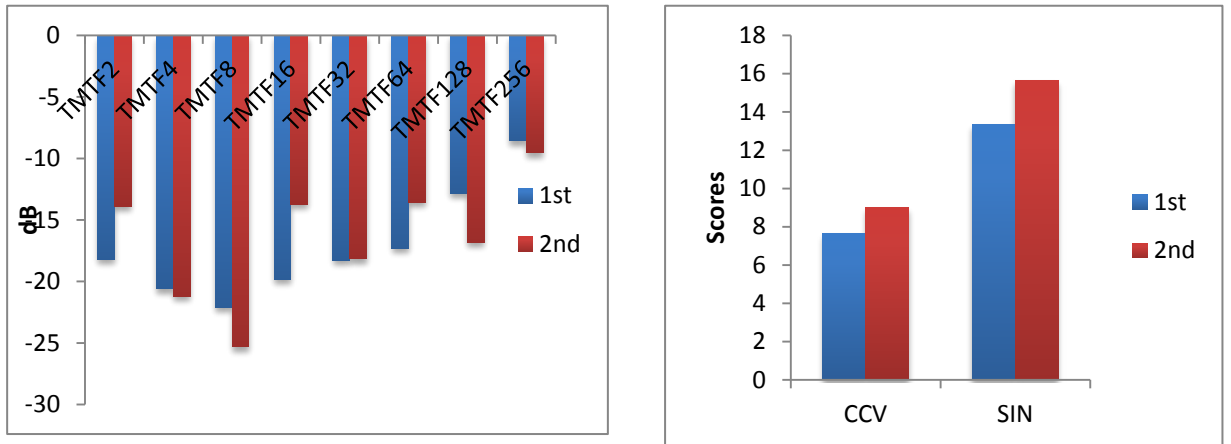
Figure.3.4. Scores of various auditory measures in first and second evaluation in control group. DPT=Duration pattern test, GDT=Gap detection test, TMTF=Temporal modulation transfer function, CCV=Concurrent vowel identification, SIN=Speech on noise)

Table 3.2 z scores and p values for various auditory measures in control group and experimental group

		Experimental	Control
DPT	z	2.04	0.2
	p	0.04	1
GDT	z	2.02	1
	p	0.04	0.3
Frequency resolution	z	2.3	1
	p	0.08	0.3
CCV	z	1.08	1
	p	0.27	0.3
SIN	z	2.2	0.4
	p	0.02	1.0
TMTF 2 Hz	z	2.3	1.1
	p	0.01	0.2
TMTF 4 Hz	z	1.1	1.3
	p	0.23	0.1
TMTF 8 Hz	z	1.3	1.01
	p	0.17	0.3
TMTF 16 Hz	z	1.01	1.01
	p	0.31	0.31
TMTF 32 Hz	z	1.101	1.10
	p	0.27	0.27
TMTF 64 Hz	z	1.01	1.1
	p	0.31	0.27

TMTF 128 Hz	z	1.10	1.3
	p	0.27	0.1
TMTF 256Hz	z	1.10	1.1
	p	0.27	0.27

3.2.2 Electophysiological tests (P300)

The P300 was recorded for each subject before and after the training in experimental group and with a gap of one month in control group. Figure 3.5 shows grand average P300 waveforms in experimental group.
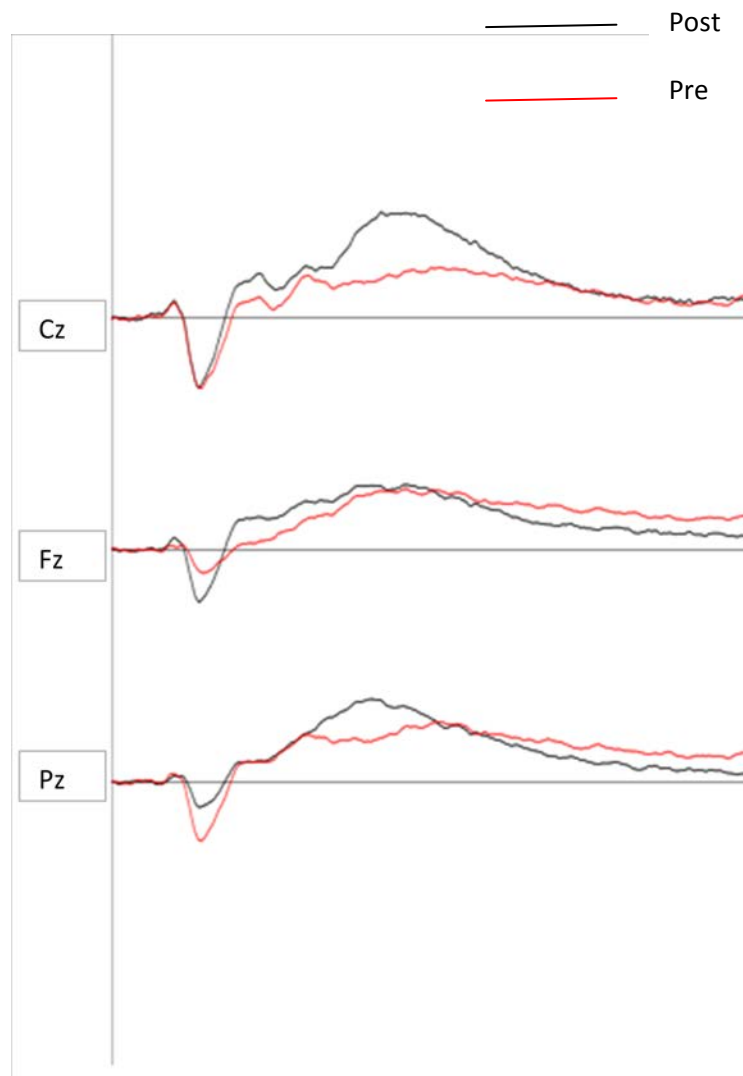

Figure 3.5. P300 waveforms in pre and post training condition

Figure 3.6a and b shows latency and amplitude of P300 peak, respectively, in experimental group at three electrode sites following training.
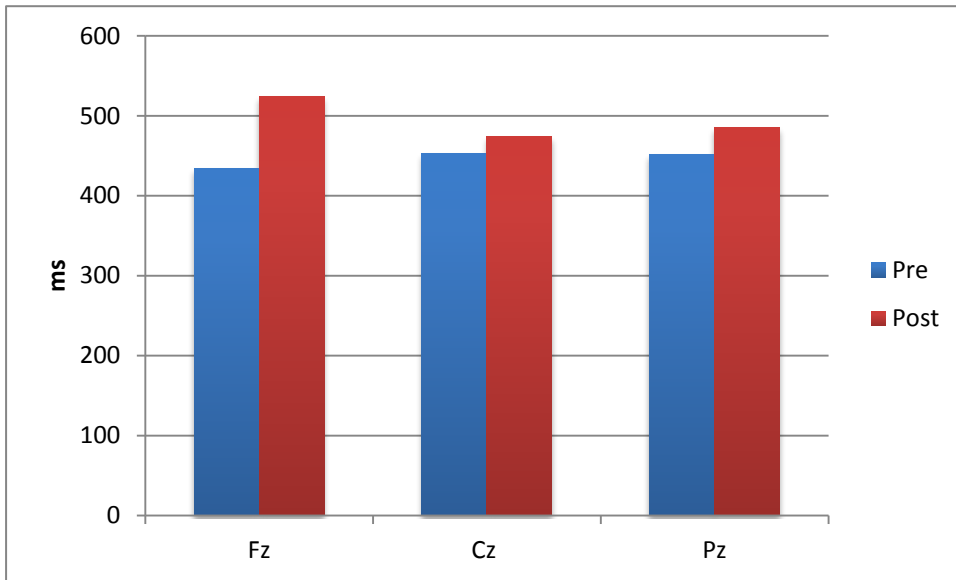
Figure.3.6a Latency of P300 peak at three electrode location in pre and post training conditions.
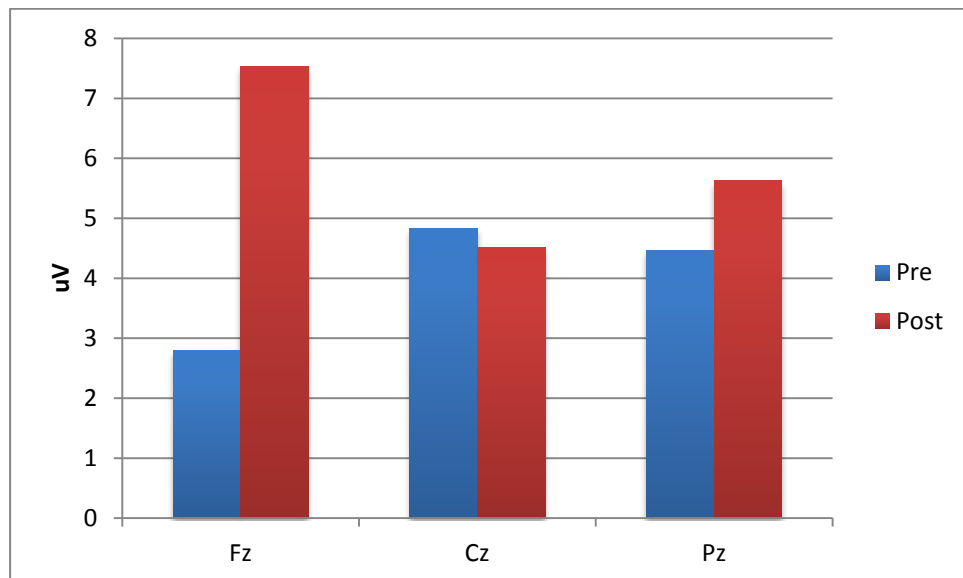

Figure. 3.6b Amplitude of P300 peak at three electrode location in pre and post training conditions.

Figure. 3.7a and b shows mean amplitude and latency of P300 peak in the control group respectively. From the Figures it is clear that P300 amplitude and latency did not change between two evaluations in the control group. Wilcoxon's signed rank test was performed to see the significance of difference between two evaluations. Table 3.3 provides the Z values and significance levels. From the Table 3.3 it can be seen there was significant difference between mean latency amplitude between pre and post training measurements in experimental group. However, this difference was not observed between first and second evaluations in control group.
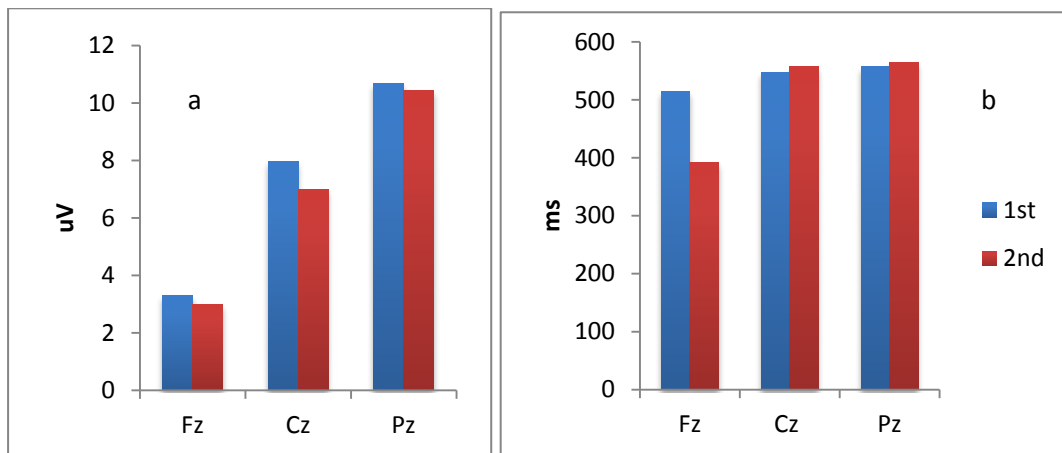

Figure3.7 Amplitude (a) and latency (b) of P300 peak at three electrode location in first and second evaluations in control group.

Table 3.3 z scores and p values for parameters of P300 in control group and
experimental group

		Experimental	Control
Peak latency at Fz	z	2.1	0.8
	p	0.02	0.3
Peak latency at Cz	z	2.03	0.3
	p	0.04	0.7
Peak latency at Pz	z	1.9	1.1
	p	0.04	0.2

Peak amplitude at Fz	z	1.9	1.01
	p	0.04	0.3
Peak amplitude at Cz	z	0.3	1.1
	p	0.7	0.2
Peak amplitude at Pz	z	0.8	0.8
	p	0.39	0.3

DISCUSSION

Large body of research evidence shows that along with hearing aids some form of aural habilitation services are beneficial to individuals with hearing impairment(Sweetow & Sabes, 2006, 2007). Main aim of the current project was to develop an adaptive auditory and cognitive training module for adults with sensori-neural hearing loss. A software-training module was developed which had activities focusing on auditory and cognitive domains. Activities in the auditory domain included training in the conditions of speech in noise, reverberation, vocoded and time compressed. Activities in cognitive domain included host of activities target towards working memory skills. The software program has following features which makes it easy to implement:

1. Adaptive and hence maintains the interest of the clients

2. Provides reinforcement

3. For working memory activities has lot of non-verbal items and hence is relatively language independent

4. Can easily adapted to other languages.

5. Both oral and written instructions

6. Can be used along with the hearing aid or through headphones

7. Improvements can be viewed by the participants on daily basis

8. Facility is provided to move along with the hierarchy or to jump to higher levels based on clinician and patient interest

Despite the benefits evidenced in the literature regarding the use of habilitation training program there are not many structured auditory training programs are available. Listening and communication enhancement (LACE) is

one such training program that is widely used in the west (Sweetow & Sabes, 2007). LACE provides training under three main categories: degraded speech, cognitive skills and communication strategies. In degraded speech is either time compressed to simulate the rapid rate of speech or presented in presence of background babble. It encompasses two cognitive training activities: missing word and target word. To our knowledge this is the first adaptive software based training program targeted to improve listening skills of adults with sensori-neural hearing loss. Compared to LACE, the current module encompasses wide range activates under auditory and cognitive domains. Clinician or clients are given flexibility to chose or to skip these activities as they progress.

