The University of Sydney
Faculties of Health Sciences and Architecture
The Home Modification:
Information Clearinghouse Project

Evidence Based Research:

Selecting Doorbells for People with Hearing Impairment

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Abstract:

Objectives: To systematically search for, obtain, and analyse available evidence of the effectiveness of visual signalling devices as alternatives to doorbells in the homes of people with severe or profound deafness.

Design: Systematic review of electronic and other published literature concerned with the effectiveness and use of visual signal devices in the homes of people with severe or profound deafness.

Main outcome measures: Flashing white lights are more effective than static lights, but even strobe lights do not reliably wake sleepers. A flash rate of 1-3 flashes/second and pulse duration of no more than 0.2 seconds are recommended. Optimal brightness depends on room size, physical conditions and whether the occupant is awake or asleep, but generally, 15 candelas is the minimum recommended for non-sleeping areas, and 177 candelas is considered best to wake a sleeper. Signals should never be more that 15m from the user and should be located in every room. Health conditions and preferences of users affect the appropriateness and effectiveness of a visual signalling device; a combination of assistive technologies is best. The Australian Standards include specifications for visual warning devices, but do not apply to doorbells. The Building Code of Australia requires communication systems to be "suitable for occupants who are hearing impaired", but does not specify what that means or how to achieve it.

Results: The results include information from 25 published sources. Most (76%) were expert opinion or anecdotal evidence. In addition, 2 personal communications, 60 manufacturer specifications, and 4 legislative documents were reviewed independently. No evidence was found regarding the effectiveness of visual signalling devices as alternatives to doorbells for people with severe or profound deafness. Two quasi-experimental studies evaluated the effectiveness of strobe lights to wake sleepers, and another evaluated the effectiveness of light colours. An observation study found that assistive devices can reduce some psychosocial effects of hearing loss.

Conclusions: Visual signalling devices may be useful alternatives to auditory doorbells for people who are deaf, particularly when used with other assistive devices. Receiver type, colour, intensity, and placement; consumer co-morbidity and preferences; and environmental conditions appear to affect effectiveness, but empirical research is needed to guide best practice.

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Liability statement

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Problem Statement:

Are visual signalling devices effective alternatives to auditory doorbells for people with severe or profound deafness?

Area of concern:

Overall effectiveness, and relevant device, environment, and personal characteristics

Background:

The conventional auditory doorbell does not alert people who are deaf that someone wants attention outside the door, which can create social and psychological problems for people who are deaf. The doorbell is the gateway to much important communication: family, community members, and even emergency personnel initiate contact at the front door. With only a conventional doorbell, people who are deaf may miss important safety and social contact. Because severe and profound deafness cannot be medically or surgically treated, assistive devices are necessary to enable people with severe or profound deafness to respond to a doorbell. Visual signalling assistive devices produce a visual signal instead of or in addition to an auditory signal and can serve as alternative doorbells for people who are deaf. There is, however, limited evidence regarding their effectiveness and best practice in their selection, installation, and use.

Complete or partial hearing loss is a common long-term health condition in Australia (Australian Bureau of Statistics, 1998). In 2001, approximately 10.7% of Australia's population was classified as either deaf or hard of hearing (Australia Bureau of Statistics, 2001b). Most people with hearing loss are over the age of 45 years; people 75 years and older have the highest incidence of hearing loss.

Hearing loss varies in degree. Degree of hearing loss is expressed in decibels (dB) and can be categorised by severity (Scheetz, 1993). See Table 1. The threshold is the intensity of sound that an individual in a particular category is able to hear (Roeser, Buckley, & Stickney, 2000a). People with severe or profound deafness also have difficulty detecting sounds of certain frequencies, particularly those of higher frequencies. (Roeser, et al., 2000; Scheetz, 1993).

Table 1: Degrees of hearing loss

Degree of hearing loss	Hearing threshold level (dB)	Decibel levels of common sounds
Mild	26-40	Library 30dB Quiet living area 40dB
Moderate	41-55	General office building 50dB
Moderately severe	56-70	Conversation 60dB Vacuum cleaner 70dB
Severe	71-90	Factory interior 80dB Power drill 90dB
Profound	91+	Exercise class, Electric drill, Jet engine, Nightclub
(Roeser, et al., 2000, p.239; Sweetow, 1998)		(Surace, 2004)

The psychosocial effects of hearing loss range from embarrassment and irritability to anxiety, depression, loneliness, and a sense of isolation (Erber, 1993; Kampfe & Smith 1998). The uncertainty that can accompany hearing loss can cause withdrawal (Leder, Spitzer, Richardson, & Murray, 1988; Newman & Sandridge, 2004), and continually straining to hear can cause stress (Kampfe & Smith, 1998). These psychosocial effects of hearing loss may damage relationships and social networks (Morgan-Jones, 2001). People with hearing impairment also receive negative feedback, stigmatisation and impressions of inadequacy (Erber, 1993; Kampfe & Smith, 1998), which can lead to social withdrawal and isolation (Kampfe & Smith, 1998) and a reduced quality of life (Appollonio, Carabellese, Lodovico & Trabicchi, 1996; Dalton, Cruickshanks, Klein, & Klein, 2003). Psychosocial problems also reduce ability to work and require costly medical treatment (Australian Bureau of Statistics, 2001a). Because severe and profound deafness cannot be medically or surgically treated (Kaplan & Fernandes, 1986; Newman & Sandridge, 2004; Wilson, 1992), the environment must be changed to enable people who are deaf to fully participate. The conventional auditory doorbell is one part of the environment that can be changed to enable people who are deaf to participate more fully. A conventional auditory doorbell has two components:

- the transmitter, (the button outside the door) and
- the receiver, (the sound-producing element, usually situated in one room within the home).

Most doorbells have only one transmitter and one receiver. The volume and frequency of conventional doorbells are often inaudible to people with severe or profound deafness. The packaging on only 5 of the 27 doorbells examined stated a specific intensity, and these values ranged from 70dB to 100dB. These values represent the intensity at the receiver; they do not correspond to the intensity that reaches the listener's ear. Sound dissipates over distance (Erber, 1993; Parkin & Humphreys, 1969), and the volume may drop below the hearing threshold before reaching the listener with severe (71-90 dB) or profound (91+ dB) deafness. Auditory doorbells also often produce high frequency sounds (Brooks, 1997; Self Help for Hard of Hearing People, 2004), which are difficult for people with severe or profound deafness to hear (Scheetz, 1993).

