Hearing-1

by

4. Manuscript

a) Background

Museum is a place of infotainment which unveils a diversity of ideas to the visitors. A study conducted by Bowen, Green and Kisida (2014) on 3,811 students who visited the Crystal Bridges Museum of American Art, found that the critical thinking skills of the visitors were getting improved after the visit. Another study conducted on 10,912 students (Green, Kisida and Bowen, 2014) showed improvements in their critical thinking, historical empathy and tolerance, as a result of the museum visit. An article published in the New York Times, November 2013 (Kisida, Green and Bowen, 2013) suggests that, considering the benefits, regular visits to museums and galleries should be included as a part of the curriculum in schools. Thus the past research shows that benefits accrued to a learner through a visit to the museum are well established. Prime objective of any museum is to engage the community and also to educate them. Colleen (2009) shortlisted ten possible benefits of a museum visit, the most important one being the informal learning experience. Museum visits in groups can also lead to fruitful social relationship by becoming an active part of the community.

Process of learning in a museum is effected through proper interaction with the curators. Room acoustics is a significant factor which influences these interactions. Smaldino et al (2008) quoting Crandell et al, (2005) short lists three acoustic factors that affect speech recognition in a room. They are :- i. Speech 4 signal-to-noise ratio (SNR), ii. The extent to which the time domain information of the speech signal is preserved and iii. The interaction between i & ii. If the background noise in a room is high, it has the potential to reduce speech recognition by masking the highly redundant acoustic cues (Nabelek & Nabelek, 1994). The sources of 1 background noise in the museum include:- (i) external noise – the noise generated from outside the building such as traffic noise, streaking of vendors etc., (ii) internal noise- the noise generated within the building such as footsteps of visitors moving in the corridors, visitors talking to each other in neighboring rooms and corridors etc. and (iii) hall noise – the noise generated within the hall where the visitor is. It includes visitors talking to each other, shuffling of foot wares on the plain floor, fan noise etc. Thus, high background noise in museums lead to reduction in intelligibility of the curator's speech. Relationship between intensity of the speech signal and intensity of the background noise (SNR) at the listener's ear is the crucial factor affecting speech intelligibility (Crandell & Smaldino, 2000). Higher background noise in the museum hall will bring down the SNR to unfavorable levels. Reverberation refers to prolongation of sound inside a room due to reflection from surfaces such as walls, ceiling, floor and windows. Reverberation also degrades speech recognition through the masking of direct and early reflected energy by reverberant speech energy (Crandell & Smaldino, 2000). The reverberant speech energy reaches the listener after direct sound and overlaps with the direct signal resulting in smearing or masking of speech (Anderson & Karen, 2004). In most of the museums noise and reverberation combine in a synergistic manner to adversely affect speech recognition. Curator-to-listener distance is another variable which add to the effects of reverberation, as reverberation dominates over direct sound with increase in distance from the curator (Crum, 1974).

Carvalho, Goncalves and Garcia (2013) conducted a study on the acoustics of modern and old museums and arrived at the values of five acoustic variables. Measured values reported in their study are:- (i) Reverberation Time (RT) – 0.8 sec at 500 Hz, 1.4 sec at 1 kHz (ii) Rapid speech Transmission Index (RASTI) – 0.45 at 500 Hz, 0.65 at 1 kHz, (iii) Background noise level – ≤ 45 dB. After measuring these variables in two museums, an old art museum and a modern museum, they observed that the values were distant from the optional values in both cases, Thus the acoustics in these museums is not conductive for listening even for visitors with normal hearing. Technical Committee on Architectural Acoustics of the Acoustical Society of America (2000) has proposed a minimum SNR of +15dB, a distance of within 1-2 meters from the speaker, a Reverberation Time within 0.4 seconds and a Noise Reduction (NR) of 35 dB for a child with some kind of hearing impairment to have at least 90% speech intelligibility in classrooms. Listening environment in a museum is similar to that of a classroom. The values of the variables reported for both the museums were far away from these minimum requirements. These acoustic barriers prevent the visitors with hearing impairment from the accrued benefits of the museum visit. Gudrun (2006) analyzed the acoustical conditions at three museums in Denmark in terms of intelligibility, listening effort, noise distraction and speech privacy. The study concludes that the acoustics play a significant role in making the museum visit a comfortable one.