After developing this training module we tested the module on 7individuals with sesnsori-neural hearing loss using host of behavioral and electrophysiological measures. Pre and post training assessment measures indicated that trained participants showed improvement on various auditory skills in both cognitive and auditory domains. Improvements were also observed on skills that were not specifically targeted during training. This improvement was not present in the control group who was fitted with the hearing aid but did not undergo any training. One of the important observations, because of the critical necessity for generalization is the improvement shown in the off training tasks. Under the cognitive domain, participants were not trained in forward and descending span skills yet there was significant improvement in these skills following training. Similarly, in auditory domain training was provided primarily in speech in noise condition but improvement was observed on range of

temporal and frequency processing skills along with speech in noise identification.

It is worth noting that P300 peak amplitude improved following training in the experimental group. Electrophysiological measures have been widely used document the effect of training regimes on the central auditory pathway. For example, Song, Skoe, Banai, & Kraus (2011) investigated the effect of LACE training on speech evoked brain stem responses of young adults with normal hearing. Their results indicate that brainstem responses to speech in noise showed significant enhancements especially in the coding of pitch related cues following training. Similarly, other electrophysiological measures such as MMN (Näätänen, Schröger, & Karakas, 1993) N1-P2 complex (Tremblay, Kraus, McGee, Ponton, & Otis, 2001) have been used to evidence the plasticity of the auditory pathway following training. To our knowledge this is the first study that has used P300 to monitor the plastic changes in the central auditory pathway following training. P300 is a cognitive event related potential and the P300 amplitude corresponds participants working memory capacity and discrimination skills (Katayama & Polich, 1998). Increase in the amplitude of P300 is thought to reflect the increased attention allocation by the participants and neuronal synchrony. Changes in the neuronal firing patterns coinciding with the learned behaviour is consistent with Hebbian principles of neural plasticity, according to which behaviourally important inputs that excite neurons, simultaneously in time are mutually strengthened (Tremblay et al., 2001). Increase in the amplitude of P300 peak indicates training enhances that neural generator contributing to this potential. Enhancement in the amplitude of the P300 also

supports the notion that observed improvements in the behavioral measures are not because of merely the practice effect but indeed due to functional plasticity of the central auditory regions of the brain.

While the preliminary results look extremely promising, caution should be taken while generalising to other subject population. Due to nature of the study, participants of the current study were literates, had some minimal knowledge of computers and were willing to participate. Therefore, further studies are required to prove the utility of the software on participants with less positive attitude or poorer literacy skills.

Chapter 4

SUMMARY AND CONCLUSIONS

Primary aim of this project was to develop an auditory and cognitive training module for adults with cochlear hearing loss. A software based training module was developed in collaboration with Voice and Speech Systems, Bangalore. Developed software training module has the following features

➢ It is user friendly and interactive.

➢ It is compatible with any of the commercially available 32 bit PCs.

➢ The training starts near the individual's skill threshold as baseline is obtained prior to initiation of training for each task.

➢ It is sufficiently difficult to maintain interest and attention while being sufficiently manageable to minimize fatigue.

➢ It proceeds at the patient's optimal pace and.

➢ It provides reinforcement to the patient.

➢ The progress in each level/sub- level is saved and a graph is displayed at the end of each session.

➢ It makes the patient assume some degree of responsibility for the ultimate outcome objective.

Auditory module trained individuals using difficult listening situations where speech was degraded by the presence of noise, reverberation, increased rate and vocoding. During training individual could be exposed to any one form of degradation or combination of multiple forms of degradation. Cognitive

training module used various working memory based activities. Specifically, forward, backward, ascending, descending, running span, paired associate learning, pattern recognition, math span, counting span, reading span and operation span tasks were used.

Developed software was tested on five individuals with acquired cochlear hearing loss to debug and check the feasibility of running the software. Changes due to training were measured using behavioural and electrophysiological measures. Results showed that the subjects themselves could easily run developed software. It could be used to train as well as monitor the effect of training. Participants demonstrated improvements in trained as well as untrained behavioural tasks. P300 showed improvement in amplitude following training. Thus, the auditory cognitive training is proved to be effective in spite of individual variability. But, in order to generalise these results to the population with cochlear hearing loss, a study with larger number of subjects is to be conducted.

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Description of tasks used in auditory module

Auditory training module was divided in to 2 parts: Auditory module part I and Auditory module part II. Each module consists of testing phase and training phase. Auditory module part I consisted of stage I and stage II and Auditory module part II consisted of stage III and IV. All the four stages were speech based auditory activities, where the sentences/stories/ paragraphs were presented in difficult listening situations. This included perception of speech in noise, vocoded speech, speech with reverberation and rapid rate.

Auditory module part I:

It consisted of stage I and stage II. High predictable sentences were used in stage I and in the stage II low predictable sentences were used. There were 4 sections in each stage (stage I and stage II) - I) speech perception in noise ii) speech perception in reverberation iii) speech perception in rapid and iv) speech perception in vocoding condition.

1. *Speech Perception in Noise (SPIN):* This module consisted of the sentences which were presented in the presence of background noise. It provides option to choose the required type of background noise from a dropdown menu (speech, broad band, pink) or to load a custom made file. It consisted of 16 levels with increasing difficulty where the signal-to-noise ratio (SNR) increased with the levels. SNR was changed in 2 dB steps from +20 dB SNR at level 1 and -10dB SNR at level 16.

2. *Reverberation: In* this section, the sentences were presented by varying their reverberation time. The reverberation time of the sentences were altered from 0.2 seconds to 3 seconds. It included 15 levels with increasing difficulty from level 1 to level 15

where the reverberation time increased by 0.2 seconds per level. Thus, the starting level (level 1) had a reverberation time of 0.2 seconds and the final level (level 15) had a reverberation time of 3 seconds.

3. *Rapid rate:*This section consisted of sentences which were presented by varying the time compression. Like above two sections, in this section also initial levels had a lower time compression rate and the higher levels had a higher rate. The time compression of the sentences was achieved using overlap-add method and compression was increased 5% per level. The first level had a time compression of 10 % and the final level had a time compression of 60%.

4. *Vocoding*: Here, the sentences were presented by varying frequency bands of sine wave vocoding. The levels were based on the number of frequency bands used for vocoding. Number of bands decreased in steps of 1 band per level. There were 15 levels with increasing difficulty from level 1 to level 15, where level 1 consisted of 15 bands and level 15 consisted of one band.

2.1.3.2 Auditory module part II:

It consisted of stage III and IV. Low predictable sentences were used in stage III and stories and paragraphs were used in stage IV. Stage III consisted of low predictable sentences. In this section,the speech degrading methods used in stages I and II were used in combinations i.e. combinations of SPIN, Reverberation, Rapid rate and Vocoding. These combinations were used in order to increase the difficulty of the auditory training. These combinations reflect real life situations like comprehending cocktail party speech in a hall or restaurant. There were 3 sections in this stage

1. *Combination of two methods:* Speech was degraded by combination of two methods. For example, SPIN + Reverberation; reverberation + Rapid rate; SPIN + Rapid rate; SPIN+ Vocoding; Rapid rate + Vocoding; Reverberation+ Vocoding.

2. *Combination of three methods*: Any three methods were used to degrade the speech. For example, SPIN + Reverberation + Vocoding; SPIN + Reverberation + Rapid rate; SPIN + Rapid rate + Vocoding; Rapid rate + Reverberation+ Vocoding.

3. *Combination of four methods:*All the methods were used simultaneously to degrade the speech material. (SPIN + Rapid rate + Reverberation+ Vocoding*).*

Stage IV section consisted of stories and paragraphs in difficult listening situations as mentioned in stage I, stage II and stage III. After presentation of a story/ paragraph, participants is required to answer questions related to these in a closed choice procedure. The distracting answers had two to three words similar to that of the target to make the closed set task sufficiently difficult.

Description of the tasks used in cognitive training

The Cognitive Module had materials for testing and training of working memory skills. This module was further divided into part I and part II. The tasks included in part I and part II are listed in table 2.2.

Table 2.2: The tasks included in cognitive module part I and part II (A=Auditory, V=Visual, S= Spatial,V-S=Visuo-Spatial).

Cognitive module part I	Cognitive module part II

Forward span: A, V, S	Paired associate learning
Backward span: A, V, S	Pattern recognition memory
Ascending span: A, V-S	Math Span
Descending span: A, V-S	Counting Span
Running span: A, V-S	Reading Span
N-back: A, V-S	Operation Span

Forward span task

This task consisted of presentation of sequences of digits/shapes/highlighted blocks with increasing levels of difficulty (longer sequences being more difficult). It required subjects to repeat/arrange/indicate the sequence in the same order. There were 3 sections in this task: Auditory, Visual and Spatial task.

1. *Auditory task:* Here, the sequences of digits were presented auditorily and subjects were instructed to type the keys on the keyboard or click on the numbers displayed in the same order as presented. There was an inter stimulus interval of 1 second.

2. *Visual task:* Here, a sequence of shapes was presented visually and subjects were instructed to click on the shapes (options) displayed on the computer screen in the same order as presented. Each shape was presented for 2 seconds followed by a 1 second gap (white screen) before the onset of the next shape.

3. *Spatial task:* Here a 4 x 4 grid consisting of 16 blocks was displayed on the screen. Different blocks on the grid were highlighted sequentially. Each block was highlighted for 2 seconds followed by a 1 second gap before the onset of the next block. After the

presentation, an empty grid was displayed and the subjects were instructed to click on the blocks which were highlighted during the presentation in the same order as presented.

Each section had 15 levels and each level had ten sequences. The number of items varied from 2 to 16 based on the level with Level 1 having 2 items and Level 15 having 16 items. Within each level the presentation of the items and the sequences was randomised.

2.1.4.2 Backward span task

In backward span task, Sequences of digits/shapes were presented with increasing levels of difficulty with longer sequences being more difficult, and the subjects required to repeat/arrange/indicate the sequence in the reverse order. Like forward span there were 3 sections in this task: Auditory, Visual and Spatial task.

1. *Auditory task:* Here, the sequences of digits were presented auditorily and subjects were instructed to type the keys on the keyboard or click on the numbers displayed in the reverse order as presented. There was an inter stimulus interval of 1 second.

2. *Visual task:* Here, a sequence of shapes was presented visually and subjects were instructed to click on the shapes (options) displayed on the computer screen in the reverse order as presented. Each shape was presented for 2 seconds followed by a 1 second gap (white screen) before the onset of the next shape.

3. *Spatial task:* Here a 4 x 4 grid consisting of 16 blocks was displayed on the screen. Different blocks on the grid were highlighted sequentially. Each block was highlighted for 2 seconds followed by a 1 second gap before the onset of the next block. After the

presentation, an empty grid was displayed and the subjects were instructed to click on the blocks which were highlighted during the presentation in the reverse order.

Each section had 15 levels and each level had ten sequences. The number of items varied from 2 to 16 based on the level with Level 1 having 2 items and Level 15 having 16 items. Within each level the presentation of the items and the sequences was randomised.

2.1.4.3 Ascending span task

In this task, the sequences of digits/polygonal-shapes with increasing levels of difficulty were presented and the subjects were asked to repeat digits/arrange shapes in the increasing order of difficulty. There were 2 sections in this task namely, Auditory and Visuo-Spatial.

1. *Auditory task:* Here, sequences of digits were presented auditorily and digits from 0 to 9 were displayed on the screen. The subjects were instructed to arrange the digits presented in ascending order and then type the keys on the keyboard or click on the numbers displayed on the screen.

2. *Visuo-spatial task:* Here, a grid was displayed on the screen. Each block on the grid had a shape. Shapes with different sizes were presented in sequences and subjects were instructed to click on the shapes in the increasing order of the size. Each shape was presented for 2 seconds followed by a 1 second gap (white screen) before the onset of the next block.

Each section had 15 levels and each level had ten sequences. The number of items varied from 2 to 16 based on the level with Level 1 having 2 items and Level 15 having 16 items. Within each level the presentation of the items and the sequences was randomised.

2.1.4.4 Descending span task

In this task, the sequences of digits/polygonal-shapes with increasing levels of difficulty were presented and the subjects were asked to repeat digits/arrange shapes the sequence in the decreasing order of difficulty. There were 2 sections in this task namely, Auditory and Visuo-Spatial.

1. *Auditory task:* Here, sequences of digits were presented auditorily and digits from 0 to 9 were displayed on the screen. The subjects were instructed to arrange the digits presented in descending order and then type the keys on the keyboard or click on the numbers displayed on the screen.

2. *Visuo-spatial task:* Here, a grid was displayed on the screen. Each block on the grid had a shape. Shapes with different sizes were presented in sequences and subjects were instructed to click on the shapes in the decreasing order of the size. Each shape was presented for 2 seconds followed by a 1 second gap (white screen) before the onset of the next block.

Each section had 15 levels and each level had ten sequences. The number of items varied from 2 to 16 based on the level with Level 1 having 2 items and Level 15 having 16 items. Within each level the presentation of the items and the sequences was randomised.

2.1.4.5 Running span task

Sequences of 10 to 20 digits/shapes were randomly presented and the subjects were asked to recall the most recent N digits/shapes in the same order. The number of digits/ shapes (N) to

be recalled varied from 1 to 8 items and the inter stimulus interval was 250 ms. There were 3 sections in this task: Auditory, Visual and Spatial.

1. *Auditory task:* Here, sequences of 10-20 digits were presented auditorily and the subjects were instructed to repeat the last N digits heard by typing the keys on the keyboard or clicking the numbers displayed in the same order as presented.

2. *Visual task:* Here, sequences of 10-20 shapes were presented visually and the subjects were instructed to indicate the last N shapes by clicking on the shapes displayed in the same order as presented.

3. *Spatial task:* Here a 4 x 4 grid was displayed on the screen. 10-20 blocks on the grid were highlighted sequentially. Subjects were instructed to click on the last N highlighted blocks in the same order as presented.

Each section had 7 levels and each level had presentation of ten sequences. The value of N ranged from 1 to 8 based on the level with level 1 having 2 items and level 7 having 8 items). Within each level, the presentation of the sequences and the sequence length which ranged from 10-20 items was randomised.