Even if a person with severe or profound deafness can hear a particular doorbell at or near the receiver, reverberation (echoing) and internal and external background noise mask sound, making it difficult or impossible for people with severe or profound deafness to hear a doorbell (Rupp, Vaughn, & Lightfoot, 1984). Echoing occurs when sounds are reflected off of hard surfaces; for people who are deaf, echoed sounds become blurred and unrecognisable (Erber, 1993). The effect of background noise depends on its relative loudness.

House layout and design also can make it difficult or impossible to hear a conventional doorbell. Sound from the doorbell will not reach everyday living areas at its loudest intensity. The kitchen, family room, and rumpus room are typically at the rear of Australian homes (Fletcher, 2004), while doorbell receivers typically are near the front door. Walls and doors absorb sound (Bowman, Jamieson, & Ogilvie, 1995; Surace, 2005). Some home designs amplify background noise. While an open floor plan enhances transmission of sound through the house by decreasing the number of walls and doors, it also enhances the transmission of background noise. Multi-family dwellings also have more background noise.

Assistive devices are practical alternatives to major home remodelling that may help people who are deaf respond to doorbells, provided the right assistive device is selected. While the hearing aid is the principal assistive device used by people with hearing loss, it is not optimal for all individuals or for use in all environments. For people with severe or profound deafness, hearing aids may not amplify sound enough to be heard (Levitt & Bakke, 1995; Scheetz, 1993). Even when hearing aids can adequately amplify sound, they fall short when there is background noise or when the desired sound must travel a considerable distance (Kaplan & Fernandes, 1986; Newman & Sandridge, 2004; Rupp, et al., 1984). Hearing aids amplify both desired sound and background noise (Kaplan and Fernandes, 1986), and the desired sound becomes jumbled with the intensified background noise. Hearing aids do not effectively amplify sound that has travelled a considerable distance because the hearing aid's microphone is situated on the aid. When the desired sound reaches the microphone, its volume is lower than at its source. Additional assistive devices are needed for people with severe and profound deafness (Kaplan & Fernandes, 1986).

Visual or tactile signalling devices are alternatives to conventional doorbells (Forbes, Sturgeon, Hayward, Agwani & Dobbins, 1992; Pehringer, 1989). Like auditory doorbells, visual signalling devices have a transmitter and receiver/s. Unlike auditory doorbells, they gain attention with light or vibration, which may occur with or without sound. Visual signalling devices are the most frequently used non-audible alarm system (Bowman, et al., 1995).

Visual signalling devices are either wired or wireless and may be designed to work with an existing doorbell. The most advanced wired systems connect the transmitter to the electrical wiring for the household lights and make the household lights flash during the day or dim at night when the transmitter is activated (Lazzaro, 1993; Vanderhoff & Lakins, 2003). Receivers in less complicated wired systems are contained in small mountable outlets, which are either battery operated and come with an inbuilt light or plug into house power points (League for the Hard of Hearing, 2003). Those that plug into house power points either come with a light or have a connection for a household light, light bulb, or strobe (Harkins, 1991). See Figure 1

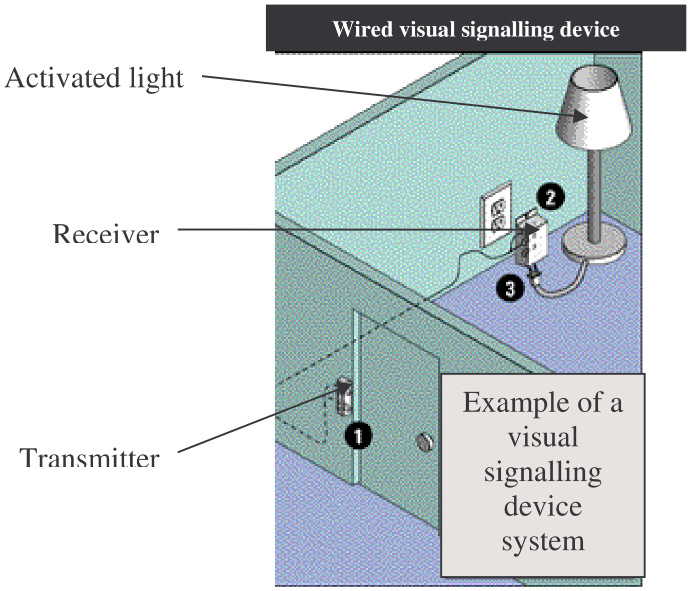

Figure 1: A wired visual signalling device used within the home

(Sonic Alert, 2003) Wireless devices transmit signals to remote receivers. A remote receiver is either a battery operated freestanding light or an outlet that plugs into a power point and to which a household lamp, light bulb or strobe is connected (Pehringer, 1989). When the transmitter is activated, the attached light flashes. Wireless devices are portable and can be transported to different rooms of the house, or receivers can be placed in various rooms throughout the house. Visual signalling devices also can be installed to work with the original doorbell so that the visual receiver, situated next to the auditory receiver (Jensema, 1990), is activated either through microphones that pick up sound waves or through sensors that detect magnetic pulses released when the auditory doorbell is activated (Lazzaro, 1993).

Typically, flashing lights signal activation of the doorbell; however, some devices produce a static light signal (Jensema, 1990). In flashing light devices, the flash rate is the number of flashes per second and is expressed in Hz (1Hz=1 flash cycle per second); the pulse rate is the amount of time the receiver is illuminated. Multifunctional visual signalling devices use different flashing patterns to alert occupants to activation of different environmental communication (e.g., doorbell, telephone).

The effectiveness of visual signalling devices to consistently gain attention is questionable. Visual signalling devices, like other alarm systems, are interrupt-based - that is, they should gain a person's attention while the person is focusing on other tasks (Wai-ling Ho-Ching, Mankoff & Landay, 2003). While hearing continually monitors 360° of a person's surroundings (Sanders, 1993), people cannot detect visual signals displayed outside the normal 110° field of vision (Stein, Slatt & Stein, 2000). See Figure 2. Therefore, a visual signal may not always gain the occupant's attention.