Limitations of hearing aids worn by person with hearing impairment in overcoming these acoustic barriers have been documented in many studies. Jerome & Patricia (2000) states that in poor acoustic conditions, hearing aids increase the listening difficulties rather then improving them. Anderson and Goldstein (2004) tested whether there is improvement in speech perception for eight 9-12 year aged children when they used assistive technology in addition to their hearing aids. The acoustic conditions were:- Reverberation Time of 1.1 second and SNR of 10dB, both far below the optimal values. They found that speech identification scores of 68.8 to 93.3 % obtained with hearing aid in these acoustic conditions were improved to 86.7 to 100 percent with the addition of assistive technology. The hearing aid amplify both the curator's speech and the noise and hence will not bring any significant change in the Speech signal-to-noise ratio (SNR) and thus won't be able to achieve the optimal SNR of +15dB. When the museum is crowded, the visitor with hearing impairment will be away from the curator by more than the optimal distance of 2 meters. The effects of longer Reverberation Time will not be addressed by the hearing aid as the hearing aid can't differentiate the curator's sound and the reverberated sound.

One solution to overcome the acoustic barriers is to improve the acoustics. But this requires expensive acoustic treatments. Moreover, there will be many practical limitations in providing such modifications in the existing structure. Another solution is to provide an assistive device for the visitor with hearing impairment, which will help to overcome the acoustic barriers. An assistive device was developed at AIISH which can be electromagnetically coupled with the hearing aid of the museum visitors with hearing impairment. The device underwent extensive field trials at the Regional Museum of Natural History, Mysuru. The objective of the present study is to quantify and critically evaluate the efficacy of this assistive device when used for visitors with hearing impairment to the Regional Museum of Natural History, Mysuru on four aspects:- a) its capability in overcoming the acoustic barriers at the museum b) functionality c) reliability and d) its adaptability to universal design.

b) Materials and methods

Smaldino et al (2008) reviewed the different approaches those have been used in the past to document the effects of intervention to improve acoustics in the listening and learning, in a classroom set up. Observing on task behavior and measuring speech recognition scores were the approaches used in the previous studies. Both these methods have the inherent drawbacks such as the practical difficulties involved in conducting the test and the complexity of the test protocols. Hence, Smaldino et al (2008) opines that subjective report questionnaires are the best media to obtain specific information on the efficacy of the intervention technology to overcome the acoustic barriers to communication. Thus, the efficacy measures used in the present study include:-

i) Measurement of acoustic variables

ii) Subjective report questionnaire.

i) **Measurement of acoustic variables**:- Acoustic variables were measured in the locations where the field trials of the assistive device were done. The variables measured include reverberation time, equivalent sound pressure level of noise (LAeq) and signal to noise ratio (SNR). All acoustic measurements were made with the precision sound Level Meter (B & K 2250) fitted with B & K 4189 free field measuring microphone or B & K 4192 pressure microphone. B & K 2734 power amplifier with built in white noise generator and B & K 4292 omni-directional sound source was used for generating noise for RT measurements as illustrated in Figure 1. B & K B7228 building acoustic software was used for measurement of Reverberation Time.