2.1.4.6 Paired associate learning

In this task, series of word pairs or shapes were presented in each trial. At the end of each trial, only one item of each pair was presented and the subject was required to choose the other item of the pair from the items on display.

There were 2 sections in this task (Auditory and Visual).

1. *Auditory task:* Here, sequences of word pairs were presented auditorily and then one of the words from each pair was presented. The subjects were instructed to choose the missing word of the pair by typing the word or by clicking on the words displayed.

2. *Visual task:* Here, sequences of pairs of shapes were presented and then one of the shapes from each pair was displayed. The subjects were instructed to choose the other shape from the pair by clicking on the shapes displayed.

Each section had 10 levels and each level had ten sequences. The number of pairs varied from 2 to 11 based on the level with level 1 having 2 items and Level 10 having 11 items. The subject was expected to respond after the presentation of each sequence. Within each level the presentation of the items and the sequences was randomised.

2.1.4.7 Pattern recognition memory

Pattern recognition memory involved presentation of sequences of visual patterns one at a time. These patterns designed were irregular and it was not possible to give verbal labels to these patterns. After the presentation of the full sequence, pairs of patterns were presented. Each pair consisted of one novel pattern and another pattern which was already seen in the presented sequence. The subject was required to click on the pattern which was from the sequence.

There were ten levels and each level had ten sequences. The number of patterns varied from 2 to 11 based on the level with level 1 having 2 patterns and level 10 having 11 patterns. Within each level the presentation of the items and the sequences were randomised.

2.1.4.8 Counting span task

The counting span task involved counting the target shapes and remembering the count totals for later recall. The target shapes were presented without distracters in the initial levels and as the difficulty of task increased, distracters were presented along with the target shapes. There were two phases in this task: A pre-training phase and the actual training phase.

2.1.4.9 Math span task

In this task, each item consisted of sequences of 2-8 simple mathematical operations which were called as elements. The subject was required to solve each mathematical operation and remember the answer for later recall. After all the elements in an item were presented the subject was required to repeat the answers obtained for each element in correct serial order. The difficulty of the items varied depending on the level and with increase in each level, the number of elements presented per item was also increased by one element. There were two phases in this task: A pre-training phase and the actual training phase.

2.1.4.10 Operation span task

In this task, each element consisted of a mathematical operation and a word. The mathematical operation presented here was similar to math span in terms of difficulty but unlike math span there was no need to calculate the answers as the solution was already given. The subject are required to read the math problem aloud, click/type "yes" or "no" to indicate whether the given answer was correct or incorrect and then say the word. Here instead of remembering the solutions of mathematical operations as in math span, the subjects were asked to remember the words presented along with the operation.

This task consisted of 7 levels and in each level 10 sequences of elements (mathematical operation and word) were presented. The number of elements within an item varied from 2 to 8 based on the level wherein the level 1 consisted of 2 elements and the level 7 consisted of 8 elements). The subject was expected to repeat all the words after the presentation of each item. Within each level the presentation of the items and the elements was randomised.

2.1.4.11 Sym span task

In this task subjects were required to recall sequences of coloured squares within a matrix while performing a symmetry-judgement task. The coloured squares were presented after every item of symmetry judgement. In the symmetry-judgement task, the subjects decided whether the design was symmetrical about its vertical axis or not. Then after that at recall, the subjects recalled the sequence of square locations in the preceding displays, in the order they appeared. An empty 4 x 4 grid was provided and the subjects were asked to enter their responses by clicking on the cells of the empty grid.

2.1.4.12 Reading span task

In the reading span task, each element consisted of a sentence and an alphabet. The subject's task was to read the sentence aloud, respond "yes" or "no" to indicate whether the sentence made sense or not and then to remember the Kannada alphabet. After all the elements in an item were presented the subject was required to type/ select all the alphabets in correct serial order of presentation.

There were seven levels according to the level of difficulty. There were ten sequences of elements (sentences with letters) per level. The number of elements in an item was

dependent on the level with level 1 having 2 elements and level 7 having 8 elements. Within

each level the presentation of the items and the sequences was randomised.

Auditory Module

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CONTENTS

I Organization of Folders, Sub-folders and Their Contents.

Application Folder: Program Folder: When you run the Setup_AUD1v2, ACTM_AUDITORY1v2.exe is installed by default in the folder C:\Program Files(32)\. ACTM_AUDITORY1v2\. This is also called the target folder. This program is common to both Auditory Modules Part I and Part II. Depending on the USB lock, the menus are appropriately enabled.

User can over-ride the default folder and specify the desired folder.

When the Auditory Module is installed, several sub-folders are also installed. Their significance and contents are as follows:

1.1. \USER:
This folder is COMMON to all tasks

This folder should contain one or more text file(s) with the User IDs.

Text file may be prepared using a note pad.

Eg. File name: **Normal_Subjects_List.txt**
First few lines:
Ar18, Aravind,18
Bo38, Bopanna,38
Ch20, Chandrika,20

Format: The first word is the User ID. In the above example, two initial letters and the name and age are used for User ID. Inside the program **only the User ID is displayed**.

The rest is for identifying the subject. Here any convention may be followed. For example, name and age. Also, indications such as normal, male (NM), normal, female (NF). Hard of hearing (HH) etc may be appended to each line

1.2. \USER\AGM

This folder is COMMON to all tasks This folder contains the audiogram data of the subjects if it has been entered or created.

Example, Da26_AGM.txt.

Facility to enter and save the audiogram data appears in each task. If audiogram data is already available it will be displayed when a task and a subject are selected

Format: Example: Six +One rows

```
250    60    60    60    60
500    70    70    70    70
1000   60    65    65    65
2000   70    75    70    75
4000   65    65    65    65
8000   55    55    55    55
SIS    70    70    NA    NA
```

1.3. Folders specific to the tasks

1.3.1. Sub Folder: \Test_Material

This folder contains the material common to all tasks:

a) The bmp files for **messages in Kannada** which are independent of the tasks. Example:

·Test· ಅಥವಾ ·Training· ಆರಿಸಿಕೊಳ್ಳಿ.

1.3.2. Sub Folder: \Test_Material\Stage1

A) **test_material.txt**: This file directs the program **to another text file** which has the **actual test material** to be used. The contents of this file may be changed by an authorized person using the 'Settings' command.

Example: The entry in the test_material.txt file may be **kannada_4sent.txt**. The file **kanada_4sent.txt** lists the actual wave files to be used. The contents of this file may be

```
\stage1\kannada\1.wav
\stage1\kannada\2.wav
\stage1\kannada\3.wav
\stage1\kannada\4.wav
```

In the above example, only 4 files are specified to test the software. In actual practice 10 or more sentences may be specified.

Only the 'wav' files need to be specified. Note that the wav files are saved in a sub-folder named \kannada\ to avoid too many files in the same folder.

The names of the bmp files are automatically generated by the program following the convention as in (C) below.

In a similar manner, utterances in English may be specified. For example, test_material.txt may have a single line specified as 'English_4sent.txt' whose content may be

\stage1\english\1.wav
\stage1\ english \2.wav
\stage1\ english \3.wav
\stage1\ english \4.wav

B) The sub-folder **\test_material\stage1** contains the test material ('wav' files) for Stage 1 task, optionally saved in an appropriate sub-folder such as \kannada\. Also, the written text of the utterances as bmp files, of appropriate size, have to be saved in the same folder that contains the 'wav' files. 14-point bold is used for the written counterparts in Kannada.

C) There are four options of written counter parts for each utterance. The convention followed is as follows: If 1.wav is the utterance, then 1_1.bmp is the correct choice and 1_2.bmp, 1_3.bmp and 1_4.bmp are the incorrect alternatives.

Similar sub-folders exist for other stages:
\Test_Material\Stage2
\Test_Material\Stage3 and
\Test_Material\Stage4.

1.3.3 \Stage1 and \Stage1\Results

The sub-folder \Stage1 contains the default files described below.

The sub-folder \Stage1\Results contains the results for the task of Stage1 for the subjects. The convention followed for assigning the file names to save the results is described in Sec.

Similar sub-folders exist for other stages:
\Stage2,   **\Stage3,**   **\Stage4 and**
\Stage2\Results,   **\Stage3\Results,**   **\Stage4\Results.**

1.4 Default files for each stage

Each sub-folder contains the following **user independent DEFAULT** files which are **Stage dependent**. These files can be accessed and edited by an authorized user with a password authentication.

1.4.1A. instruction.txt: This specifies the **wav file** containing the instruction to be **played** for the very first time a task is run. If this txt file is absent or the wav file is absent then no instruction is played.

Example: English_Instruction.wav. This contains the instruction in English for the specific task. For example, if the task is Forward Span, Digits then the instruction may be: "4 digits will be played. After listening to them, identify the digits in the same order."

Another example: Kannada_Instruction.wav. This contains the instruction in English for the specific task. For example, if the task is Forward Span, Digits then the instruction may be: "soochiruvashtu ankegalannu kelariddeeri. ade kramadalli avgalannu guruthisi."

1.4.1.B. kannada_before.bmp and kannada_after.bmp: These are picture files to display the written instruction in Kannada. .An example:

<p align="center">ಕೇಳಿದ ವಾಕ್ಯವನ್ನು ಗುರುತಿಸಿ.</p>

1.4.2. start_level.txt: A single line containing the default start level. Ex.3.

If a **subject has already taken a task** in **Test** mode and his/her starting level is available then user_id_base_level.txt saved in the appropriate folder will be used.

Example: \Stage1\Results\An27_AUDIO_Base_Level.txt: For User ID An27, Stage 1, the base level to be used is written into this file. This level will be used as the staring level for the very first time of the training mode.

If a **subject has already taken a task** in **Training** mode and his/her starting level is available then user_id_start_level.txt saved in the appropriate folder will be used for the next run.

Example: \Stage1\Results\An27_AUDIO_Start_Level.txt: For User ID An27, For Stage 1, the start level to be used is written into this file.

1.4.3. response_time.txt: If there is no response by the user within a certain allowed response time the answer is taken as incorrect. The response time required depends on the the level. This file consists of two entries: the minimum response time, the increment per Level. Example. 10, 3. Here the minimum response time is 10 sec and for every level above it is 3 seconds extra. Thus the

Allowed response time = Minimum response time + Level*Increment response time.

1.4.5. reversals.txt: This is meaningful only in 'Test Mode'. In two successive trials, if the outcomes are different (success-failure or failure-success) then a reversal is said to have taken place. The maximum number of reversals to be encountered in test mode to decide the starting level. Also, the number of latest reversals to be averaged considered for scoring. Example: 7,3 Wait for 7 reversals and take the average of the latest 3 to determine the starting level. For testing the software a low value such as 3,1 may be used.

1.5 Settings

There exists a command button named 'Settings' in the Opening form. When the user clicks on this command button, a password is requested. Only the authorized user can change the contents. The contents of the various files including instruction material are shown. The user can edit the default values for the chosen stage and save the edited values. The default values **only for the chosen stage** are changed.

II. Noise and Analysis

3.1. \Test_Material\noise_file.txt: For the SPIN task, the noise to be added can be either white noise or babble noise. This choice is specified in the file noise_file.txt. If the content of the file reads 'white' then white noise is generated by the program. If noise is to be read from a file, then the file name has to be specified. For example, babble_19k.wav. If the length of the file is shorted than the length of the utterance then the noise samples read are appended (as many times as required) to crate the desired length.

3.2. Analysis for Rapid Rate: Compression of speech files is implemented by using linear prediction coding (LP) technique. In order to save the computational time, LP analysis is performed before running the task, using a separate dedicated exe file called SSL_Batch_Analysis.exe. The synthesis, for the desired degree of compression, is done within the task by appropriately scaling the frame rate.

SSL_Batch_Analysis.exe looks for a file named **defaults.txt**. This file may contain either a single specific file name including the path or the name of a folder. In case of the former, only the specified file is analyzed. In the case of the latter, all 'wav' files in the specified folder are analyzed. For example: \Test_Material\Stage2\Kannada\. This means analyze all the files in the specified folder.

There are two output files for each wav file. For example if **1.wav** is the input file being analyzed, its output files are **1_parcor.txt** and **1_source.txt**. These files must exist for

running the task. These files MUST NOT BE EDITED else unpredictable results may occur.

**3. 3. Analysis for Vocoder**: In order to save the computational time, vocoder analysis is performed before running the task, using a separate dedicated exe file called SSL_ _Batch_Analysis_Voc.exe. The synthesis, for the desired degree of compression, is done within the task by appropriately selecting the bands depending on the level.

SSL _Batch_Analysis_Voc.exe looks for a file named **defaults_voc.txt**. This file may contain either a single specific file name including the path or the name of a folder. In case of the former, only the specified file is analyzed. In the case of the latter, all 'wav' files in the specified folder are analyzed. For example: \Test_Material\Stage2\Kannada\. This means analyze all the files in the specified folder.

There is one output file for each wav file. For example if **1.wav** is the input file being analyzed, its output file is **1_voc.txt**. This file must exist for running the task. This file MUST NOT BE EDITED else unpredictable results may occur.

III. General Procedure to Run a Task and the Output Files

2.1 Preliminaries

1. Click on 'User-ID'.
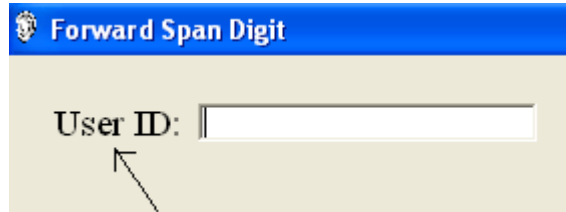
2. Specify the file with the user IDs to be opened.
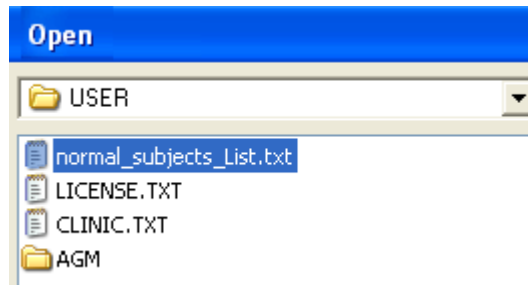
3. The entire list is shown. Select the desired subject by clicking on the User ID.
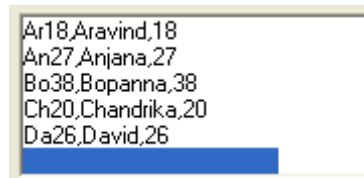
4. The chosen User-ID is displayed.