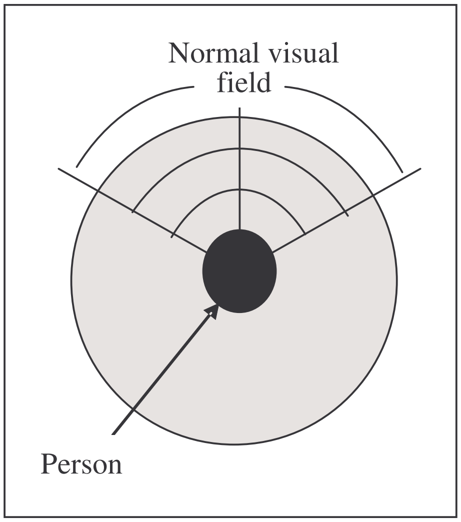

Figure 2: The normal human visual field

This systematic review sought evidence regarding optimal receiver number, placement, type, intensity, colour, range, and pattern; and ambient lighting conditions.

Evidence Based Practice Methodology Question Refinement Strategy

The Home Modification and Maintenance Information Clearinghouse protocol guidelines (Bridge & Phibbs, 2003) guided this systematic review. The research question was refined into an operational format that could be researched systematically by the application of appropriate search criteria (Bridge & Phibbs, 2003). See Tables 2 and 3.

Table 2: Five-part question refinement

Problem	Intervention	Outcome	Comparison	Target population
Auditory doorbells	Visual signalling device	Quality of response to activation	Auditory signal	Severe and Profound deaf

Table 3: Search terms identified using a standard and an online thesaurus:

Problem	Intervention	Comparison	Target population
- Doorbell - Device - Technology - Equipment	- Visual - Signalling - Alerting - Assistive - Light - Flashing light	- Alarm - Notification - Communication	- Deaf - Hard of hearing - Hearing loss - Hearing impairment - Hearing disorder - Severe deafness - Profound deafness

Inclusion criteria

Relevant material was included if it was: (a) written in English; (b) attainable through the University of Sydney or the World Wide Web; (c) based on studies that exclusively involved human subjects with hearing loss; (d) obtained via and related to the above-specified search terms; and (e) written after 1953, as electronic hearing aids replaced other hearing devices in 1953 (Audiotech Healthcare Corporation, 2000), and home modification technology and practice have changed substantially since then (Bridge & Phibbs, 2003).

Exclusion criteria

Material that did not meet the inclusion criteria and general or unoriginal editorials, whole of subject books, and conference papers were excluded.

Search Process

The following sources were searched:

1) **The Home Modification Information Clearinghouse's Library**

2) **Standard electronic databases, including:**
   - Ageline
   - AMED (Allied and Complementary Medicine)
   - AMI: Australasian Medical Index
   - APAIS: Australian Public Affairs
   - APAIS: Health
   - API: Architectural Publications Index
   - ARCH: Australian Architecture Database
   - BUILD: Australian Building Construction and Engineering Database
   - CAB Abstracts
   - CINAHL (nursing and Allied Health)
   - Compendex Plus
   - Current Contents
   - EVA: environmental Abstracts
   - Expanded Academic ASAP
   - Medline Ovid
   - OSH-ROM
   - ProQuest 5000
   - Science Direct
   - University of Sydney Thesis
   - Web of Science

Truncation & wildcard symbols

*, ?, $, #, ! (depending on which data base was searched

Boolean operators

AND, OR, NOT, WITH, NEAR, ADJ, XOR, W/nn, PRE/nn, %, !

3) World Wide Web, using the 'Google' search engine and the following specific websites:

Web sites	Web Address
TRACE research and development Centre	www.trace.wisc.edu
Joseph Rowntree Foundation	www.jrf.org.uk
Centre for Accessible Environments	www.cae.org.uk/
IDEA Centre	www.idea.ksu.edu
National Resource Centre on Supportive Housing and Home Modifications	www.homemods.org/
Access Board	www.access-board.gov/adaag/html/adaag.htm
RERC	www.rerc.ufl.edu/
American Academy of Audiology	http://www.audiology.org/index.php
Self Help for Hard of Hearing	http://www.shhh.org/
American Speech-Language-Hearing Association	http://search.asha.org/http://search.asha.org/

Table 4: Websites searched[1]

4) Grey literature, including:

- visual signalling device manufacturer specifications
- suppliers' websites
- journals that were not available through electronic databases
- assistive device/technology books on the shelves at the University of Sydney's Health Sciences library.

5) Anecdotal evidence

Personal telephone calls or emails were sent to organizations and some manufacturers, respectively, and a query was posted on the HM Information Clearinghouse list serve. Figure 3 summarises the literature review process.

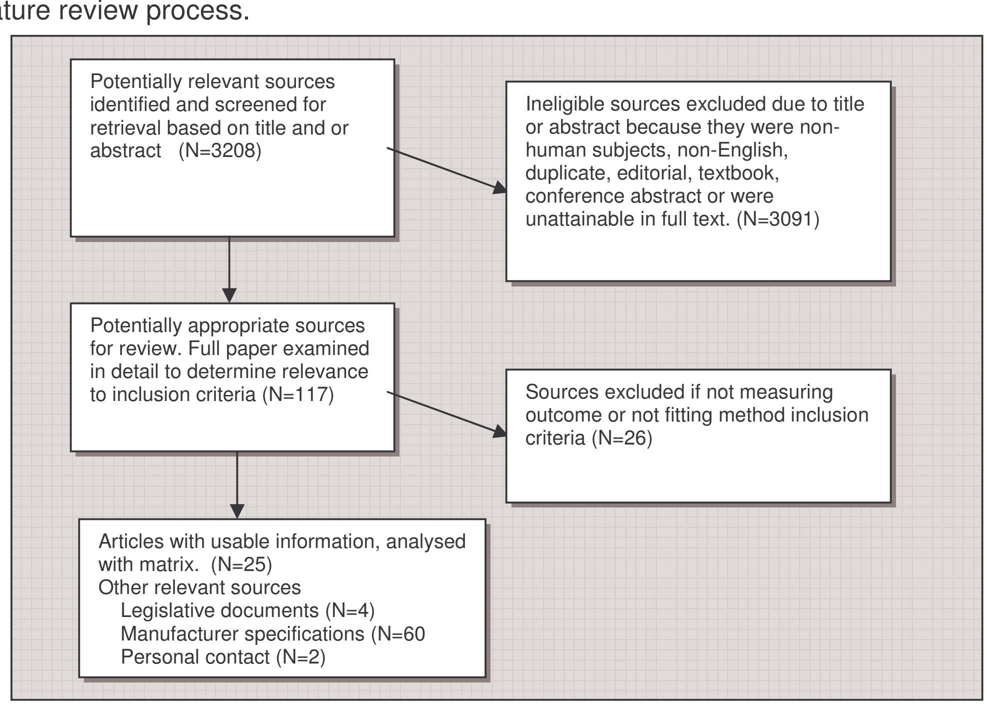

Figure 3. Flow chart of the review process

[1] No relevant material was found from the specific website searches.

