DIRECTIONAL SPEAKER ARRAYS FOR ELDER CARE FACILITIES - REDUCING NEARBY ANNOYANCE WHILE MAINTAINING QUALITY OF LIFE

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A common pattern exists in elder care facilities whereby a hearing impaired person viewing a television in one living area disrupts a resident in an adjacent area due to excessive audio volume. With current technology, options exist including Bluetooth interfaced hearing aids and wired/wireless headphones. Often, though, the elderly are resistant to such approaches due to a lack of familiarity with technology or an unwillingness to wear hearing devices for entertainment. The fact that the resident is typically located in one particular location affords us an opportunity to use directional speaker arrays to provide local sound a high volume with little or no spillover into adjacent living spaces. This paper implements such an approach with measures of local loudness and doorway to the adjacent areas.
Keywords: directional, speakers, elder, annoyance

1. Introduction

Age-related hearing loss is the loss of hearing that occurs in most of us gradually as we grow older. It is one of the most common conditions affecting older and elderly adults. [1] Around 71% of people aged over 70 have some kind of hearing loss. [2] As our overall population ages, the likelihood of this hearing loss affecting both us and those around us. Assisted living facilities and nursing homes put people with hearing loss in close proximity through adjacent living spaces and – in some cases – in the same room. It is estimated that 75% of people in a care home have hearing loss and that this will increase to 80% by 2032. [2]

Personal entertainment (TVs and radios) are a large part of the elder – and elder care – environment. Adults aged >65 years spent threefold more waking time watching television than young adults. [3] Hearing this entertainment is, of course, important. A recent study of television viewers over age 50 indicated that over 80% of respondents considered the importance of hearing well while watching
TV to be either “very important” or “extremely important.” [4] The combination of hearing loss and a desire to hear increases the likelihood of personal entertainment negatively impacting others. That same study reported that more than 45% of hearing impaired respondents affirmed that other’s complained about the TV loudness when the hearing impaired respondent set the volume. [4] Environmental noise pollution from TV/radios has even been correlated to instances of resident-to-resident elder mistreatment in residential care facilities. [5]

Electronic assistive devices are now available at low cost. Wireless headphones and personal listening devices can provide assistance. It is even possible to directly interface Bluetooth hearing aids (HAs) with televisions. These advanced technologies are not as beneficial to aging users, though. Despite its utility, technology can be frightening and is perceived as a sensitive issue for the majority of elders, mainly if it is too intrusive, complex, embarrassing, or environmentally disruptive. [6] As shown in figure 1, almost 80% of respondents to a recent survey (hearing aid and non-hearing aid assisted) addressed their TV listening difficulty with a volume increase while little more than 10% used headphones or personal listening devices. Only 0.7% connected their TV output directly to their hearing aid. [4]

![Figure 1: Strategies used for television viewing by older hearing loss sufferers.](image)

Some older people will not rely on advanced hearing assistive technology because they simply do not want to accept that they have a hearing loss. A US government report stated that the gradual onset of hearing loss and negative social attitudes associated with it can reduce a patient’s acceptance hearing loss and – so – limit their understanding or willingness to address the issue through unconventional means. [7]

Patient diagnosis can sometimes exacerbate the issue. People with dementia are particularly affected by the acoustic environment with their bedroom being of particular importance. A paper by Hayne et al. describes it as “often the only defensible personal space the resident has access to.” The paper goes on to say, “In this personal space the person with dementia needs to be able to adjust their television or radio to a level where they can hear it comfortably. As many older people with dementia also suffer from hearing loss, this means that the noise level within the bedroom can be of the order of 80dBA.” [8]

As such, personal entertainment use in elder care facilities can represent a perfect storm of hearing loss, proximity, embarrassment, complexity, fear, and annoyance.
2. Directional speakers

It is proposed that a potential mitigating technology for the reduction of noise annoyance in elder care facilities is directional speakers. Directional speakers are intended to focus sound in unidirectional patterns. When properly implemented, the desired recipient of the sound hears the sound, while others outside of the restrictive sound field do not. Figure 2 shows the topfield (a) and crossfield profile (b) for a typical parametric loudspeaker array. [9]

![Figure 2: Topfield (a) and crossfield profile (b) for a typical parametric loudspeaker array.](image)

Parametric loudspeaker arrays (PLAs) were first proposed by Westervelt in 1963. [10] The method relies on the interaction of two collimated sound beams at different frequencies that then produce a beat note in the audible range upon intersecting. Figure 3 shows a representative parametric loudspeaker made from ultrasonic source. [11]

![Figure 3: Representative parametric loudspeaker made from ultrasonic source.](image)
3. Elder care application

Elder care – and, in particular – memory care rooms are small and close in proximity. Figure 4 shows two adjacent rooms in the memory care wing of the elder care facility in which this sound experiment was undertaken. It is apparent that the spaces are small and are in close proximity to one another.