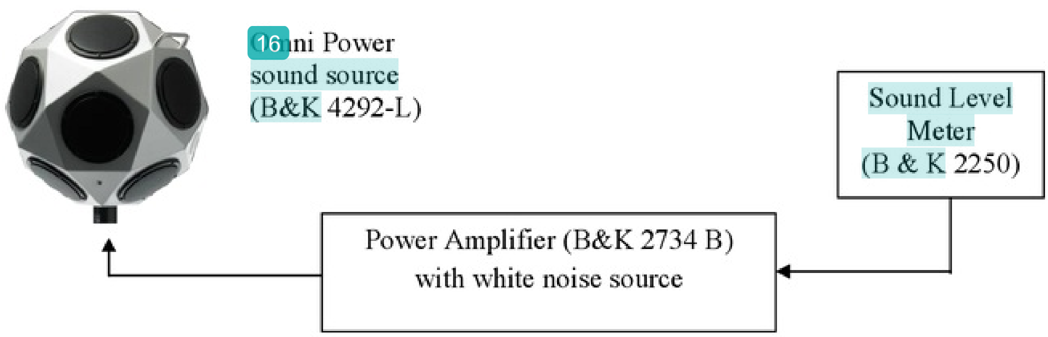
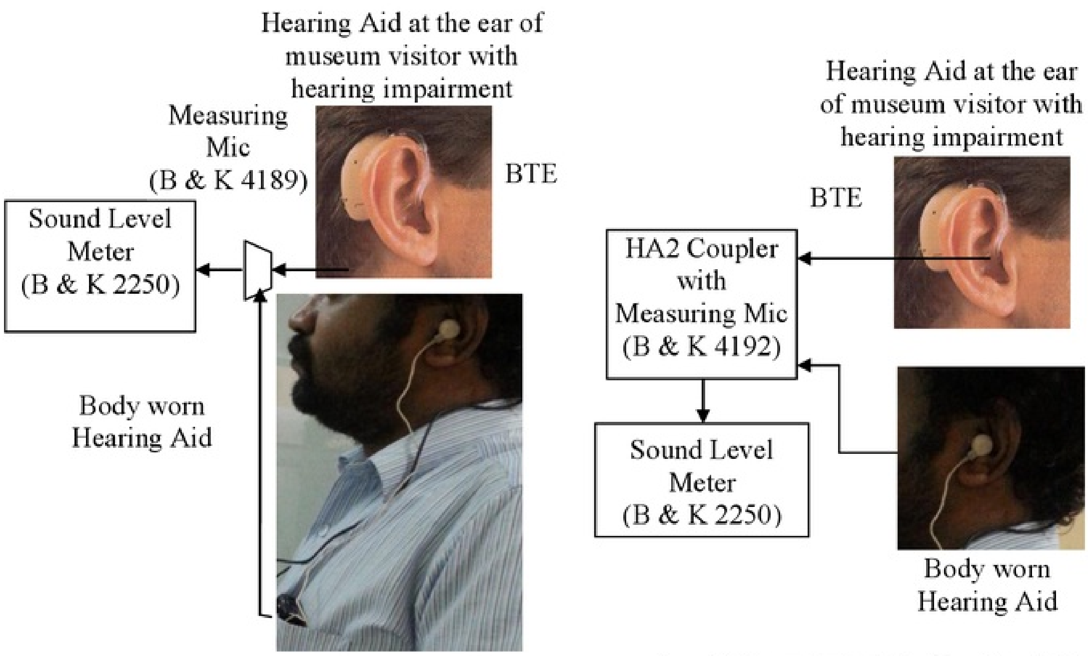


Figure 1: Setup used for measurement of acoustic variables

Three representative locations were selected in the Regional Museum of Natural History, Mysuru – one at the entrance hall, one at the auditorium and one at the cave for measurements. RT values were measured at three positions in each location at 500 Hz, 1kHz & 2kHz and the average RT values were calculated. Measurement of the background noise was done at one position in each location for octave band frequencies from 31 Hz to 8Khz, each measurement for a duration of 10 minutes and the equivalent sound pressure level (LAeq) was noted using the Precision Sound Level Meter.

The assistive device is issued to visitors with hearing impairment at the entry point of the museum. They are instructed to wear the neckloop and switch their hearing aids to telecoil mode of operation. The exhibits in the museum are coded. When the visitor is near the exhibit, the visitor can enter the respective code through the numerical keypad of the device and press the '#' button to hear a description about the exhibit through their hearing aids. If the visitor doesn't wear a hearing aid or doesn't have the telecoil option in their hearing aids, they can still use the device by opting the headphone instead of neckloop.



a. At the input to the Hearing Aid

b. At the output of the Hearing Aid

Figure 2: Setup used for measurement of speech signal-to-noise ratio (SNR)

Figure 2 shows the setup used for measurement of speech signal-to-noise ratio (SNR). The SNR at the input of the hearing aid was measured by placing the SLM microphone close to the location of the microphone of the hearing aid. For Behind The Ear (BTE) hearing aids, the sound measuring microphone was kept at the ear level and for body worn hearing aid, the measurement was done at the pocket level. As illustrated in Figure 2 (a), B & K 4189 free field microphone coupled to B & K 2250 SLM constituted the measurement set up. The output SNR was measured by coupling the hearing aid output to the HA2 coupler (Figure 2 - b). The pressure microphone (B & K 4192) was kept inside the HA2 coupler and then coupled to the SLM (B & K 2250). The same set up was used to measure the output SNR with the assistive device electromagnetically coupled to the hearing aid.