Each of the other 25 sources was analysed to determine whether it addressed the variables in the matrix shown in Table 5. Information from the personal contacts, manufacturer specifications, and legislative documents was included in the discussion of results, but these sources were not analysed with the variable matrix.

Table 5: Definitions of matrix variables

Variable		Does the source specify…
Severe deafness	**Person**	Severe deafness, as opposed to simply referring to hearing loss as a whole? Severe deafness can be specified by referring to people who are deaf or through giving the corresponding dB value of severe deafness.
Profound deafness	**Person**	Profound deafness, as opposed to simply referring to hearing loss as a whole? Profound deafness can be specified by referring to people who are deaf or through giving the corresponding dB value for profound deafness.
Psychosocial implications	**Person**	Recognise pyschosocial repercussions of hearing loss and refer to intervention device effects or lack thereof on those psychosocial repercussions of hearing loss?
Attend to the door with use of a visual signalling device	**Activity**	That visual signalling devices are effective at alerting an occupant who is deaf to the activation of the doorbell?
Fail to attend to door with use of visual signal	**Activity**	That visual signalling devices are ineffective at alerting an occupant who is deaf to the activation of the doorbell?
Visual Signal	**Environment**	Use of a visual signalling device used to transmit environmental communication?
Auditory output	**Environment**	A combination of a visual and audtiory output to transmit environmental communication?
Light colour	**Environment**	Use of a specific colour of light in a visual signalling device or that one colour is better than another?
Signalling pattern	**Environment**	A light flashing pattern that is most appropriate for gaining attention?
Range of receiver/s	**Environment**	A range or distance that the visual signalling devices project light in an enclosed environment, such as the home?
Situation around home	**Environment**	The most appropriate placement of device throughout the home?
No. of Receivers	**Environment**	An appropriate number of visual receivers for placement in a home?
Placement in rooms	**Environment**	The most appropriate placement of visual receivers within a room?
Dist. Signal to person	**Environment**	A maximum distance between the visual signal and the occupant for the signal to gain attention?
Brightness of light	**Environment**	A minimum or maximum brightness of the light in a visual signalling device?
Ambient light affected	**Environment**	The visual signalling device's attention gaining abilities in the presence of ambient light?
Background noise	**Environment**	That visual signalling devices are an alternative way to overcome difficulties that hearing aids present within the home?

OUTCOMES

General Outcomes

Table 6 summarises the number of usable items retrieved from each source searched. Ninety-one relevant items were retrieved: 25 articles that referred to one or more relevant variables in the matrix in Table 5, and 2 personal communications, 60 manufacturer specifications, and 4 legislative documents that were reviewed independently of the matrix.

Table 6: The total number of usable items retrieved from the each search source

Search Source	No.of usable items retrieved
HMinfo Library	2
Databases	14
World Wide Web 'Google' Search	7
Legislative Documents	4
Grey Literature	60 manufacturer specifications, 1 journal article & 1 book chapter from hand searching
Anecdotal evidence	1 phone call, 1 email

The 25 articles covered a span of 16 years, from 1988 to 2004. No research was found that evaluated visual signalling devices used as doorbells; the studies that were retrieved investigated visual signalling devices used as smoke alarms. Other articles discussed assistive technology for people with hearing loss and specifically mentioned signalling devices.

Articles Analysed with Variable Matrix

Nationality of authors

Authors from the United States wrote the majority of the 25 articles included in this systematic review. Figure 4 shows the material reviewed by author nationality.

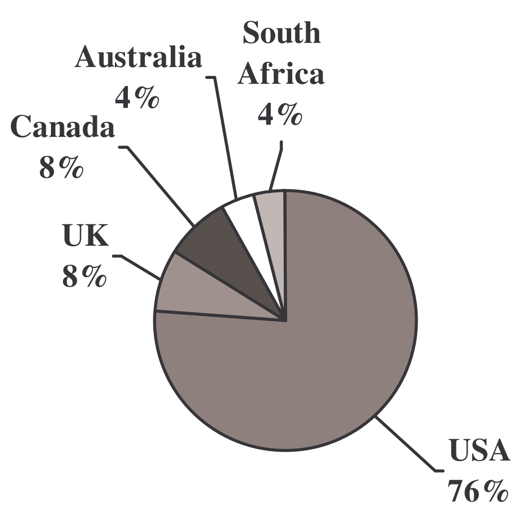

Figure 4: Nationality of authors

Quality of evidence

Figure 5 depicts the quality of evidence. The majority of the 25 sources (68%) included in this review were classified as expert opinion (68%) and anecdotal evidence (8%). No systematic reviews or randomised control trials were retrieved. Twenty-four percent of the articles reported on studies, evenly divided between quasi-experimental, observation, and case studies.

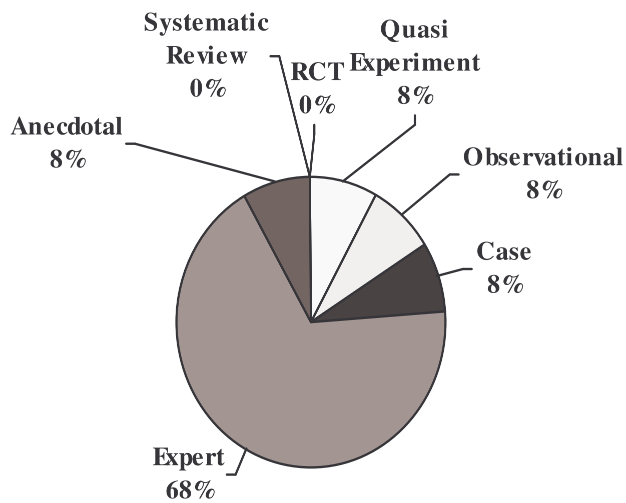

Figure 5: Method of the included sources

Analysis outcomes

The variables in each of the 25 articles analysed with the matrix were categorised as person, activity or environment.

