Smoke alarms and sleep

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"Smoke alarms as part of a system"

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"Waking effectiveness of alarms"

Part 1

"Smoke alarms as part of a system"

- *domestic smoke alarms are part of a system*
  - designed, installed and maintained for a specific purpose
  - purpose: save occupants who would otherwise be killed or injured by fire
- *measure of effectiveness*
  - occupants safe who would not otherwise have been safe

The smoke alarms are not the whole system

Introduction

Domestic fire safety system

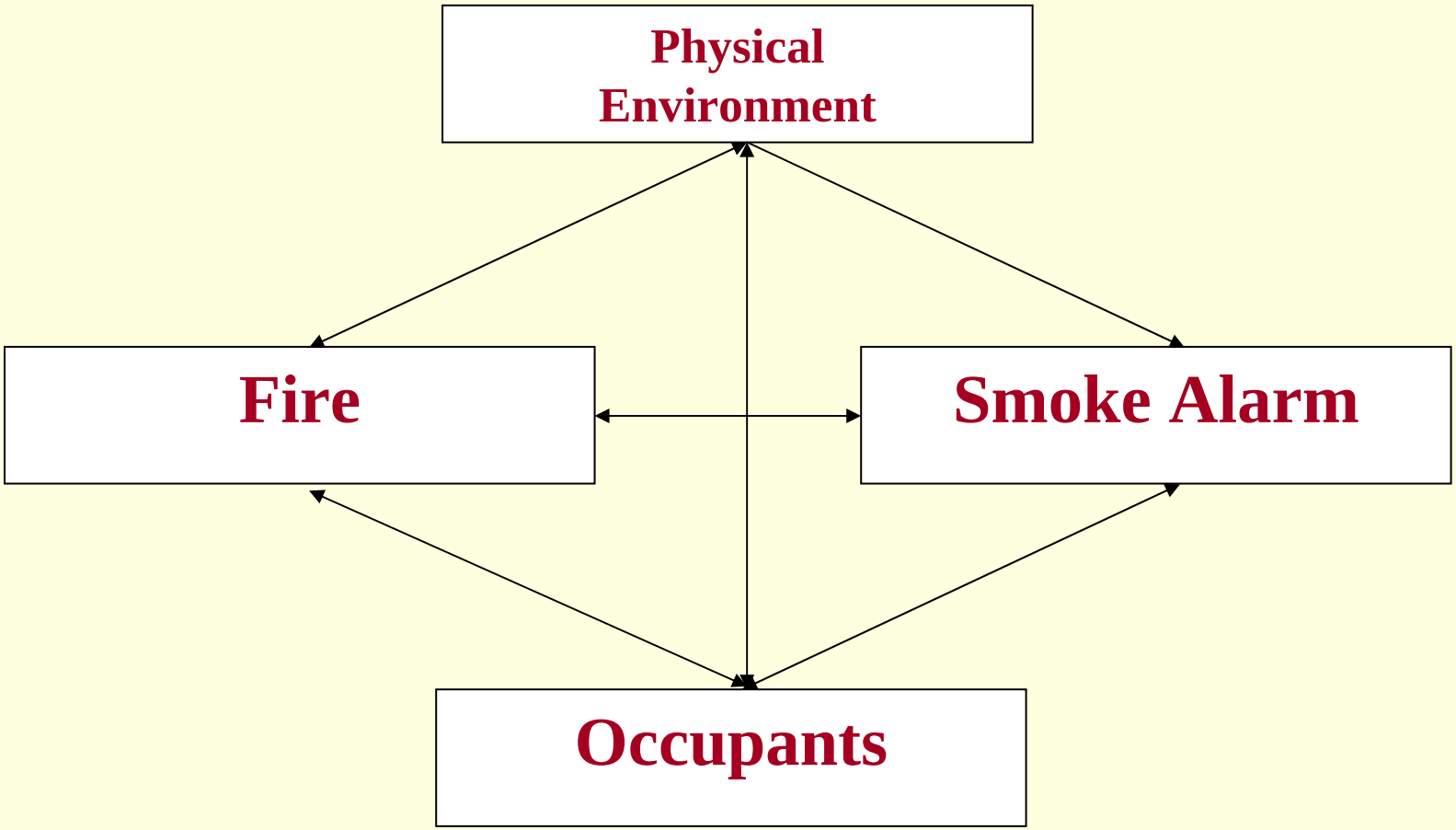
- smoke alarms

plus

- *a plan and action* to reduce unwanted fires
- *plan of action(s)* when a fire occurs
- means of extinguishment
- training
- the provision of more than one exit
- etc