ii) Subjective report questionnaire

Feedback questionnaires in English / Hindi / Kannada (Appendix I, II & III respectively) were issued to the museum visitors to whom the assistive device was issued. Five questions were put forth to the user. All the questions were provided with options and user had to just tick the appropriate option. The first question was on connectivity between handset of the assistive device and the hearing aid device. The second was regarding the time taken by the assistive device to respond to the code entered by the user. The third one was on the intelligibility of speech through headphones. The fourth one was to judge the intelligibility of the description heard through the hearing aid when the hearing aid is coupled to the device. The last question was to find out whether the device was giving adequate backup or not.

Field trials were conducted at Regional Museum of Natural History, Mysuru on 50 visitors with hearing impairment who were using either body worn or Behind The Ear (BTE) hearing aids. The age group distribution of the participants is shown in Figure 3. Distribution of participants according to their degree of hearing loss and the type of hearing aid worn are shown in Figure 4 – a & b respectively.

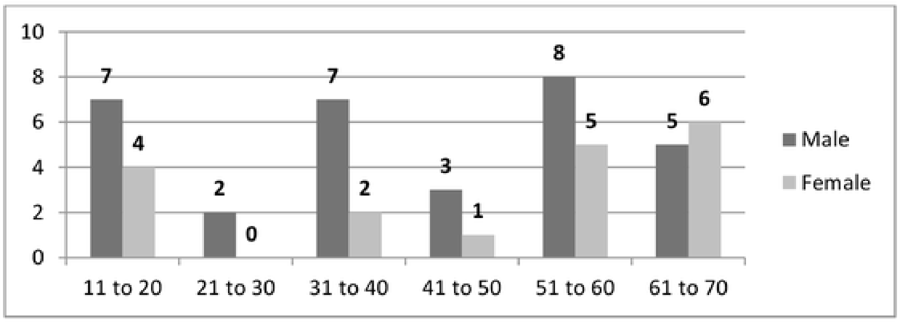
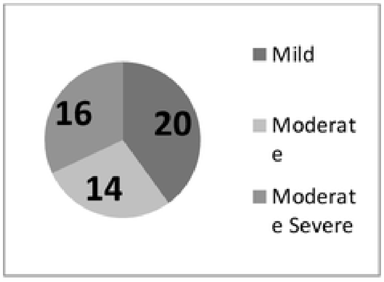


Figure 3 : Age group distribution of participants of field trials.



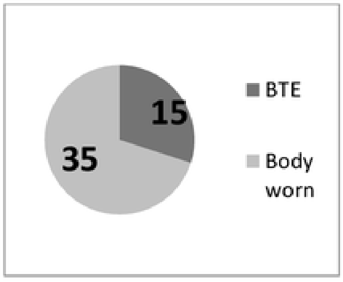


Figure 4a : Degree of hearing loss of the participants

Figure 4b: Type of hearing aid worn by the participants

c) Results

i) Measurement of acoustic variables

The acoustic variables measured at 3 different locations in the museum are shown in Table – 1. None of the measured values were within the optimal values reported by Carvalho et al, 2013.

Acoustic variable	Location – 1	Location – 2	Location – 3	Optimal values for (Carvalho et al, 2013)
Background noise level (dB L_{Aeq})	77.53	80.40	79.87	< 45
Reverberation Time (RT) in seconds (500, 1K, 2K)	1.98	2.68	1.77	< 0.80
Signal-to-Noise Ratio (SNR) (in dBA)	- 7.5 dB	- 10 dB	- 8dB	> 0 dB

Table – 1: Measured values of acoustic variables at RMNH, Mysuru

Table -2 shows the measured values of the acoustic variables at the output of the hearing aid after coupling through the neckloop of the assistive device.