Person Variables

Figure 6 depicts the percentage of the articles that included one of the three person variables. Forty-eight percent did not mention any of the person variables; 32% referred specifically to device use in relation to severe and profound deafness; the remainder (20%) spoke generally of device use by people with hearing loss. Twenty-four percent of the material reviewed mentioned the effect of device use on psychosocial repercussions of hearing loss.

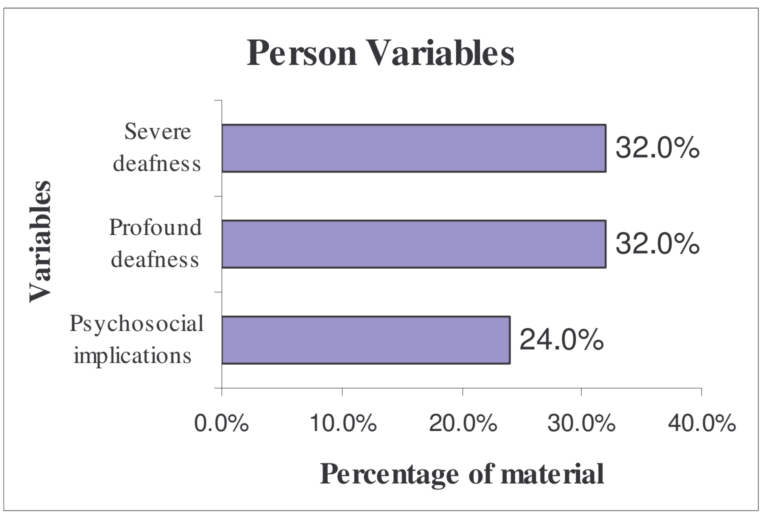

Figure 6: Percentage of sources that specifically referred to one or more person variables

Activity Variables

Figure 7 depicts the percentage of the 25 articles that mentioned one of the activity variables. Seventy-two percent of the material reviewed did not discuss either activity variable. Twenty-eight percent mentioned successful use of the visual signalling device as a doorbell alternative, and no sources mentioned failure to answer the door with the use of a visual signalling device.

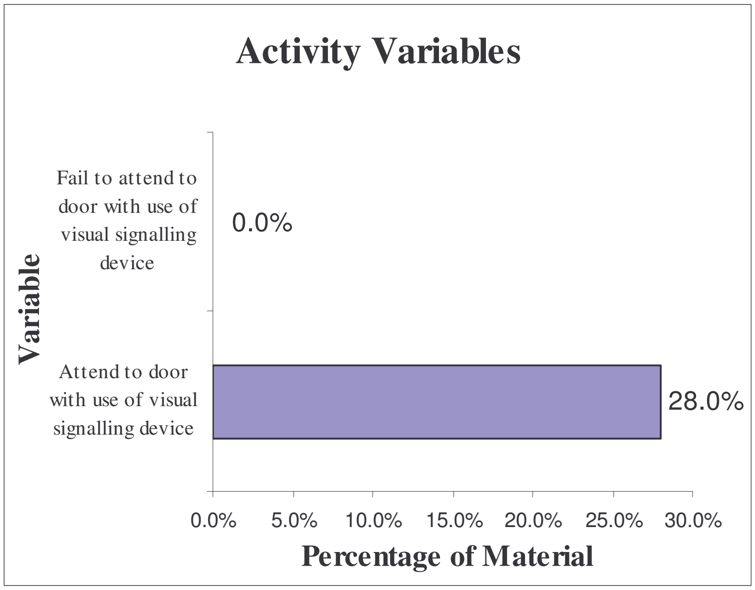

Figure 7: Percentage of sources that specifically referred one or more activity variables

Environment Variables

Figure 8 depicts the percentage of the 25 articles that referred to an environment variable. No articles mentioned the range of visual signals within an enclosed environment; all other environment variables were mentioned in one or more of the articles. Eighty-four percent referred to the use of visual signalling devices; the remaining 16% referred to 'signalling devices', but did not specify whether the signal was visual or tactile. The second most frequently mentioned environment variable was placement, which appeared in 24% of the sources.

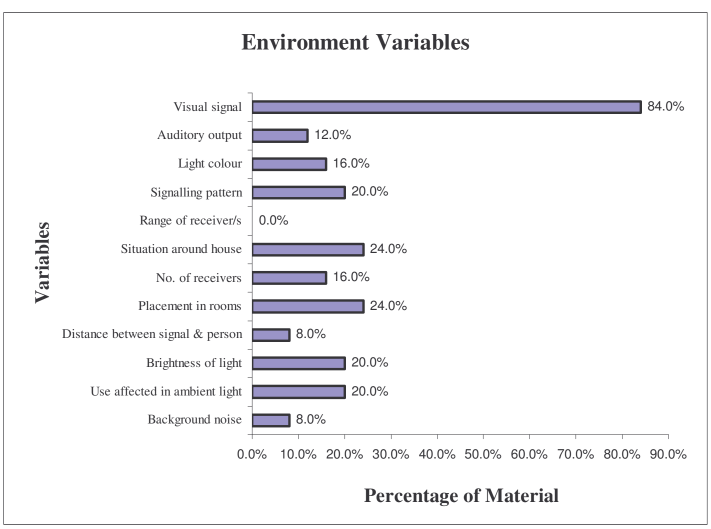

Figure 8: Percentage of sources that specifically referred to one or environment variables

Other Sources

Anecdotal Evidence

The two personal communications that included relevant information were one telephone call to Deafness Resources Australia and one email reply from SilentCall. No one responded to the question posed on the list serve.

Manufacturer Specifications

Table 7 shows the manufacturers that were identified from the Google searches, their specific product line, and their web addresses.

Table 7: Manufacturers and products[2]

Manufacturer	Product Line	Web address
Bellman & Symfon	Bellman Visit	http://www.bellman.se/web2/
Clarity	Ameriphone	http://www.clarityproducts.com/
Global Assistive Devices	Door Beacon	http://www.globalassistive.com/
SilentCall communications	Silentcall	http://www.silentcall.com/
Sonic alert	Sonic Alert	http://www.sonicalert.com/
Ultratec	Ultratec	http://www.ultratec.com/

Laws and Regulations

Legislative and regulatory documents from the Home Modification Information Clearinghouse Library, standard electronic data bases, and the World Wide Web were examined to identify those that contained requirements and guidelines applicable to visual signalling devices. Four relevant documents were found. Excluding the Building Code of Australia, they pertained to visual signalling devices used as smoke or fire warning signals, but contained standards that could be adapted to visual signalling devices used as doorbells.