5. For this user, the program looks for the files with base level and start level. Accordingly recommends the use of 'Test Mode' or 'Training Mode'.

Select the option Test or Training Mode.
Base level is not available.
Recommended to use the option Test Mode.
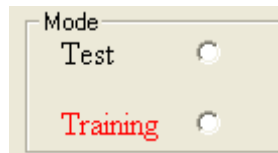
Mode
Test   ○
Training   ○

In the above example, 'Test Mode' is recommended.

6A. The starting level is shown. This is the default value.

Level 3, Test Condition: SNR @ 16 dB

6.B. If Base level is available or if the user has undertaken the training earlier then training mode is recommended. The starting level changes the value stored in the appropriate file (See Sec.3.1, start level) for that user.

Select the option Test or Training Mode.
Base level is available.
Recommended to use the option Training Mode.

Mode
Test   ○
Training   ○

Level 3, Test Condition: SNR @ 16 dB

2.2 Test Mode

7.A. **Test Mode**:

User's response

The alternatives are shown.

A clock registers the time to respond.

The user selects the option which he/she feels is correct.

The user's response is shown with red boundary.

The clock stops.

 'Cancel the selection':

If the user does not cancel the entry within a certain waiting interval, the selection is taken to be the user's response and then proceeds to present the next stimulus.

If cancelled, then the clock begins to increment again and waits for the user's response. If the user selects another response, similar action as above takes place.

If the user does not respond within the allowed time or does not responds after cancellation within the allowed time, the user's response is assumed to be incorrect.

7.B. Scoring in Test mode

For every success at a given level for a number of takes equal to maxtake, the level is incremented. For every failure at a given level for a number of takes equal to maxtake, the level is decremented. When the number of reversals is equal to the maximum number of reversals specified for that task then the test mode ends. The average level of the latest 3 (or specified no.) is noted as the base level. If the level reached is 1, then the lowest level is taken as the base level. If the level equals the maximum level, test mode ends.

THERE IS NO FEED BACK (Correct/Incorrect or reinforcement) DURING THE TEST MODE.

2.3. Output files for Test Mode:

Results of the Test Mode will be written into files with appropriate names automatically assigned to be described below. In Test mode three files are created: (a) History file (b) Score file and (c) Base Level file if test is complete.

Da26_Hist_Test.txt: Here Da26 is the user ID. Hist denotes history file. The mode 'Test' is also shown. Typical contents of this file are as below:

8/3/2013 7:52:14 PM
User ID: Da26
------- TEST ---------
Loaded file: kannada_stage1.txt
Test Condition: SNR @ 16 dB , Rev. Time 0.6 s
Level: 3
Stimulus: Response   Response Time
1   1_1   5900
4   4_1   3200
3   3_1   3100
2   2_3   2200
   Acc. Score: 0

Avg. Response Time: 3600.0 ms

Loaded file: kannada_stage1.txt
Test Condition: SNR @ 18 dB , Rev. Time 0.4 s
Level: 2

```
Stimulus:       Response       Response Time
3               3_1            3600
4               4_1            2500
1               1_1            3400
2               2_1            1800
   Acc. Score: 1
```

Avg. Response Time: 2825.0 ms

Da26_Score_Test.txt: Here Da26 is the user ID. This file contains only the scores. The typical contents are as follows: RT is the response time in mill-sec. A.S. is the accuracy score.

```
---------- Date and Time 8/3/2013 7:52:14 PM   --------------------
Loaded file: kannada_stage1.txt
Test Condition: SNR @ 16 dB , Rev. Time 0.6 s
Level    RT            A.S.
 3      3600.0         0
 2      2825.0         1
```

An27_Base_Level.txt: Here An27 is the user ID. This file contains the base level. Content may be as follows: 3

2.4. Training Mode

7.B. **Training Mode**: The training mode is run as per the task chosen. The test begins either at the default level or the base level or the level achieved during the previous training mode.

Number of trials: At a given level, the number of trials is equal to the maximum number of takes specified in maxtake.txt file.

User's response and 'cancel the last entry': This is same as in the 'Test Mode'.

Reinforcement and feedback:

In a given trial, if accuracy score =1, a positive reinforcement is given.

GOOD

In a given trial, if accuracy =0, a negative reinforcement is given along with a feedback.
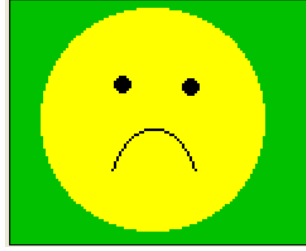
Sorry, NOT ALL entries were correct.
Note the correct answer.

Your Answer is INCORRECT.

ರಸ್ತೆ ನಡುವೆ ಓಡುವುದು ಅಪಾಯಕಾರಿ.

CORRECT ANSWER

ರಸ್ತೆ ನಡುವೆ ನಡೆಯುವುದು ಅಪಾಯಕಾರಿ.

During a trial the time taken to respond is shown both graphically and in text mode as follows:

Response Time 9500 ms

IF THE RESPONSE TIME EXCEEDS THE ALLOTED TIME then it is considered as a failure. Negative reinforcement (as above) is given along with a feedback.

Completion: When accuracy score for maxtake number of (ex. 10) trials is greater than or equal to 80%, the level is **incremented**. The **achieved level is saved** in the appropriate start_level.txt file for the subject. A feedback is given.

Congitive_Module1v0

Maximum allowed number of trials 4 is over.
CONGRATS. You have succeeded with 6 digits.

OK

When accuracy score for maxtake number of trials (ex.10) is lesser than 80%, the training mode is repeated at the **same level**.

Congitive_Module1v0

Maximum allowed number of trials 4 is over.
SORRY. You have NOT succeeded 6 digits.
Training is repeated.

OK

IF there are **THREE SUCCESSIVE failures** (accuracy score = 0 or item score = 0) then the level is decremented.

2.5. Output files for Training Mode:

Results of the Training Mode will be written into files with appropriate names automatically assigned to be described below. In Training mode four files are created: (a) History file (b) Score file (c) Cumulative score file and (d) Start Level file if training is successful at a given level is complete. These are similar to output files during Test Mode. Cumulative score contains the final result after the maximum number of trials.

Cognitive Module Part-I

CONTENTS

<u>I Organization of Folders, Sub-folders and Their Contents.</u>

Application Folder: Program Folder: When you run the Setup_COGAUD1v0, COGNITIVE1_MODULE1v0 is installed by default in the folder C:\Program Files(32)\.ACTM\. This is also called the target folder

When the Cognitive Module is installed, several sub-folders are also installed. Their significance and contents are as follows:

1.1. \USER:
This folder is COMMON to all tasks

This folder should contain one or more text file(s) with the User IDs.

Text file may be prepared using a note pad.

Eg. File name: **Normal_Subjects_List.txt**
First few lines:
Ar18, Aravind,18
Bo38, Bopanna,38
Ch20, Chandrika,20

Format: The first word is the User ID. In the above example, two initial letters and the name and age are used for User ID. Inside the program **only the User ID is displayed**.

The rest is for identifying the subject. Here any convention may be followed. For example, name and age. Also, indications such as normal, male (NM), normal, female (NF). Hard of hearing (HH) etc may be appended to each line

1.2. \USER\AGM

This folder is COMMON to all tasks This folder contains the audiogram data of the subjects if it has been entered or created.

Example, Da26_AGM.txt.

Facility to enter and save the audiogram data appears in each task. If audiogram data is already available it will be displayed when a task and a subject are selected

Format: Example: Six +One rows

250	60	60	60	60
500	70	70	70	70
1000	60	65	65	65
2000	70	75	70	75
4000	65	65	65	65
8000	55	55	55	55
SIS	70	70	NA	NA

1.3. Folders specific to the tasks.

1.3.1. Sub Folder: \Test_Material\Digits

This folder contains the test material (digits in any language) to be used with digits task. Sec.III discusses the convention for preparation of the test material.

1.3.2. Sub Folder: \Test_Material\Visual

This folder contains the test material (shapes) to be used with visual tasks. Sec.III discusses the convention for preparation of the test material.

1.3.3. Sub Folder: \Test_Material\Visuo-Spatial

This folder contains the test material (shapes of different sizes) to be used for visuo-spatial tasks. Sec.III discusses the convention for preparation of the test material.

1.3.4 Forward Span Task (FST)
Sub-folder**: \ FST\DIGITS**
Sub-folder**: \ FST\SPATIAL**
Sub-folder**: \ FST\VISUAL**

1.3.5 Backward Span Task (BST)
Sub-folder**: \ BST\DIGITS**
Sub-folder**: \ BST\SPATIAL**
Sub-folder**: \ BST\VISUAL**

1.3.6 Running Span Task (RUN)
Sub-folder**: \ RUN\DIGITS**
Sub-folder**: \ RUN\SPATIAL**
Sub-folder**: \ RUN\VISUAL**

1.3.7 Ascending Span Task (ASC)
Sub-folder**: \ ASC\DIGITS**
Sub-folder**: \ ASC\VISUAL**

1.3.8. Descending Span Task (DSC)
Sub-folder**: \ DSC\DIGITS**
Sub-folder**: \ DSC\VISUAL**

1.3.9. N-Back
Sub-folder**: \ NBack \DIGITS**
Sub-folder**: \ NBack \VISUAL**

1.4 Default files

Each sub-folder contains the following user independent **DEFAULT** files which are task dependent. When running a specific task, these files can be accessed and edited by an authorized user with a password authentication.

1.4.1A. instruction.txt: This specifies the **wav file** containing the instruction to be **played** for the very first time a task is run. If this txt file is absent or the wav file is absent then no instruction is played.

Example: English_Instruction.wav. This contains the instruction in English for the specific task. For example, if the task is Forward Span, Digits then the instruction may be: "4 digits will be played. After listening to them, identify the digits in the same order."

Another example: Kannada_Instruction.wav. This contains the instruction in English for the specific task. For example, if the task is Forward Span, Digits then the instruction may be: "soochiruvashtu ankegalannu kelariddeeri. ade kramadalli avgalannu guruthisi."

1.4.1.B. kannada_before.bmp and kannada_after.bmp: These are picture files to display the written instruction in Kannada. .An example:

ಸೂಚಿಸಿರುವಷ್ಟು ಅಂಕೆಗಳನ್ನು ಕೇಳಿರಿದ್ದೀರಿ.
ಅವುಗಳನ್ನು ಅದೇ ಕ್ರಮದಲ್ಲಿ ಗುರುತಿಸಿ.

1.4.2. start_level.txt: A single line containing the default start level. Ex.3.

If a **subject has already taken a task** in **Test** mode and his/her starting level is available then user_id_task_base_level.txt saved in the appropriate folder will be used.

Example: Bo38_FST_Digit_Base_Level.txt: For User ID Bo38, For Forward Span task for Digits, the base level to be used is written into this file. This level will be used as the staring level for the very first time of the training mode.

If a **subject has already taken a task** in **Training** mode and his/her starting level is available then user_id_task_star_level.txt saved in the appropriate folder will be used for the next run.

Example: Bo38_FST_Digit_Start_Level.txt: For User ID Bo38, For Forward Span task for Digits, the start level to be used is written into this file.

1.4.3. response_time.txt: If there is no response by the user within a certain allowed response time the answer is taken as incorrect. The response time required depends on the task and the level. This file consists of two entries: the minimum response time, the increment per Level. Example. 10, 3. Here the minimum response time is 10 sec and for every level above it is 3 seconds extra. Thus the

Allowed response time = Minimum response time + Level*Increment response time.

1.4.4. maxlevel.txt: A single line containing the maximum No. of levels. Example: 15. For testing the software a value such as 3 or 4 may be used.

1.4.5. maxtake.txt: This is meaningful only in 'Training Mode'. A single line containing the number of tasks to be completed in the training mode before comparing the score achieved with the threshold (0.8).
For testing the software a lower value may be used. For example:3.

1.4.6. reversals.txt: This is meaningful only in 'Test Mode'. In two successive trials, if the outcomes are different (success-failure or failure-success) then a reversal is said to have taken place. The maximum number of reversals to be encountered in test mode to decide the starting level. Also, the number of latest reversals to be averaged considered for scoring. Example: 7,3 Wait for 7 reversals and take the average of the latest 3 to determine the starting level. For testing the software a low value such as 3,1 may be used.

1.4.7. nrun.txt: This is meaningful only in 'Running Span' tasks. This contains a number. For a given level, the number of stimuli to be presented is random but the range is decided by this number. Example: 6. This number is for level 1. For subsequent levels, this is incremented by 2 for each level. Thus for example for level, 3 nrun is $6+2*(3-1) =$ 10. The actual number of stimuli used is random lying in the range nrun-3 to nurun+3 but not less than the level+3. For the example, for level 3, nrun will lie in the range 7 to 13.

1.5 Settings

There exists a command button named 'Settings' for each task. When the user clicks on this command button, a password is requested. Only the authorized user can change the contents. The contents of the various files including instruction and test material are shown. The user can edit the default values for the chosen task and save the edited values. The default values only for the chosen task are changed.

II. General Procedure to Run a Task and the Output Files

2.1 Preliminaries

1. Select the task from the opening screen. Example 'Forward Span Task-Digits'.

2. Click on 'User-ID'.
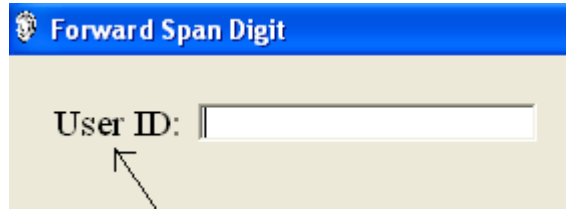
3. Specify the file with the user IDs to be opened.

4. The entire list is shown. Select the desired subject by clicking on the User ID.

4. The chosen User-ID is displayed.

5. For this user, the program looks for the files with base level and start level. Accordingly recommends the use of 'Test Mode' or 'Training Mode'.