Variable	Location – 1	Location – 2	Location – 3
SNR (in dBA) with assistive device coupled to Body worn hearing aids	+ 24 dB	+ 22 dB	+ 19 dB
SNR (in dBA) with assistive device coupled to BTE hearing aids	+ 32 dB	+ 29 dB	+ 27 dB
Noise at the output of Body worn Hearing Aid	27 dB	25 dB	29 dB
Noise at the output of BTE Hearing Aid	14 dB	17dB	19 dB

Table – 2: Measured values of speech signal-to-noise ratio and background noise at the output of the hearing aid coupled with the assistive device.

ii) Questionnaire

Figure – 5 shows the feedback regarding connectivity of device with hearing aid of the visitors. Figure – 6 shows the response of the device in executing the request for commentary by the user. Figure – 7 shows the response of the user on the intelligibility of the speech heard through head phones and Figure - 8 shows the intelligibility of the commentary heard through the hearing aid, when coupled through the neckloop.

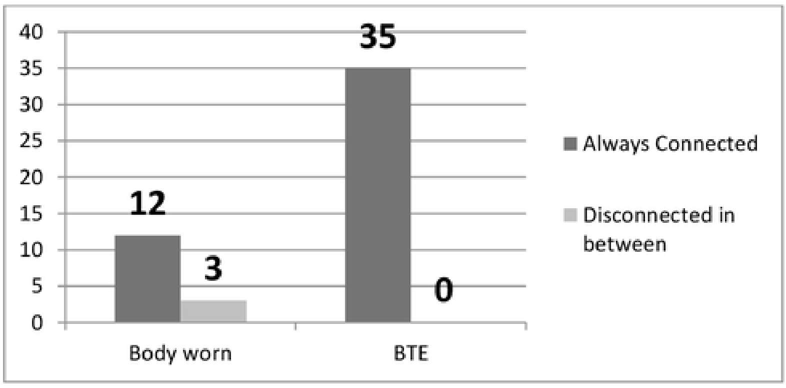


Figure 5 : Response to connectivity of the device with hearing aid of the visitors

Figure 6 : Response of the device towards a commentary request from the visitor

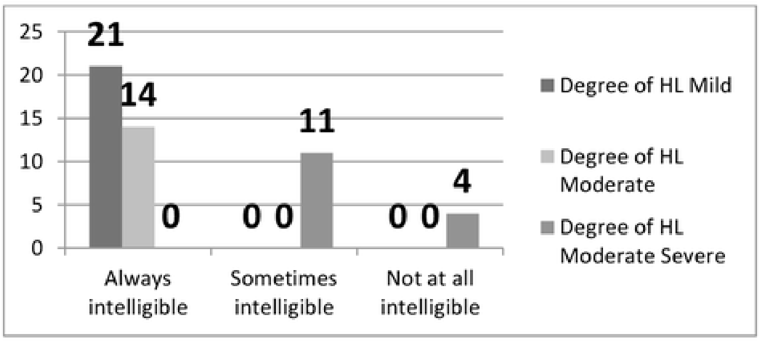


Figure 7 : Feedback towards intelligibility of output sound through head phone across degree of hearing loss.

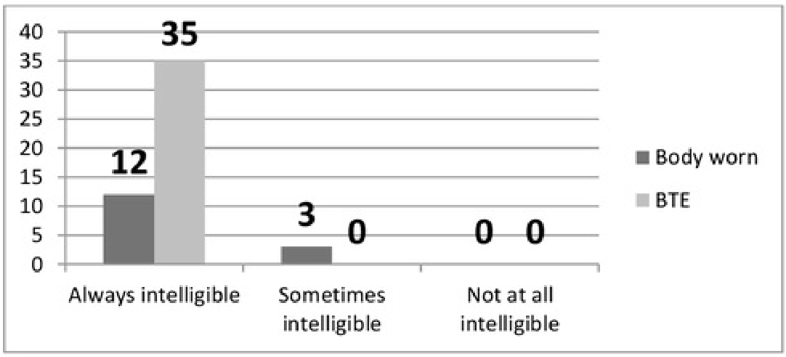


Figure 8: Feedback towards intelligibility of output sound through neck loop coupling across different hearing aids.

d) Discussion

i) Capability of the assistive device in overcoming the acoustic barriers at the museum