Building Code of Australia (BCA), 2004 Section D, Access and Egress (Australian Building Codes Board, 2004).

The BCA section D, Access and Egress, clause DP9 states that "in built communication systems for entry, information, entertainment or for the provision of a service must be suitable for occupants who are hearing impaired". The BCA does not state how the requirements are to be met or what makes a communication system "suitable for occupants who are hearing impaired". The search yielded no Australian Standards corresponding to this section of the Building Code.

Australian Standards AS 1603.11-2001, Automatic fire detection and alarm systems Part 11: Visual warning devices (Standards Australia, 2001).

AS 1603.11, section 2.5 applies to devices used in fire detection, warning, control and alarm systems, and not to communication devices (such as a doorbell), in private residential buildings. The Standard requires the following characteristics for strobe visual warning devices:

- White light; however, if coloured lenses are used intensity needs to be adjusted according to attenuation of the coloured lens;
- Flash rate of no less than 1Hz and no more than 3Hz and pulse duration of no more than 0.2 seconds; and
- When multiple units are installed, they must be synchronised.

[2] These are not the only manufacturers of visual signalling devices, but were identified as the primary companies involved in production of visual signalling doorbell devices because they consistently appeared in web search results.

Standards Australia HB123-1999 Guidelines for the selection, location and installation of visual warning devices in building (Standards Australia, 1999).
HB123-1999 provides that all visual warning devices should be located in such a way that they are visible to any person in the required coverage area, regardless of the person's orientation. The light should be white. Within sleeping areas of residential facilities, the minimum intensity of the strobe light should be 110 candelas,[3] measured at pillow level. Within non-sleeping areas, the minimum light intensity should be 15 candelas. Strobes should be mounted 2 to 2.4 metres from the floor. Tables 8 and 9 show the required intensities for single or double strobe lights mounted on the wall or ceiling, respectively, for various room sizes. Rooms larger than $15m^2$ require more than one visual device when mounted on the ceiling.

Table 8: Specifications for wall mounted visual signalling device receivers (Standards Australia, 1999)

Room Size (metres)	Intensity of a single strobe (candela)	Intensity of two strobes located on opposite walls (candela)
6m x 6m	15 candela	n/a
9m x 9m	30 candela	15 candela
12m x 12m	60 candela	30 candela
15m x 15m	95 candela	60 candela

Table 9: Specifications of ceiling mounted visual signalling device receivers (Standards Australia, 1999).

Room Size (metres)	Ceiling height	Minimum intensity of a single strobe mounted in centre of ceiling (candela)
6m x 6m	3m	15
9m x 9m	3m	30
12m x 12m	3m	60
15m x 15m	3m	95

No international legislation or regulations were found that applied to the use of communication devices within private dwellings, but the Americans with Disabilities Act Accessibility Guidelines for visual fire alarms in public facilities could be adapted to visual doorbell signals.

Americans with Disabilities Act Accessibility Guidelines for Buildings and Facilities- Appendix A to part 36- Standards for Accessible Design (United States Department of Justice, 1994).

The ADA Accessibility Guidelines provide that visual alarms shall be visible from all areas of a room and that:

- The lamp shall be of a xenon strobe type of clear colour or nominal (unfiltered) white;
- The maximum pulse duration shall be 0.2 seconds;
- The minimum intensity shall be 75 candelas;
- The appliance shall be placed at the lower or 2030mm above the highest floor level or 152mm below the ceiling; and
- No room or space shall be more than 15m from the signal (Department of Justice United States of America, 1994).

[3] A candela is the equivalent of the light output of one candle, measured at the light source (Stein, et al., 2000).

Summary of Findings

Visual signalling devices may be useful alternatives to auditory doorbells for people who are deaf, but there is little empirical evidence regarding their effectiveness or important characteristics. Audible signals are not appropriate for people who are deaf (Ross & Mulvany, 2003), and merely amplifying audible signals is not practical for people with severe or profound deafness (Pehringer, 1989). Although visual signalling devices are the most commonly used alternatives to auditory devices (Harkins, 1991; Ross & Mulvany, 2003), they are not used extensively by people who are deaf. See Table 10.

Reference	Finding regarding the number of signalling device consumers
Tomita, Mann & Welch, 2001	Out of 227 people with hearing loss only 32 owned assistive intervention devices other than hearing aids and only 3 of these were signalling devices for the doorbell.
Leder, et al., 1988	Only 3 out of 25 participants with hearing loss owned a signalling device.
Mann, Hurren, & Tomita, 1994	A study specifically focused on the needs of home based elderly people with hearing loss. A total of 35 participants owned between them a total of 40 assistive hearing devices. Out of these 40 devices only 2 were signalling devices.
Ross, 1988	Only 20% of all participants owned a visual signalling device for a doorbell.
Forbes, et al., 1992	Signalling devices were the 3rd highest identified category on the "% of persons reporting a severe hearing impairment with a need for various assistive devices".

Table 10: Summary of research regarding the low number of signalling device consumers

Low use rates do not appear to be due to consumer dissatisfaction (Forbes, et al., 1992; Leder, et al., 1988; Mann, et al., 1994; Ross, 1988; Tomita, et al., 2001), but to consumers' lack of knowledge about available devices (Mann, et al., 1994). Health professionals are often less informed about visual signalling devices than they are about interventions that amplify sound (Harkins, 1991), which could contribute to consumers' lack of knowledge. Little evidence was found regarding the effectiveness of visual signalling devices. There is general information about types, purposes and availability of visual signalling devices and expert and anecdotal information regarding specific device characteristics that are associated with effectiveness. There is, however, little empirical research.

Focus Questions

What type, colour and brightness of light most effectively gain attention?