Select the option Test or Training Mode.
Base level is not available.
Recommended to use the option Test Mode.

Mode
Test   ○
Training   ○

In the above example, 'Test Mode' is recommended.

6A. The starting level is shown. This is the default value.

Number of digits: 4

6.B. If Base level is available or if the user has undertaken the training earlier then training mode is recommended. The starting level changes the value stored in the appropriate file (See Sec.3.1, start level) for that user.

Select the option Test or Training Mode.
Base level is available.
Recommended to use the option Training Mode.

Mode
Test   ○
Training   ○

Number of digits: 6

2.2 Test Mode

7.A. **Test Mode**: The test mode is run as per the task chosen. For every success the level is incremented. For every failure the level is decremented. When the number of reversals is equal to the maximum number of reversals specified for that task then the test mode ends. The average level of the latest 3 (or specified no.) is noted as the base level. THERE IS NO FEED BACK DURING THE TEST MODE.

2.3. Output files for Test Mode:

Results of the Test Mode will be written into files with appropriate names automatically assigned to be described below. In Test mode three files are created: (a) History file (b) Score file and (c) Base Level file if test is complete.

Ar18_FST_Digit_Hist_Test.txt: Here Ar18 is the user ID, FST_Digit indicates the task: 'Forward Span Task for Digits'. Hist denotes history file. The mode 'Test' is also shown.Typical contents of this file are as below:

```
-------------------------------------------------------------------
6/27/2013 10:07:49 AM
User ID: Ar18
------- TESTING ---------
Stimulus:        Response
1                1
3                2
4                3
1                4
   Acc. Score: 0
Stimulus:        Response
5                5
4                4
1                1
   Acc. Score: 1
```

Ar18_FST_Digit_Score_Test.txt: Here Ar18 is the user ID, FST_Digit indicates the task: 'Forward Span Task for Digits'. The mode 'Test' is also shown. This file contains only the scores. The typical contents are as follows: IRT is the response time in mill-sec. I.S. is the item score. A.S. is the accuracy score.

```
---------- Date and Time 6/27/2013 10:07:49 AM   --------------------
Level   RT    I.S.    A.S.
3       5400  0       0
2       2500  1       1
3       3300  1       1
4       4600  1       1
5       5800  0       0
4       5400  1       1
5       6900  1       1
6       6200  0       1
```

Ar18_FST_Digit_Base_Level.txt: Here Ar18 is the user ID, FST_Digit indicates the task: 'Forward Span Task for Digits'. This file contains the base level. Content may be as follows: 5

2.4. Training Mode

7.B. **Training Mode**: The training mode is run as per the task chosen. The test begins either at the default level or the base level or the level achieved during the previous training mode.

Number of trials: At a given level, the number of trials is equal to the maximum number of takes specified in maxtake.txt file.

User's response and 'cancel the last entry': User's response is displayed (4 5 8 1 9). Also the number of entries is shown (5/6). There is a facility to cancel the latest entry ('9' in the example below)
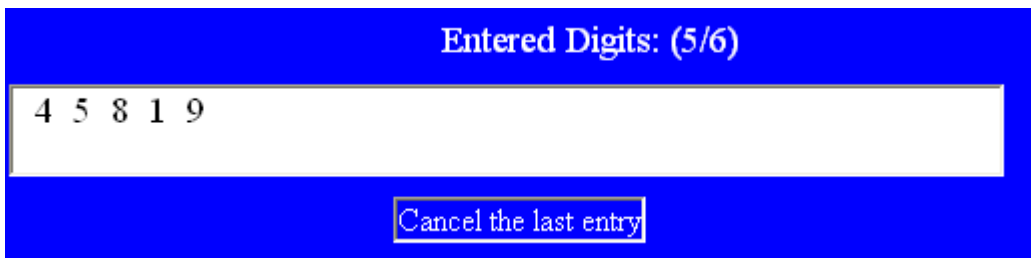
Reinforcement and feedback:

In a given trial, if accuracy score =1, a positive reinforcement is given.

In a given trial, if accuracy =0 and item accuracy=1, a negative reinforcement is given along with a feedback.
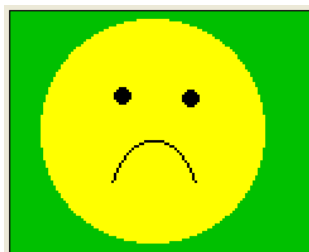
Sorry, Order was incorrect. Note the correct answer.
The correct answer is: 3 2 5 6 3 2

In a given trial, accuracy score = 0, item score =0, a negative reinforcement (as above) is given along with a feedback.

Sorry, Entry was incorrect. Note the correct answer.
The correct answer is: 5 9 5 4 1 8

During a trial the time taken to respond is shown both graphically and in text mode as follows:

Response Time 9500 ms

IF THE RESPONSE TIME EXCEEDS THE ALLOTED TIME then it is considered as a failure. Negative reinforcement (as above) is given along with a feedback.

Oops!, Entries not made in the alloted time. Note the correct answer.
The correct answer is: 4 3 2 5 4 3

Completion: When accuracy score for maxtake number of (ex. 10) trials is greater than or equal to 80%, the level is **incremented**. The **achieved level is saved** in the appropriate start_level.txt file for the subject. A feedback is given.
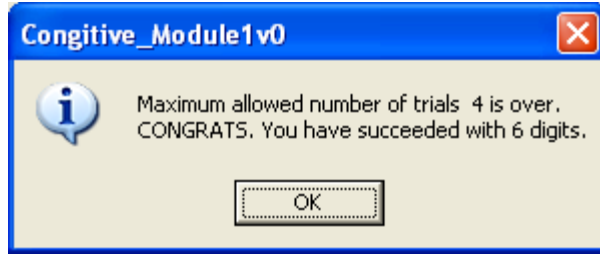
When accuracy score for maxtake number of trials (ex.10) is lesser than 80%, the training mode is repeated at the **same level**.

IF there are **THREE SUCCESSIVE failures** (accuracy score = 0 or item score = 0) then the level is decremented.

2.5. Output files for Training Mode:

Results of the Training Mode will be written into files with appropriate names automatically assigned to be described below. In Training mode four files are created: (a) History file (b) Score file (c) Cumulative score file and (d) Start Level file if training is successful at a given level is complete.

Ar18_FST_Digit_Hist_Train.txt: Here Ar18 is the user ID, FST_Digit indicates the task: 'Forward Span Task for Digits'. Hist denotes history file. The mode 'Train' is also shown. Typical contents of this file are as below:

```
--------------------------------------------------------------------
6/27/2013 11:34:06 AM
User ID: Ar18
------- TRAINING ---------
Level:  5
Take:   1
Stimulus:        Response
 9               9
```

```
1              1
2              2
9              9
5              5
4              4
```
RT in ms: 7000
Item Score: 1
Acc. Score: 1

Level: 5
Take: 2
Stimulus: Response
```
3              3
2              2
5              5
6              6
3              2
2              3
```
RT in ms: 4700
Item Score: 1
Acc. Score: 0

Level: 5
Take: 3
Stimulus: Response
```
4              4
3              3
2              2
5              5
4              3
3             -2
```
RT in ms: 19100
Item Score: 0
Acc. Score: 0

Ar18_FST_Digit_Score_Train.txt: Here Ar18 is the user ID, FST_Digit indicates the task: 'Forward Span Task for Digits'. The mode 'Train' is also shown. This file contains only the scores. The typical contents are as follows: IRT is the response time in mill-sec. I.S. is the item score. A.S. is the accuracy score.

---------- Date and Time 6/27/2013 11:34:06 AM --------------------

Level	Take	RT	I.S.	A.S.
5	1	7000	1	1
5	2	4700	1	0
5	3	19100	0	0

Ar18_FST_Digit_CumSc_Train.txt: Here Ar18 is the user ID, FST_Digit indicates the task: 'Forward Span Task for Digits'. The mode 'Train' is also shown. This file contains only the cumulative (overall) score. The typical contents are as follows:

6/27/2013 11:50:15 AM
User ID: Ar18
-------CUMULATIVE SCORE-----
Level: 5
Avg. RT: 10267.0 ms
Item Score: 75.0 %
Accuracy Score: 50.0 %

****
SORRY. You have NOT succeeded 6 digits.
Training is repeated.
▪▪▪

OR

6/27/2013 12:22:13 PM
User ID: Ar18
-------CUMULATIVE SCORE-----
Avg. RT: 5075.0 ms
Level: 5
Item Score: 100.0 %
Accuracy Score: 100.0 %

****
CONGRATS. You have succeeded with 6 digits.
****

Ar18_FST_Digit_Start_Level.txt: Here Ar18 is the user ID, FST_Digit indicates the task: 'Forward Span Task for Digits'. This file contains the start level for training mode. Content may be as follows: '6'

III. Preparation of the Test Material

3.1. \Test_Material\Digits

This folder contains the audio files of digits and also the text files to direct the program as to which audio files are to be used for the test.

test_material.txt: This file directs the program **to another text file** which has the **actual test material** to be used. For example for digit task, the entry in the above file may be english_digits.txt. The file **English_digits.txt** is another text file which lists the actual wave files o be used. For example a few lines may be

4.wav, 4
three.wav, 3
etc.

In each line, the first word is the file name and the second is the identification. The identification is required for the ascending, descending tasks.

Another example: test_material.txt may contain **Kannada_digits.txt**. The contents of Kannada_digits.txt may be

Ondu.wav, 1
Naaku.wav, 4

In each line, the first word is the file name and the second is the identification. The identification is required for the ascending, descending tasks.

Convention:

The 'wav' files must exist. If any file is missing it is skipped though specified in the 'txt' file. If no 'wav' files are available, the test is not run.

The 'wav' files must be PCM, 16 bit. Mono,

3.2. \Test_Material\Visual

This folder contains the image (picture) files of digits and also the text files to direct the program as to which image audio files are to be used for the test.

test_material.txt: This file directs the program **to another text file** which has the **actual test material** to be used. For example for the Forward Span Visual task, the entry in the above file may be images.txt or images_with_no.txt or pictures.txt etc.

Convention:

Since at the end of the trial, all the pictures are to be shown for the user to select them, the pictures have to be of suitable number (**not greater than 16**) and also of appropriate size (**100X100).** Pictures must be in **"bmp"** format.

Example.1. The file **images.txt** is another text file which lists the actual image wave files to be used. A few lines may be

image4.bmp, 1
image3.bmp, 2
image2.bmp, 3
image1.bmp, 4

etc.
In each line, the first word is the file name and the second is the identification. The identification is required for the ascending, descending tasks.

Example.2. The file **images_with_no.txt** is another text file which lists the actual image wave files to be used. Here "with_no" denotes an image with a number appearing along with the image for ease of testing a program. A few lines may be

image4_with_no.bmp, 1
image3_with_no.bmp, 2
image2_with_no.bmp, 3
image1_with_no.bmp, 4
etc.

In each line, the first word is the file name and the second is the identification. The identification is required for the ascending, descending tasks.

Example.3: pictures.txt. First few lines are:

sun.bmp,1
glasses.bmp, 2
cake.bmp, 3
fan.bmp, 4

In each line, the first word is the file name and the second is the identification. The identification is required for the ascending, descending tasks.

3.3. \Test_Material\Visuo-Spatial

This folder contains the images of the one and the same object but in different scales. This is required for Ascending and Descending tasks where the response is based on the size of the images.

test_material.txt: This file directs the program **to another text file** which has the **actual test material** to be used. It lists all the objects of different sizes so that these objects are picked up in a random order.

Example: The entries may be

squares.txt
circles.txt

Convention:
squares.txt lists the images of squares and their sizes as follows:
sq1.bmp, 1
sq2.bmp, 2
sq3.bmp, 3
sq4.bmp, 4
sq5.bmp, 5
sq6.bmp,6

Similarly, circles.txt lists the images of circles and their sizes as follows:
circle1.bmp, 1
circle2.bmp, 2
circle3.bmp, 3
circle4.bmp, 4

circle5.bmp, 5
circle6.bmp, 6

Images of any object of different sizes may be created using the above convention.

Note that the images have to be in '**bmp**' format. **All images must be of the same size (100X100)** though the objects within each picture file are of different sizes.

A file **blank.bmp** must also be available.

Cognitive Module Part-II

<u>CONTENTS</u>

I.   Organization of Folders, Sub-folders and Their Contents
\USER
\USER\AGM
Folders specific to the tasks: \PAL_Audio, \ PAL_Visual etc
Default Files
Settings
Output files

II.   Preparation of the Test Material

I Organization of Folders, Sub-folders and Their Contents.

Application Folder: Program Folder: When you run the Setup_Cognitive2_1v1.exe, Cognitive2_1v1is installed by default in the folder C:\Program Files(32)\.ACTM\ or a folder of user'choice. This is also called the target folder

When the Cognitive Module Part-II is installed, several sub-folders are also installed. Their significance and contents are as follows:

1.1. \USER:
This folder is COMMON to all tasks

This folder should contain one or more text file(s) with the User IDs.

Text file may be prepared using a note pad.

Eg. File name: **Normal_Subjects_List.txt**
First few lines:
Ar18, Aravind,18
Bo38, Bopanna,38
Ch20, Chandrika,20

Format: The first word is the User ID. In the above example, two initial letters and the name and age are used for User ID. Inside the program **only the User ID is displayed**.

The rest is for identifying the subject. Here any convention may be followed. For example, name and age. Also, indications such as normal, male (NM), normal, female (NF). Hard of hearing (HH) etc may be appended to each line

1.2. \USER\AGM

This folder is COMMON to all tasks This folder contains the audiogram data of the subjects if it has been entered or created.

Example, Da26_AGM.txt.

Facility to enter and save the audiogram data appears in each task. If audiogram data is already available it will be displayed when a task and a subject are selected

Format: Example: Six +One rows

250	60	60	60	60
500	70	70	70	70
1000	60	65	65	65
2000	70	75	70	75
4000	65	65	65	65
8000	55	55	55	55
SIS	70	70	NA	NA

1.3. Folders specific to the tasks.

These folders contain the test material (words or shapes of different sizes) to be used for the tasks. Sec.III discusses the convention for preparation of the test material.