Table 1 shows that the measured values of acoustic variables such as background noise level, Reverberation Time (RT) and signal-to-noise ratio (SNR) at the three locations in the Regional Museum of Natural History, Mysuru were far distant from the optimal values reported by Carvallo et al (2013). The enhancement in SNR when the assistive device is added to the hearing aid is evident from Table 2. The SNR values in both cases i.e., when the assistive device is coupled with Body worn hearing aids and when coupled with BTE hearing aids were well above the minimum SNR limits reported by ASHA (2005) and ASA (2000). Noise levels at the output of both the hearing aids show that the noise levels are will within the maximum optimum levels of background noise. The assistive device electro-magnetically couples only the direct sound of the curator through the neckloop. Hence the reverberated sound will not be carried through the electromagnetic coupling between the assistive device and the hearing aid. Thus the results indicate that the assistive device has removed the acoustic barriers for the visitors with hearing impairment.

ii) Functionality

Functionality of the device was evaluated through the fourth question in the questionnaire which asked the user to judge whether the speech with the assistive device coupled with the hearing aid was always intelligible, sometimes intelligible or not at all intelligible. Figure 8 reports the responses. All the users of BTE hearing aids commented that the speech was always intelligible, whereas in body worn hearing aid users, 3 out of 15 of them felt that the speech in intelligible only sometimes. Chi square test was done to find out whether there is any significant association between the type of hearing aid and the intelligibility. Results established ($\chi^2(2)$ = 7.447, $p<0.01$) a significant association between the type of HA and intelligibility. In the pocket type hearing aids, the telecoil which couples the electromagnetic signal from the neckloop of the assistive device lies at the pocket level. When the visitor is moving, the neckloop may get shifted from its position, which might have lead to "sometimes intelligible" opinion of three users. Chi square test ($\chi^2(2)$ = 6.782, $p<0.05$ showed that there is no significant association between the degree of hearing loss and intelligibility. Thus the results establish that the functional objective of the device is to make the curator's speech audible and intelligible always, is accomplished.

iii) Reliability

Reliability of the device was evaluated with the response of the user from 2 questions. The first question was regarding the connectivity of the hearing aid with the assistive device. Figure 5 shows that the user of Behind The Ear hearing aids reported that their aids were always connected with the assistive device. 20% of the body worn users experienced some disconnection in between which may be due to the slipping of neckloop sometimes. Chi Square test ($\chi^2(2)= 7.447$, $p<0.05$) indicated a significant relationship between the type of hearing aid and connectivity. This indicates that the shifting of neckloop creates problem only for users of body worn hearing aids and not for BTE users.

The second question was regarding the response of the device towards a commentary request from the user. Figure 6 indicates all users opined that there was immediate response from the assistive device. Thus, the reliability of the device in performing its functions has been validated.

iv) Adaptability to universal design

A provision was made in the assistive device to route its output through headphones, so that the device can be used for visitors with normal hearing as well as for visitors who has hearing problems but not using hearing aids. The participants were requested to remove their hearing aids and listen to the commentary through headphones. As shown in figure 7, for visitors with mild to moderate hearing loss, the commentary was always intelligible through headphones For visitors with moderately severe to profound loss it was not intelligible always. Chi Square test ($\chi^2(2) = 50.00$, $p<0.001$) showed a significant relationship between the intelligibility through headphones and the degree of hearing loss. Thus, the device can be used for visitors with normal hearing as well as for visitors up to moderately severe hearing loss even if they are not using their hearing aids. This proves that the device is successful in its universal design strategy.

e) Conclusion

The results of the study, shows that the assistive device developed will make the visit of a hearing impaired person to the museum more informative and enjoyable. Universal design of the device makes it suitable for use by persons with normal hearing also. The availability of the device in any museum will make it accessible to persons with hearing impairment by overcoming the acoustic barriers. Affordability and maintenance is taken care of through the indigenous design. The field trials established the efficacy of the device across the type of hearing aids as well as for persons with different degrees of hearing loss.

f. **References**

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g. Appendix

Appendix I

Assistive device for museum access to Persons with hearing impairment

Questionnaire for field trail

Date: Venue of trails:

Name, Address & Contact No:

1. Connectivity between handset and server	: Always connected/getting disconnected in between
2. Response from the server towards intermediate request by the handset	: Immediate response/delayed response/ no response
3. Intelligibility of description heard through handset headphone	: Always intelligible/ sometimes intelligible/ not intelligible
4. Intelligibility of description heard through neck loop coupling with hearing aid	: Always intelligible/ sometimes intelligible/ not intelligible
5. Battery backup of the handheld unit	: one hour/ two hours/ three hours

- Respondent for field trail: museum visitors with hearing impairment.
- Time given for respondents: one day during visit of the respondent to the museum.
- Cadre of people participating in the field trail: all museum visitors with hearing impairment.