Type. Experts stated that hardwired systems currently are more reliable than wireless systems (Hersh, Johnson & Anderson, 2003; Vanderhoff & Lakins, 2003). Experts also advised that, whether wired or wireless, systems should have a back up power plan for use during power failures (Ross & Mulvany, 2003). Installation requirements must be considered (Palmer, 1993); for example, a wired single receiver system is less complicated to install than a system that is wired to household ceiling lights.
Experts suggested that flashing lights are more effective than static lights (Jensema, 1990), and, within daylight conditions, strobe lights are the most visible form of light signal from a distance (Hersch, et al., 2003). Only 25% of the products reviewed had strobe light receivers. While one quasi-experimental study found that strobe lights also are the most effective at waking a deaf person (Nober, Well, & Moss, 1990), another found that strobe lights do not consistently wake sleepers (Bowman, et al., 1995). The United States Access Board (2003) recommends that tactile devices may be more appropriate for use during sleep.

Colour. Expert and quasi-experimental sources agreed that white light is more discernible than coloured light (Nober, et al., 1990; United States Access Board, 2003) and that red light is the least effective, even when used at extreme intensities (Bowman, et al., 1995; Nober, et al., 1990; United States Access Board, 2003).

Figure 9 summarises available information about colour and type of light.

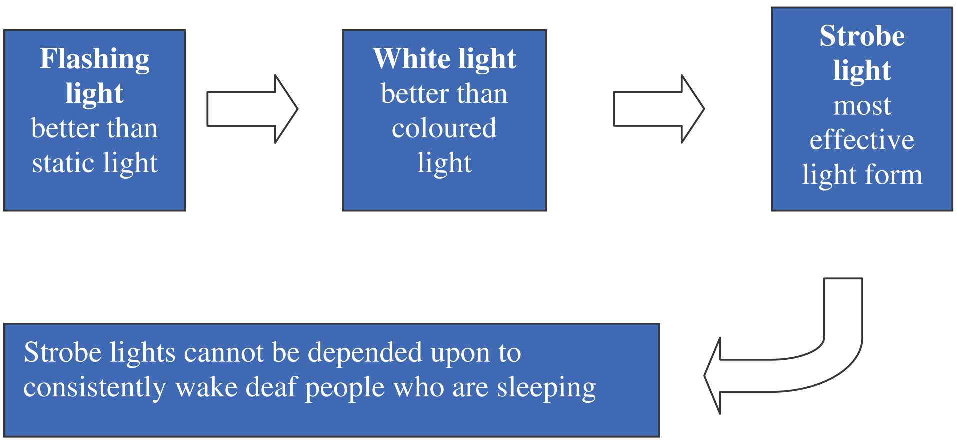

Figure 9. Cycle of results regarding type and colour

Brightness. According to expert opinions: the minimum intensity to effectively gain attention is 15 candelas for non-sleeping areas of the dwelling (G. Elwell personal communication, December 2, 2004); a minimum of 110 candelas at eye level is required to have any chance of waking a sleeping person (Hillson, 2001); 177 candelas is optimal to wake a sleeping person (Ross & Mulvany, 2003); light intensity should be maximised for each signal receiver to minimize the number of receivers required (United States Access Board, 2003); and the optimal intensity will depend on room size, physical conditions, and whether the occupant will be awake or asleep. HB 123-1999 includes specific recommendations for brightness for wall and ceiling mounted receivers in various room sizes. Although light dissipates with distance, no information was found regarding the distance that light of a particular intensity could travel and still gain attention.

What is the most effective signalling pattern?
Based on expert opinion, the flash rate of a visual signalling device should be a minimum of 1 Hz and a maximum of 3 Hz (United States Access Board, 2003), that is 1-3 flash cycles per second. The pulse duration, that is the amount of time the device is illuminated, should be no more than 0.2 seconds (United States Access Board, 2003). If multiple devices are used, their flashes should be synchronised.

Are visual signalling devices effective in ambient light?
According to anecdotal evidence and expert opinions, visual signalling devices can go undetected in brightly lit rooms (Fox, 2001; Harkins, 1991; Jensema, 1990).

What is the optimal number of device receivers in a home?
The optimal number of receivers depends on the size and floor plan of the dwelling. According to expert sources, it is best to have a receiver in every room of the house (Harkins, 1991), but the adequacy of one receiver per room depends upon the size and layout of the room (United States Access Board, 2003).

What is the most advantageous situation of device receivers around the home, and what is considered the best placement of receivers within a room?
Experts stated that, at a minimum, receivers should be placed in the most frequently used rooms (Harkins, 1991; Pehringer, 1989; Piesse, 1996); ideally they should be placed in every room (Harkins, 1991). Experts also stated that receivers must be placed where they can be seen regardless of a person's location (Ross & Mulvany, 2003); at a minimum, the person for whom the signal is intended should never be more than 15m from a receiver at any time (United States Access Board, 2003). HB 123-1999 recommends that receivers be placed 2.0m to 2.4m from the floor; the ADAAG requires placement at either 2030mm above the highest floor level or 152 mm below the ceiling, whichever is lower. A single centrally-located 15 candela strobe is adequate for rooms that are less than 15m in diameter. In irregularly shaped rooms the receiver should be placed on a wall where it can reach each corner (United States Access Board, 2003). See Figure 10.

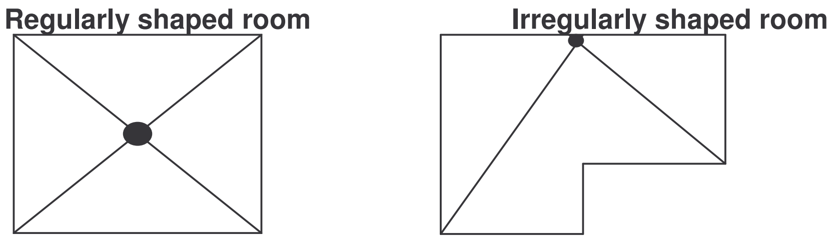

Figure 10: Placement of visual signalling devices within a regular and irregular shaped room

Do visual signalling devices effectively gain attention in all spaces of the house?
No definitive answer can be given because of the lack of substantial evidence. One expert suggested that, if receivers are placed within all rooms of the house, they may be able to gain attention within all rooms (Harkins, 1991).

Additional Questions of Interest

What personal consumer characteristics affect device selection?

Comorbidity. One observational study found that elderly people with hearing loss had an average number of 5.3 co-existing health conditions (Mann, et al., 1994). Expert opinion suggested that the usability and effectiveness of visual signalling devices may be compromised by coexisting health conditions that affect vision, cognition or problem solving skills (Palmer, 1993). Experts also stated that flashing lights may be contraindicated in the presence of photosensitivity or epilepsy (Royal National Institute for Deaf People & British Deaf Association, 1999; United States Access Board, 2003). For a device to be effective, the user must be able to see the light, must not be sensitive to signals from a flashing light, and must be able to operate the system (Royal National Institute for Deaf People & British Deaf Association, 1999). Because the health status of people changes over time, the appropriateness of interventions may change over time; reassessment should be ongoing.