It is common in elder care facilities for a resident to have a particular chair used for their television viewing. For the purposes of this study, a directional speaker array was placed 18” above the seat in a resident’s room and operated in both a direct downward facing and upward reflective facing modes.

![Figure 4: Memory care living spaces showing two adjacent rooms.](image)

4. Installation results and discussion

The audio source was a continuous pink noise excitation played through an entertainment speaker and PLA, respectively. The entertainment speaker was at the base of the television mounting location – 1.75m above the floor on the wall opposite the chair. It is worth noting that – out of space limitations – wall mounted televisions can only be mounted on the walls shared with adjacent rooms – increasing the likelihood of unwanted disturbances.

Ambient noise SPL measurements were made at each location. SPL measurements were then made at each location due using the conventional entertainment speaker, a downward facing directional speaker and an upward facing (reflective) directional speaker. The locations and the orientations of the directional speaker are shown in figure 5. A planned measurement in the adjoining room was not possible at the time that the test was conducted.

In each speaker-active case, the loudness at the seat head location was set to approximately 60dBA. The SPL at the other locations were then measured based on that setting.

At the time of the measurements, the facility was serving the mid-day meal. An effort was made to make the measurements when the noises from the dining area – roughly 20m down the hallway – were inaudible. The facility itself demonstrated good sound level discipline as the ambient noise levels were quite low.
Table 1 shows the measurement results. It can be seen that the use of the directional speaker results in reduced noise spillover into other locations within the room and at the doorway to the adjacent living spaces. The doorway reduction is important because this represents the primary path for the noise within the room to be added to the cumulative facility noise. A reduction in noise at the pillow head location is important because – often – a family member is with a patient while the patient is resting. Localizing the sound at the seat can result in the patient being able to rest while the family member uses the entertainment source.

<table>
<thead>
<tr>
<th>Location</th>
<th>Ambient (no TV)</th>
<th>Conventional TV speaker</th>
<th>PLA Direct Downward</th>
<th>PLA Upward (Reflective)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Seat head location</td>
<td>40 dBA</td>
<td>61 dBA</td>
<td>60 dBA</td>
<td>62 dBA</td>
</tr>
<tr>
<td>B Immediate TV front (0.5m)</td>
<td>40 dBA</td>
<td>69 dBA</td>
<td>40 dBA</td>
<td>44 dBA</td>
</tr>
<tr>
<td>C Pillow head location</td>
<td>41 dBA</td>
<td>61 dBA</td>
<td>40 dBA</td>
<td>42 dBA</td>
</tr>
<tr>
<td>D Doorway to hall</td>
<td>40 dBA</td>
<td>56 dBA</td>
<td>41 dBA</td>
<td>41 dBA</td>
</tr>
</tbody>
</table>

5. Conclusions

This document described the application of directional speaker arrays for the purposes of reducing extraneous noise exposure from television audio in elder care facilities. By focusing the sound on the resident, the resident can enjoy the higher noise levels that hearing loss requires while restricting the stray audio content from disinterested or unappreciative neighbors.

While maintaining an approximate 60dBA level at the head area of the resident seated in the room, the doorway sound pressure level was reduced by approximately 15dBA. The level at the pillow head location was reduced by approximately 18dBA. As such, the results support the use of directional speakers for this application.
While directional speakers demonstrate promise for the purpose of reducing noise in elder care facilities, the particular technology of the directional speaker should be considered. The carrier wave of ultrasonic PLAs is loud, although outside of the range of normal hearing – especially that of elderly individuals. Widespread application of ultrasonic directional speakers for this use would be contingent on further investigation into the impact of high level ultrasonic exposure or – until then – the use of an alternative technology.

REFERENCES