1.3.1. Sub Folder: \Test_Material\PAL_Audio

1.3.2. Sub Folder: \Test_Material\PAL_Visual

1.3.3. Sub Folder: \Test_Material\PRM_Visual

1.3.4. Sub Folder: \Test_Material\RST : Reading Span Task

1.3.5. Sub Folder: \Test_Material\MST : Maths Span Task

1.3.6. Sub Folder: \Test_Material\ORST : Operation Span Task

1.3.7. Sub Folder: \Test_Material\CST : Count Span Task

1.3.8. Sub Folder: \Test_Material\SST : Symmetric Span Task

1.4 Default files

Each sub-folder contains the following user independent **DEFAULT** files which are task dependent. When running a specific task, these files can be accessed and edited by an authorized user with a password authentication.

1.4.1A. instruction.txt: This specifies the **wav file** containing the instruction to be **played** for the very first time a task is run. If this txt file is absent or the wav file is absent then no instruction is played.

Example: English_Instruction.wav. This contains the instruction in English for the specific task. For example, if the task is Forward Span, Digits then the instruction may be: "4 digits will be played. After listening to them, identify the digits in the same order."

Another example: Kannada_Instruction.wav. This contains the instruction in English for the specific task. For example, if the task is Forward Span, Digits then the instruction may be: "soochiruvashtu ankegalannu kelariddeeri. ade kramadalli avgalannu guruthisi."

1.4.1.B. kannada_before.bmp and kannada_after.bmp: These are picture files to display the written instruction in Kannada. .An example:

ಸೂಚಿಸಿರುವಷ್ಟು ಅಂಕೆಗಳನ್ನು ಕೇಳರಿದ್ದೀರಿ.
ಅವುಗಳನ್ನು ಅದೇ ಕ್ರಮದಲ್ಲಿ ಗುರುತಿಸಿ.

1.4.2.A start_level.txt: A single line containing the default start level. Ex.3.

If a **subject has already taken a task** in **Test** mode and his/her starting level is available then base_level.txt saved in the appropriate folder will be used.

Example: \User\Bo38\RST\Base_Level.txt: For User ID Bo38, For Reading Span task, the base level to be used is written into this file. This level will be used as the staring level for the very first time of the training mode.

If a **subject has already taken a task** in **Training** mode and his/her starting level is available then user_id_task_star_level.txt saved in the appropriate folder will be used for the next run.

Example: \User\Bo38\RST\Start_Level.txt: For User ID Bo38, For Reading Span task, the start level to be used is written into this file.

1.4.2B. \User\Bo38\RST\start_take.txt: A single line containing the take where the test has to begin. If the user has undertaken the test earlier in training mode and has stopped the training when take was say 3, then next time he/she can begin with this take..

1.4.3.A min_response_time.txt: If there is no response by the user within a certain allowed response time the answer is taken as incorrect. The response time required depends on the task and the level. This file consists of the minimum response time, Example. 3. Here the minimum response time is 3 sec

1.4.3.B inc_response_time.txt: If there is no response by the user within a certain allowed response time the answer is taken as incorrect. The response time required depends on the task and the level. This file consists of the increment response time, Example. 1. Here the increment response time is 1 sec

Allowed response time = Minimum response time + Level*Increment response time.

1.4.4. maxlevel.txt: A single line containing the maximum No. of levels. Example: 15. For testing the software a value such as 3 or 4 may be used.

1.4.5. maxtake.txt: This is meaningful only in 'Training Mode'. A single line containing the number of tasks to be completed in the training mode before comparing the score achieved with the threshold (0.8).
For testing the software a lower value may be used. For example:3.

1.4.6. reversals.txt: This is meaningful only in 'Test Mode'. In two successive trials, if the outcomes are different (success-failure or failure-success) then a reversal is said to have taken place. The maximum number of reversals to be encountered in test mode to decide the starting level. Also, the number of latest reversals to be averaged considered for scoring. Example: 7,3 Wait for 7 reversals and take the average of the latest 3 to determine the starting level. For testing the software a low value such as 3,1 may be used.

1.4.7. inter_stim_int.txt: This file contains the inter-stimulus-interval, the interval for which the stimulus is to be shown before proceeding to the next stimulus presentation.

1.4.8. wait_for_display.txt: This file contains the inter-stimulus-interval, the interval for which the stimulus is to be shown before proceeding to the next stimulus presentation.

1.4.8. max_score_percept.txt: This file contains the maximum score in percent for the accuracy before proceeding to the next level.

1.4.8. math_max_score_percept.txt: This file contains the maximum score in percent for math score before proceeding to the next level.

1. 5. Settings

There exists a program named 'Settings.exe'. Select the task. When the user runs this program, a password is requested. Only the authorized user can change the contents. The contents of the various files including instruction and test material are shown. The user can edit the default values for the chosen task and save the edited values. The default values only for the chosen task are changed.

1. 5. Output Files

Results of the pre-training and training modes will be written into files with appropriate names automatically assigned. A sub-folder under \User\ is created. For ex: \User\Bo38. Depending on the task, asub-sub-folder is created. Ex: \User\B038\RST. This folder contains the results for user BO38 and reading span task.

In pre-training mode, History and Base Level files are created.

In training mode the following files are created:

(a) History file and Score file and

(b) Start_Take file if the training is stopped in the middle

(c) Start Level file if test is complete

(d) Cumulative score file if the test is complete.

II. Preparation of the Test Material - Convention
For each task, some sample files have been provided to serve as examples.

3.1. \Test_Material\ test_material.txt: This file directs the program **to another text file** which has the **actual test material** to be used. For example for PAL_Audio task, the entry in the above file may be **kananda_words1.txt**. This file **Kannada_words1.txt** is another text file which lists the actual files to be used. For example a few lines may be

\Kannada_Words\bekku.wav
\Kannada_Words\mane.wav
\Kannada_Words\hudagi.wav
\Kannada_Words\meju.wav
\Kannada_Words\aloogadde.wav

NOTE: The path is also specified along with the file name. Thus the actual files may reside in a sub-folder.

Convention:

The 'wav' files must exist. If any file is missing it is skipped though specified in the 'txt' file. If no 'wav' files are available, the test is not run.

The 'wav' files must be PCM, 16 bit. Mono,

WORDS: Although words are text material these are stored as bmp files. This ensures that the test is independent of the language and the absence of fonts will not cause any problem.

True_False: For some tasks, a sentence is either true or false. In such a case the file name must be suffixed with '_1.bmp for True or '_0.bmp' for False. Ex: cat_1.bmp, sebu_0.bmp.

Symmetric: Symmetric pictures are created and are suffixed with '_sym.bmp'. But the test material does not specify these files. But these files must be present in the appropriate folder. Ex: image1.bmp:original file, image1_sym.bmp, the symmetric file.
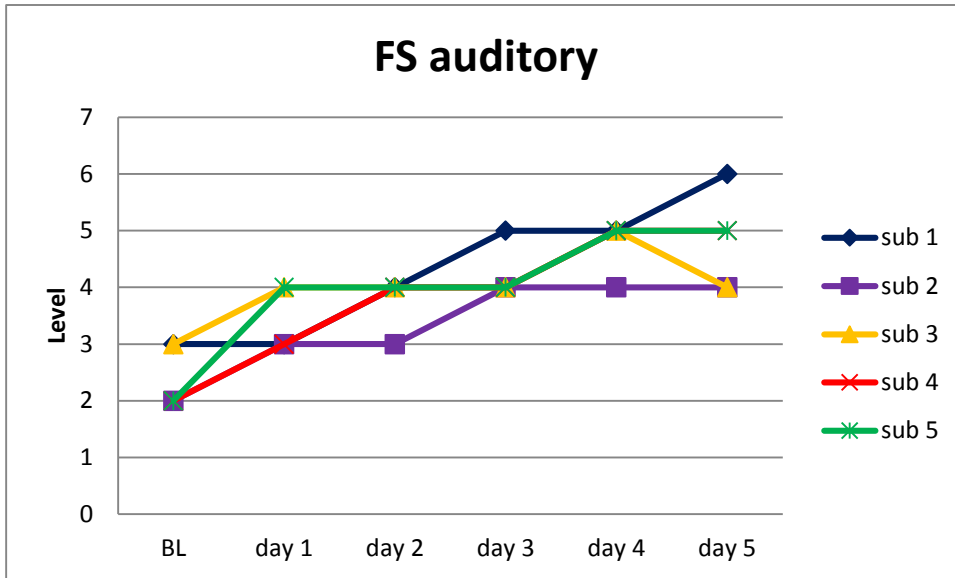
Figure 1.: Baseline scores and training scores across sessions of auditory forward span task for
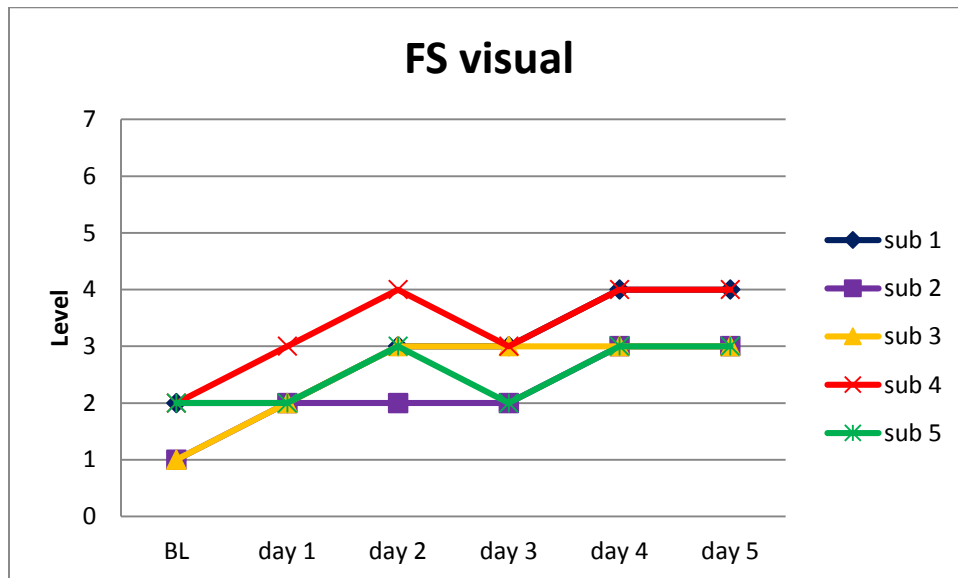
five subjects.

Figure 2. The baseline scores and training scores across sessions of visual forward span task for
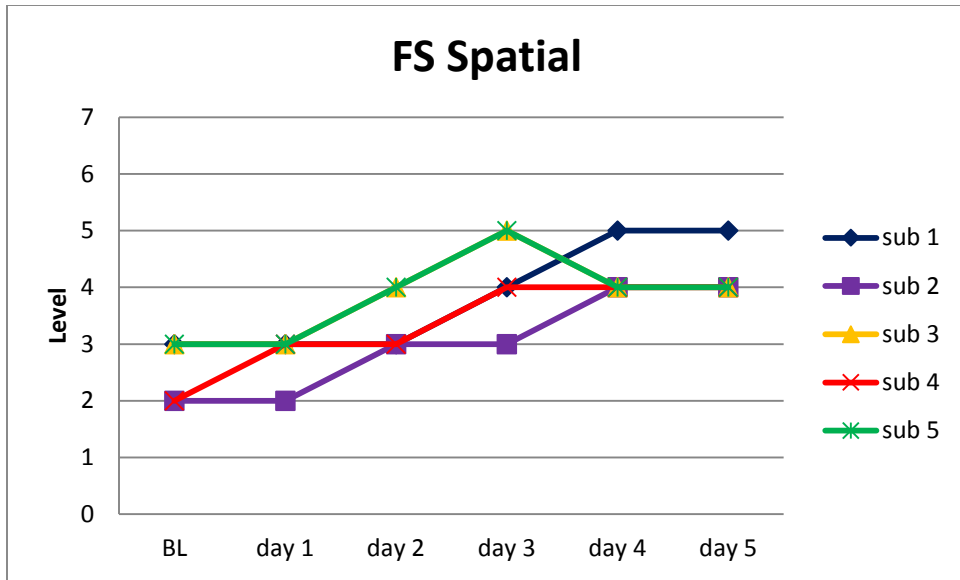
five subjects.