Consumer preferences. The person for whom the device is intended should be the primary person involved in decision-making throughout the entire process (Ross & Mulvany, 2003). The acceptability of specific device characteristics will vary from person to person. For example, strobe lights can become too annoying for everyday use (G. Elwell, personnel communication, December 2, 2004). Most people prefer using table lamps to alert them to the telephone or doorbell (G. Elwell, personal communication, December 2, 2004; Harkins, 1991). Experts also noted that it is important to consider the needs and preferences of the consumer's family and communication partners (Palmer, 1993); flashing lights, for example, can annoy people for whom they are unintended (Jensema, 1990).

Can signalling devices alleviate some of the psychosocial effects of hearing loss?

An observation study concluded that assistive devices, including visual signalling devices, can decrease social isolation and promote independence and self-esteem for people who are deaf (Leder, et al., 1988). Similarly, experts stated that signalling devices promote self-reliance (Palmer, 1993) and encourage independence and freedom at home (Vanderhoff & Lakins, 2003). Anecdotal evidence indicated that visual signalling devices promote a sense of safety and awareness of sound (Fox, 2001).

Is a visual signalling device enough?

Probably not. According to expert opinion, people with hearing loss rarely depend on a single system of communication (Joint Committee of the American Speech-Language-Hearing Association, 1998); usually, a combination of technologies is better than a single device (Montano, 2003; Pehringer, 1989). A quasi-experimental study found that visual signals do not reliably wake people who are sleeping (Bowman, et al., 1995); anecdotal evidence and expert opinion suggested that ambient light can cause a visual signal to be difficult to detect (Fox, 2001; Harkins, 1991; Jensema, 1990) and that an occupant who is outdoors will not see light signals (Ross & Mulvany, 2003). Experts noted that vibration pagers may be appropriate in some circumstances (Harkins, 1991; United States Access Board, 2003). Specifications for nine vibration pagers to signal activation of the doorbell were found.

Do manufacturers' specifications provide the information that consumers need to select an appropriate visual signalling device?

No. For the most part, manufacturers provided general information that did not address device characteristics that appear to be linked to effectiveness. Although light dissipates with distance, manufacturer specifications did not state the range of the visual signal or the optimal or maximum viewing distance; none of the available manufacturer specifications indicated a flash rate or pulse duration. Thirty percent indicated that they had a flash code for different occurrences (e.g., doorbell or telephone), and 8% (all non-strobe devices) indicated that the occupant could select the desired number of flashes.

Policy Development

Because visual signalling devices can be used for different purposes, laws should address all potential uses of visual signalling devices, not just use as emergency alarms. Laws also should govern the type of information manufacturers are required to provide; at a minimum, manufacturers should provide information about installation requirements, light intensity, optimal viewing distance and/or distance the visual signal travels, optimal number of receivers per given amount of space, flash rate, and pulse duration.

Further Research

There is a significant need for future research about the effectiveness of visual signalling devices as alternatives to doorbells for people with severe or profound deafness and regarding the device characteristics that impact effectiveness.

Additional research is needed regarding the influence of house layout on the effectiveness of visual signalling devices. No empirical evidence was found regarding optimal viewing distance from signals of various intensities and forms or the impact of floor plans on visual signal effectiveness.

Future research regarding interventions for people with hearing loss should be conducted and reported in a manner that specifies the degree of hearing loss for which the intervention was assessed. Only 32% of the sources used in this review specified a degree of hearing loss. The majority of sources' general reference to people with hearing loss mistakenly implies that the same interventions are appropriate for people with different degrees of hearing loss (National Association of the Deaf, 2003; Roeser, et al., 2000; Scheetz, 1993).

Additional research regarding the psychosocial effects of hearing loss should be conducted. Although studies have addressed depression in people with hearing loss (Mann, et al., 1994; Tomita, et al., 2001), studies have not assessed other psychosocial effects.

Additional research also is needed regarding the psychosocial benefits of visual signalling devices. Only one observational study (Leder, et al., 1988) and no experimental studies were found.

Interviews with people who are deaf and have first hand experience with visual signalling devices could provide guidance about what is practical in the home environment and identify gaps in available technology.

Research about health care professionals' knowledge of hearing loss and assistive devices is necessary. A case study concluded that health care professionals' lack of knowledge about available assistive devices leads to low use rates (Forbes, et al., 1992). Research is needed about health professionals' knowledge about hearing loss; their care strategies; their knowledge about the existence, benefits, and limitations of assistive devices; and the techniques they use to convey this information to their clients.

A comprehensive systematic review of evidence of the effectiveness of tactile signalling devices is needed.

Practice Tips

The following is intended only as a guide to some important considerations during the process of selecting assistive devices for people with hearing loss.

What to ask consumers who are considering a visual signalling device:

- *Degree of hearing loss*: How much residual sound can you hear? How much auditory environmental communication can you receive and respond to?
- *Co-morbidity issues*: Do you have any health conditions other than hearing loss?
- *Communication environment*: Do you live in a house or a unit?
- *Communication environments around the home*: How much time do you spend indoor/outdoors each day?
- *Communication partners*: Do you live with other people? Do they have hearing loss or other health conditions?
- *Personal preference*: Have you ever used a visual or tactile type device? If so do you have a preference?
- *Purpose of visual signalling devices*: For what purposes are the visual signalling device intended?
- *Installation*: Could you install the selected device or will it require an electrician?

The occupational therapist or home modification and maintenance service provider also should:

- inspect the home environment to determine how many receivers are required and where they should be placed;
- provide trial periods with assorted devices to help ensure selection of the most suitable device;
- assess the existence of and potential to prevent secondary complications of hearing loss; and
- be familiar with referral options to ensure comprehensive service for clients.

Sources of Additional Information

- Manufacturers or suppliers of the signalling device/s,
- Specialised hearing loss organisations such as the Deafness Resources Australia, or Self Help for Hard of Hearing (SHHH).
- The HMInfo Clearinghouse Resource Library.

These organisations can be located through the local telephone books or the Web.

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