Appendix II

श्रवण क्षतिग्रस्त व्यक्तियों के संग्रहालय अभिगमन हेतु सहायक उपकरण

<u>क्षेत्र परीक्षण हेतु प्रश्नावली</u>

दिनांक : जाँचने की जगह :

नाम, पता एवं संपर्क संख्या :

१.	सर्वर एवं हैंड्सेट में संयोजकता	: हमेशा संपर्क में / बीच-बीच मे बाधित
२.	हैंड्सेट के मध्यवर्ती मांग पर सर्वर की प्रतिक्रिया	: तात्कालिक प्रतिक्रिया / विलंबित / प्रतिक्रिया नही ।
३.	हैंड्सेट हेड्फोन के द्वारा सुने गये विवरण की बोधगम्यता	: हमेशा बोधगम्य / कभी-कभी बोधगम्य / अबोधगम्य
४.	श्रवण यंत्र के साथ नेक लूप कपलिंग के द्वारा सुने गये विवरण की बोधगम्यता	: हमेशा बोधगम्य / कभी-कभी बोधगम्य / अबोधगम्य
५.	हैंड्हेल्ड ईकाई का बैटरी बैकअप	: एक दौर / दो दौर / तीन दौर

Appendix III

ಶ್ರವಣ ದೋಷವುಳ್ಳ ವ್ಯಕ್ತಿಗಳ
ಸಂಗ್ರಾಲಯ ಪ್ರವೇಶಕ್ಕೆ ಸಹಾಯಕ ಸಾಧನ

ದಿನಾಂಕ: ಸ್ಥಳ:

ಹೆಸರು, ವಿಳಾಸ, ದೂರವಾಣಿ:

೧. ಹ್ಯಾಂಡ್‌ಸೆಟ್ ಮತ್ತು ಸರ್ವರ್ ನಡುವಿನ ಸಂಪರ್ಕ :
ತಡೆರಹಿತ ಸಂಪರ್ಕ/ ಆಗಾಗ್ಗೆ ಸಂಪರ್ಕ ತುಂಡಾಗುವುದು

೨. ಹ್ಯಾಂಡ್‌ಸೆಟ್ ವಿನಂತಿಗೆ ಸರ್ವರ್ ಪ್ರತಿಕ್ರಿಯೆ :
ತಕ್ಷಣದ ಪ್ರತಿಕ್ರಿಯೆ/ತಡವಾದ ಪ್ರತಿಕ್ರಿಯೆ/ಪ್ರತಿಕ್ರಿಯೆ ಇಲ್ಲ

೩. ಹ್ಯಾಂಡ್‌ಸೆಟ್ ಹೆಡ್ಫೋನಿಂದ ತಿಳಿಯುವ ವಿವರಣೆ :
ಯಾವಾಗಲು ಗ್ರಹಿಸಬಹುದು/ ಕೆಲವೊಮ್ಮೆ ಗ್ರಹಿಸಬಹುದು/
ಗ್ರಹಿಸಲು ಸಾಧ್ಯವಿಲ್ಲ.

೪. ನೆಕ್ ಲೂಪ್ನೊಂದಿಗೆ ಶ್ರವಣ ಸಾಧನದಿಂದ ತಿಳಿಯುವ ವಿವರಣೆ :
ಯಾವಾಗಲು ಗ್ರಹಿಸಬಹುದು/ ಕೆಲವೊಮ್ಮೆ ಗ್ರಹಿಸಬಹುದು/
ಗ್ರಹಿಸಲು ಸಾಧ್ಯವಿಲ್ಲ.

೫. ಹ್ಯಾಂಡ್ ಹೆಲ್ಡ್ ಘಟಕದ ಬ್ಯಾಟರಿ ಬ್ಯಾಕ್ಅಪ್ :
ಒಂದು ಸರಧಿ/ ಎರಡು ಸರಧಿಗಳು/ ಮೂರು ಸರಧಿಗಳು

Hearing-1

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