Figure3.: The baseline scores and training scores across sessions of spatial forward span task
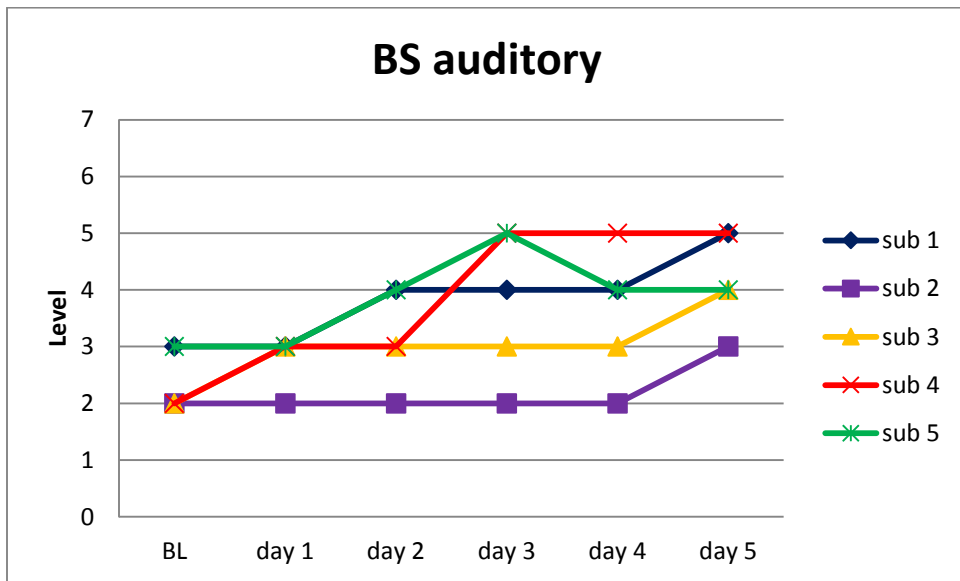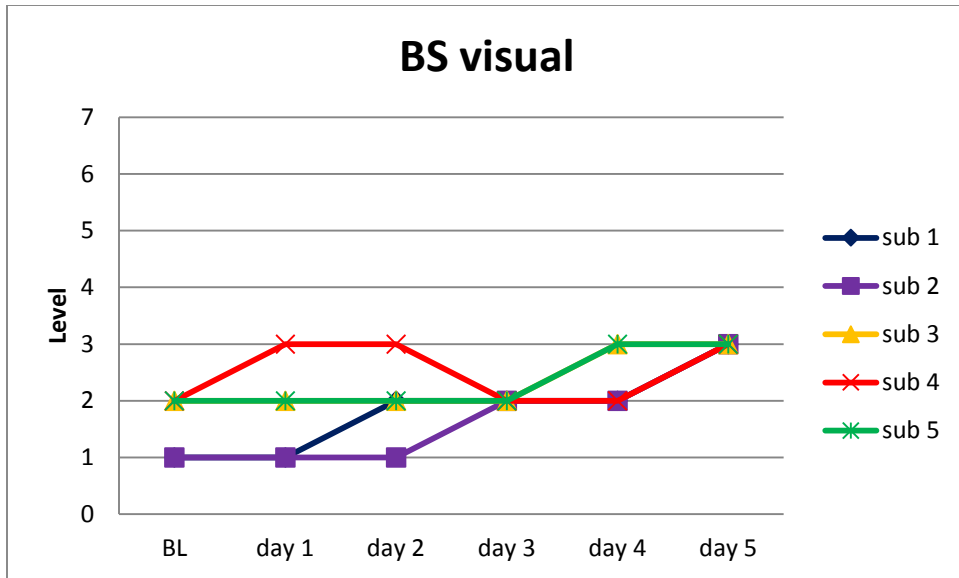
for five subjects.

Figure 4. The baseline scores and training scores across sessions of five subjects for auditory
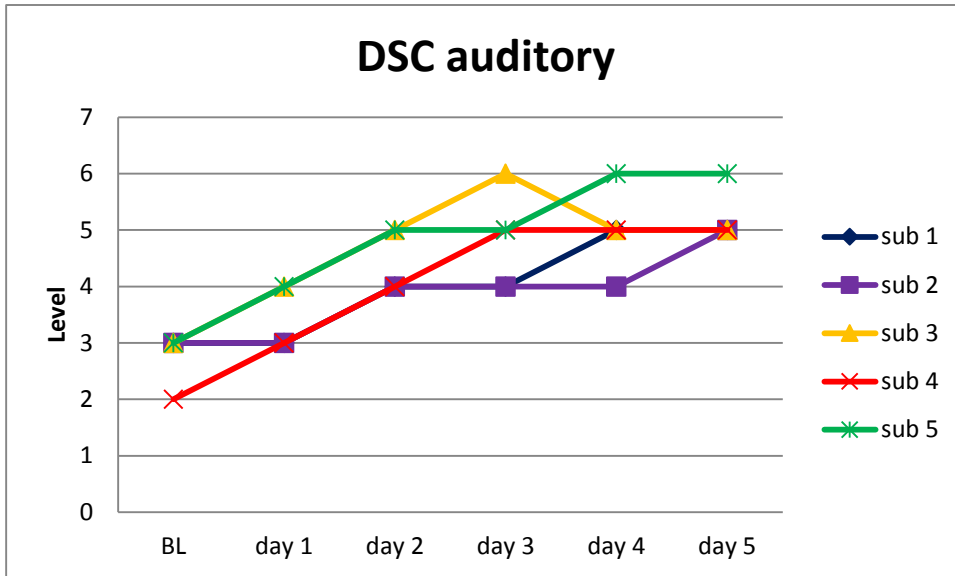
backward span task.

Figure 5: The baseline scores and training scores across sessions of five subjects for visual backward span task.
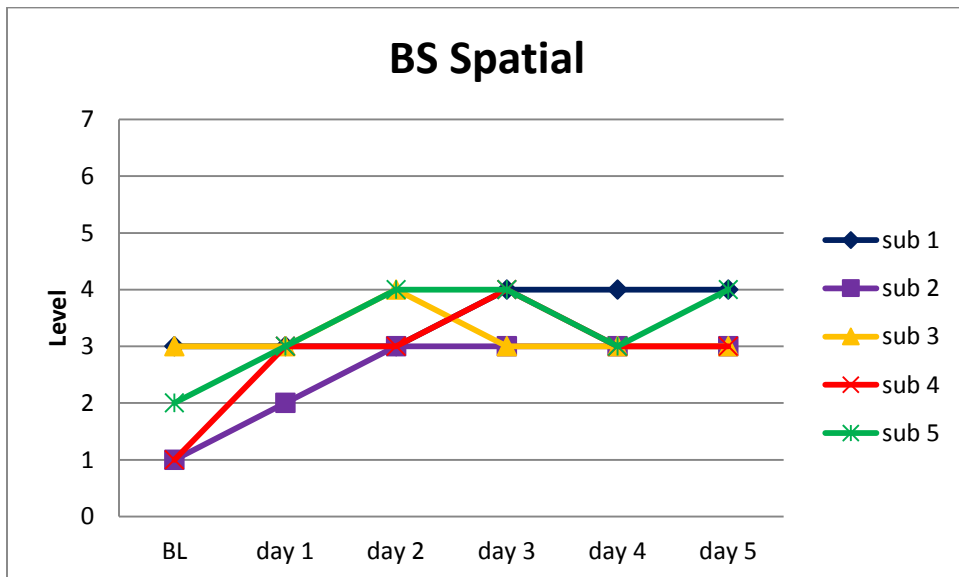
Figure 6. The baseline scores and training scores across sessions of five subjects for spatial backward span task.
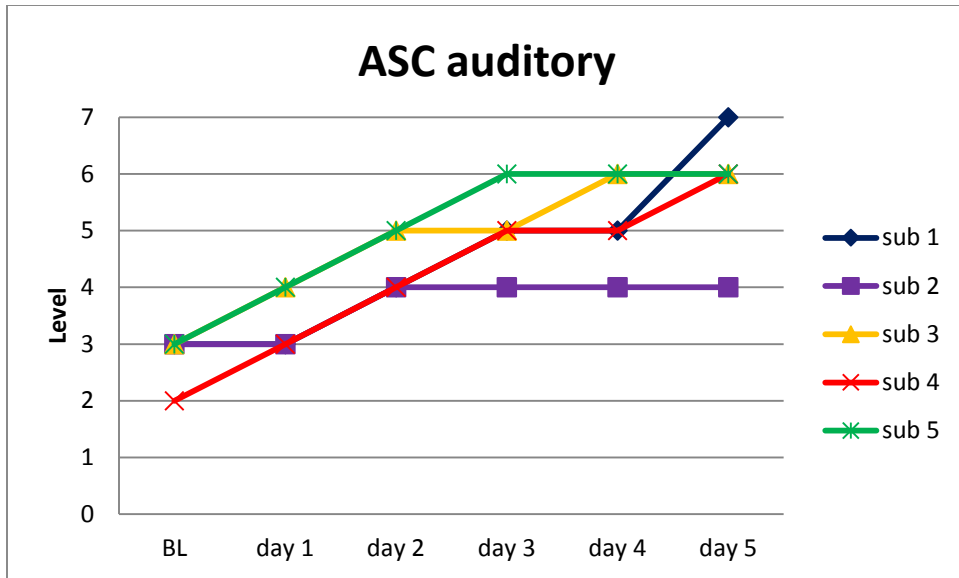
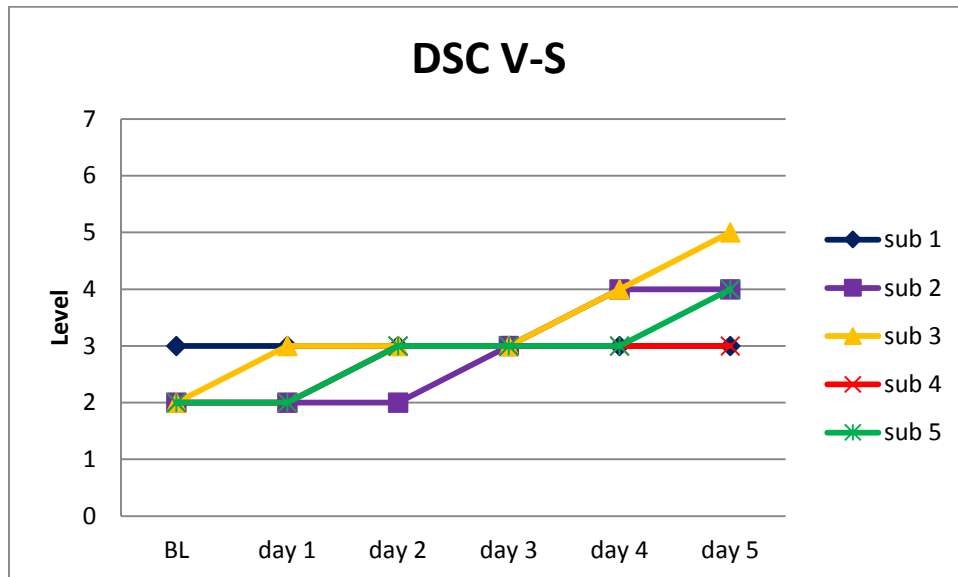*Figure 7. The baseline scores and training scores across sessions of five subjects for auditory ascending span task.*
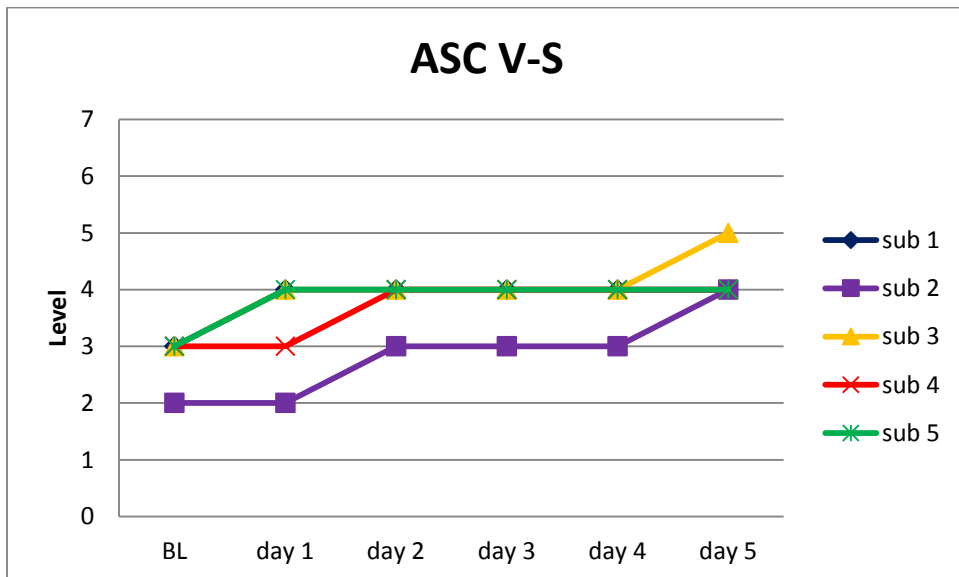
Figure 8. The baseline scores and training scores across sessions of five subjects for visuo-spatial ascending span task.
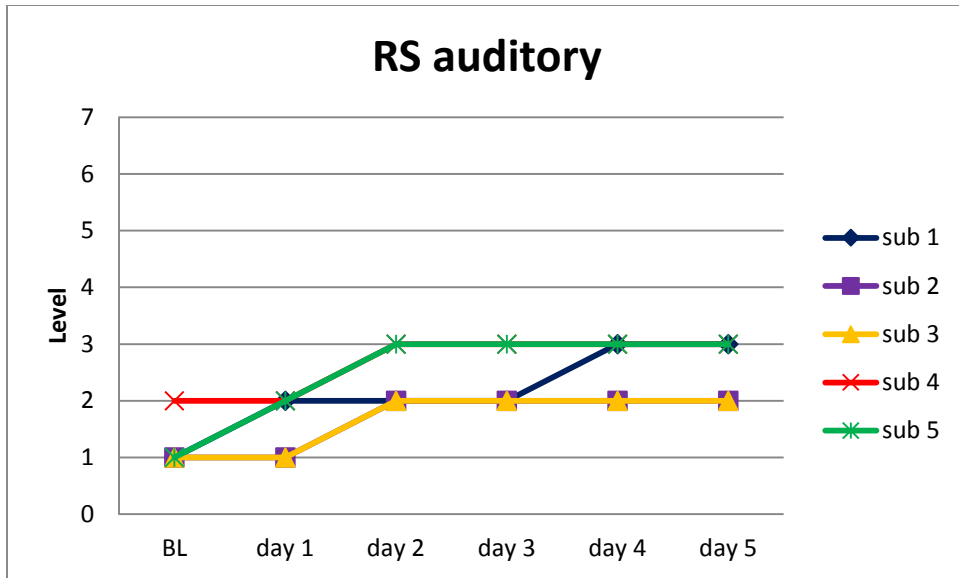
Figure 9. The baseline scores and training scores across sessions of five subjects for auditory descending span task.

Figure 10. The baseline scores and training scores across sessions of five subjects for visuo-spatial descending span task.

Figure 11. The baseline scores and training scores across sessions of auditory running span task
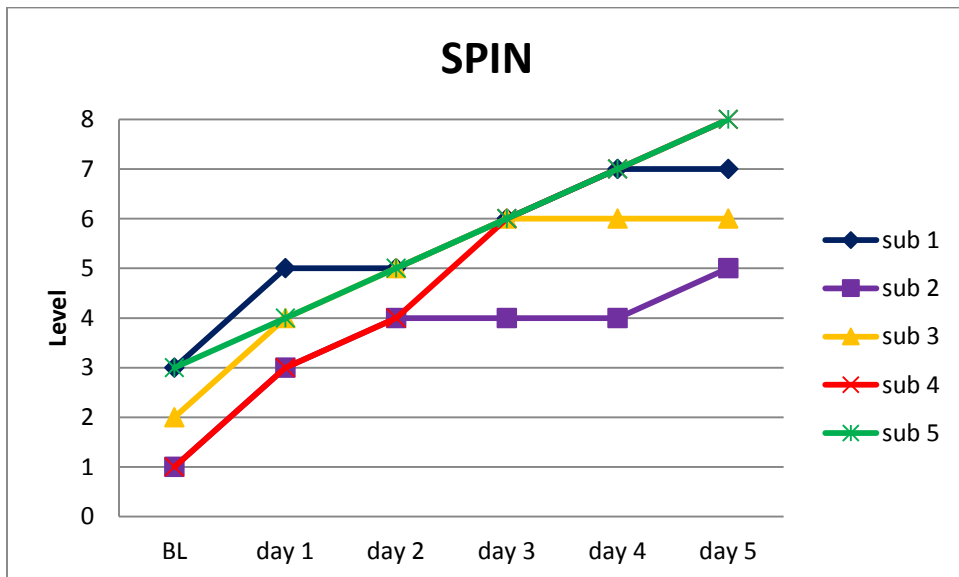
for five subjects.

Figure 12. The baseline scores and training scores across sessions of speech perception in noise
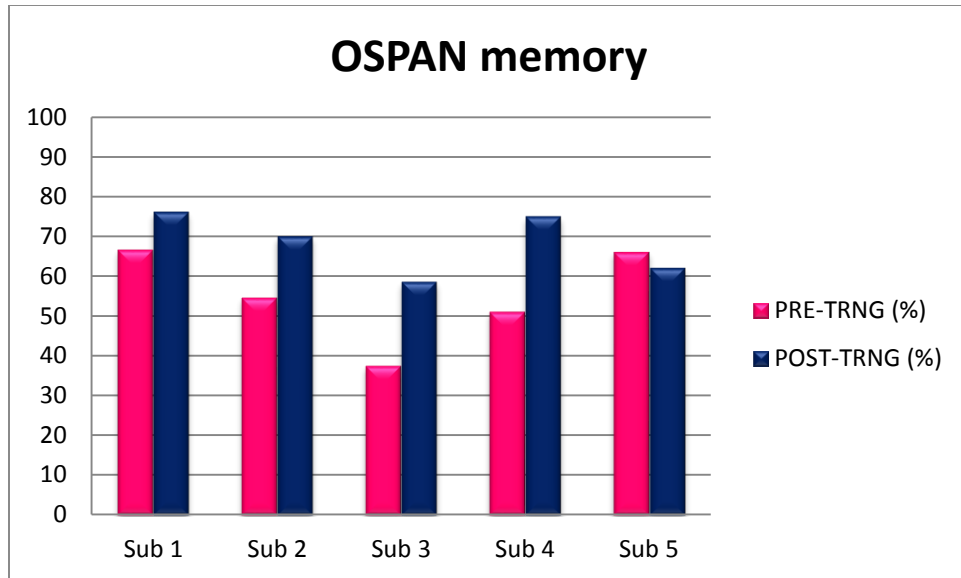
for five subjects.

3.2.1.6 Operation span:

Figure 13. The pre training and post training item scores of operation span (OSPAN) for five
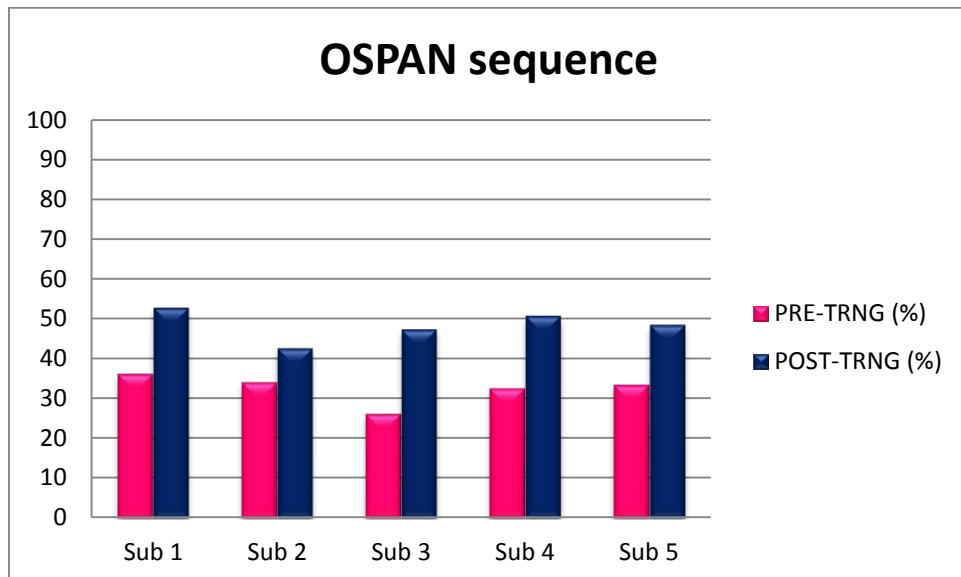
subjects.

Figure 14. The pre training and post training accuracy scores of operation span (OSPAN) for
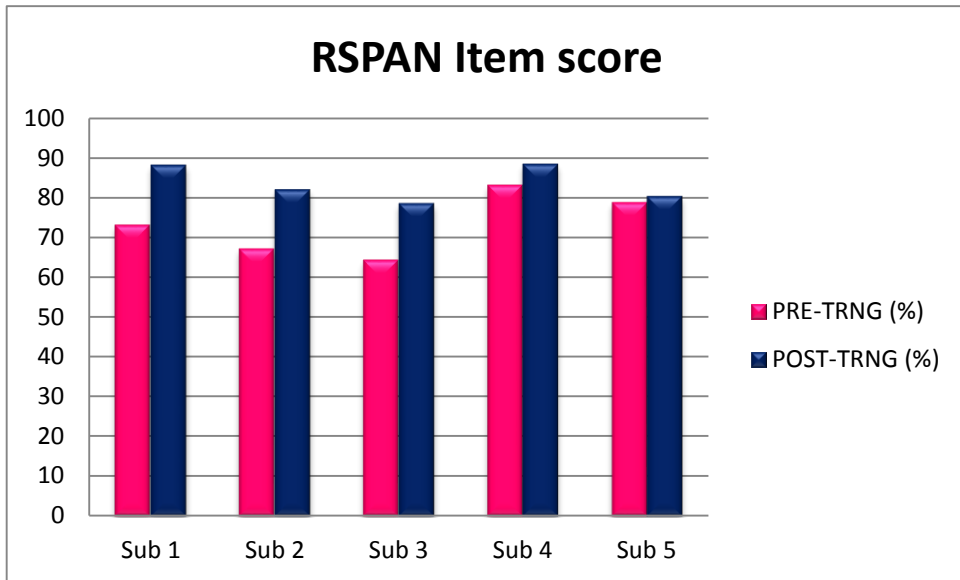
five subjects.

Figure 15. The pre training and post training item scores of reading span (RSPAN) for five
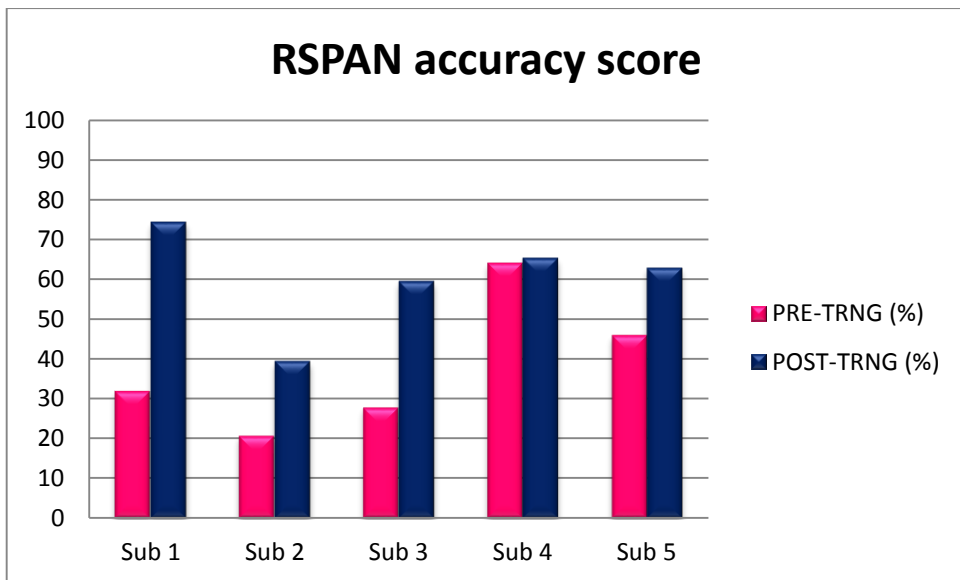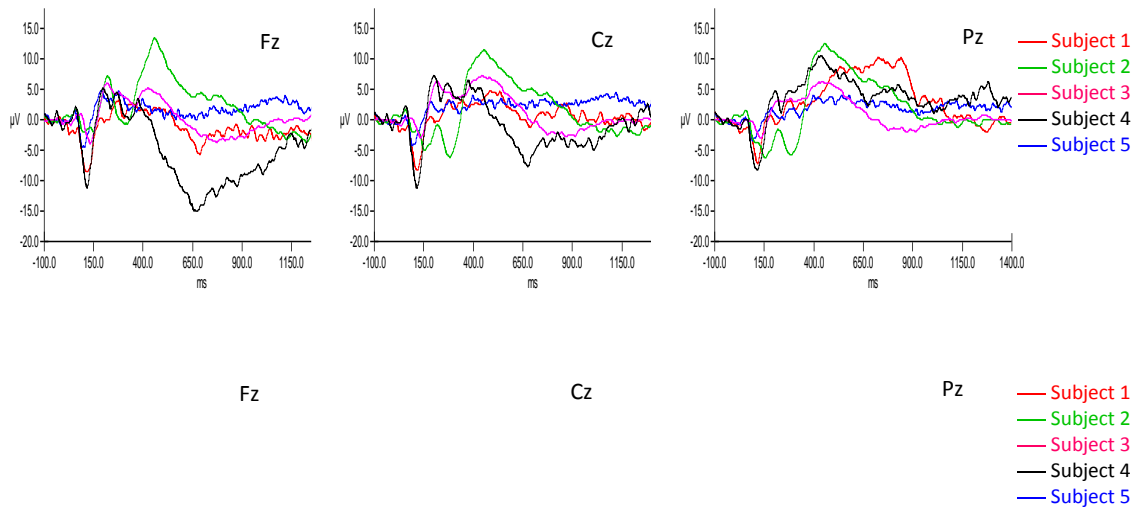
subjects.

Figure 16. The pre training and post training accuracy scores of reading span (RSPAN) for five

subjects.

Table 1 The latency and ampliude values of post training P300 responses for five subjects for da and ga stimuli at Fz, Cz and Pz in pre training.

| Subject		Da		Ga	
		Latency	Amplitude	Latency	Amplitude
Subject 1	Fz	457	13.70706	469	-0.55096
	Cz	455	11.72776	513	-3.03088
	Pz	455	12.71017	513	-2.54756
Subject 2	Fz	376	3.755691	406	4.537061
	Cz	406	5.021258	406	5.678735
	Pz	438	10.75932	430	8.716951
Subject 3	Fz	428	5.385566	470	4.860857
	Cz	461	7.154619	513	6.103248
	Pz	467	6.288075	496	5.617193
Subject 4	Fz	495	1.692112	480	9.168684
	Cz	511	4.835002	492	11.05719
	Pz	532	8.99272	549	12.93831
Subject 5	Fz	396	3.763386	500	4.273541
	Cz	409	3.455969	504	3.457892
	Pz	411	3.612972	501	2.860267
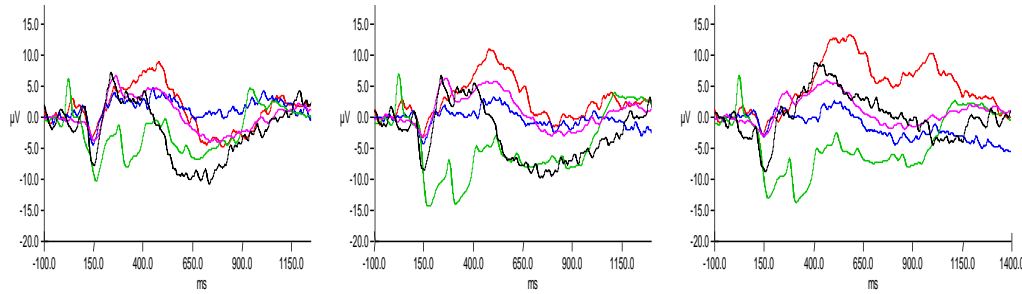
Figure 17: Pre training P300 responses of five subjects for /ga/ stimuli at Fz (left side),

Cz(middle) and Pz(right side) electrode sites

Table 2 The latency and ampliude values of post training P300 responses for five subjects for da

and ga stimuli at Fz, Cz and Pz.

Subject		Da		Ga	
		Latency	Amplitude	Latency	Amplitude
Subject 1	Fz	423	6.099317	443	4.753503
	Cz	505	8.381269	522	7.438643
	Pz	509	8.389995	557	9.192734
Subject 2	Fz	460	4.131343	423	5.592382
	Cz	478	8.336698	459	8.471993
	Pz	479	8.139504	460	8.690386
Subject 3	Fz	437	6.631829	456	6.785673
	Cz	438	7.092975	458	7.075082
	Pz	449	8.029255	455	7.437089
Subject 4	Fz	372	4.672612	411	6.826811
	Cz	470	13.20909	465	13.62368
	Pz	473	14.09345	493	15.63054
Subject 5	Fz	437	6.631829	456	6.785673
	Cz	438	7.092975	458	7.075082
	Pz	449	8.029255	455	7.437089