Components

of Domestic Smoke Alarm System



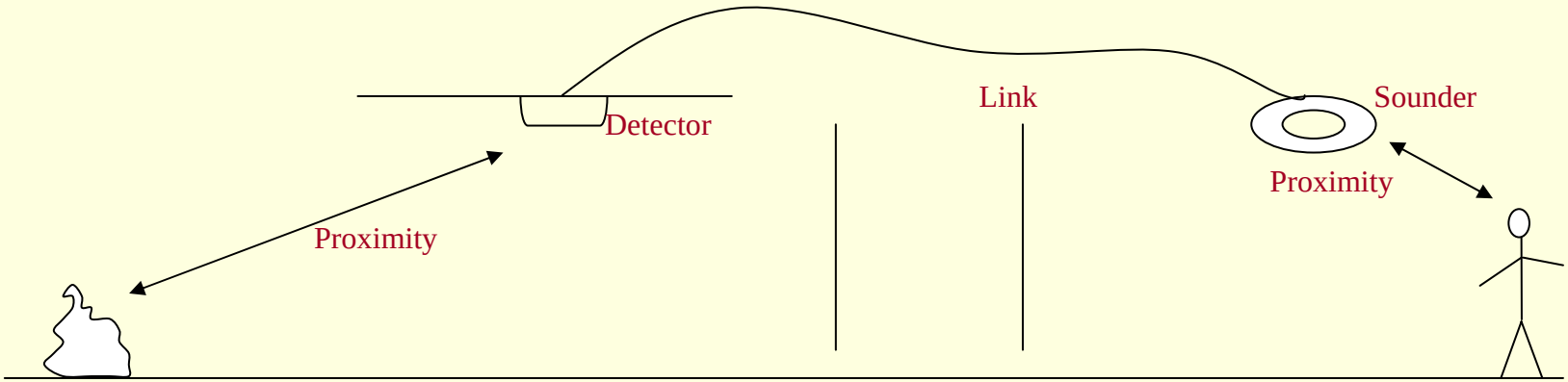
Detector

- triggered by outputs of fire
- triggered by similar (non-fire) phenomena
  - minimised to reduce false, or nuisance alarms
  - should be considered a failure of the *system*

Sounder

- activated by *detector*
- make occupants aware of the fire

Proximity Considerations



- occupant *awake and close to fire*: may become aware of the fire without smoke alarm
- occupant *remote from fire* or *close and asleep*: may need warning from smoke alarm

Occupants (before fire)

Actions Prior to Fire
(effect on physical environment, effect on smoke alarm(s) involvement in ignition, etc)

Physical Environment

Area of Fire Origin
(kitchen, lounge, bedroom, etc)

Configuration of RFO
(dimensions, ceiling and door heights, windows, exposed beams, etc)

Connectivity
(other rooms, hallways, stairways, etc)

Ventilation
(doors open/closed, windows open/closed, air conditioning, ducted heating, ceiling fan, weather conditions, etc)

Construction
(building materials, finishes, etc)

Furnishings and Other Contents
(quantity, type etc)

Fire

Ignition Factor
(children playing, cigarette, etc

Means of Ignition
(match, cigarette, etc)

Type of Material Ignited
(solid, liquid, gas, etc)

Form of Material Ignited
(flimsy fabric, floor covering, etc)

Rate of Development
(very slow … ultra fast, etc)

Type of Fire
(smouldering, flaming, etc)

Products of Fire
(CO, CO2, decreased O2, smoke, reduced visibility, heat, flames, etc)

Smoke Alarm

Location(s)
(relative to fire and occupants)

Power Source
(battery, mains, both, etc)

Detector Type
(ionisation, photoelectric, etc)

Type of Warning Signal
(beep, whoop, voice, vibration, strobe, etc)

Warning Signal Parameters
(volume/intensity, pitch, pattern, etc)

Interconnectivity
(not connected, connected, etc)

Reliability
(false/nuisance alarms, non-operation, etc)

Occupants (during fire)

Consciousness
(conscious/unconscious, awake/asleep, etc)

Endogenous Characteristics
(age, disabilities, etc)

Exogenous Factors
(alcohol, drugs, etc)

Reaction
(none, investigate, extinguish, evacuate, ignore, etc)

Domestic Smoke Alarm System

Occupants

(during fire)

Role: receiver and user of the smoke alarm signal

- notice it
- recognise it
- react appropriately
  - state of consciousness (conscious/unconscious)
  - state of sleep (awake/asleep)
  - other cues or information perceived
  - cognitive and physical abilities
  - location compared with location of signal emitter

Further from emitter: higher probability not heard
Further from detector: higher probability other cues not perceived

Alarm emitted but occupant fails to respond:

smoke alarm system has failed

Effectiveness

of smoke alarm system

Measure: occupants *safe who would not otherwise have been safe*

Factors include:

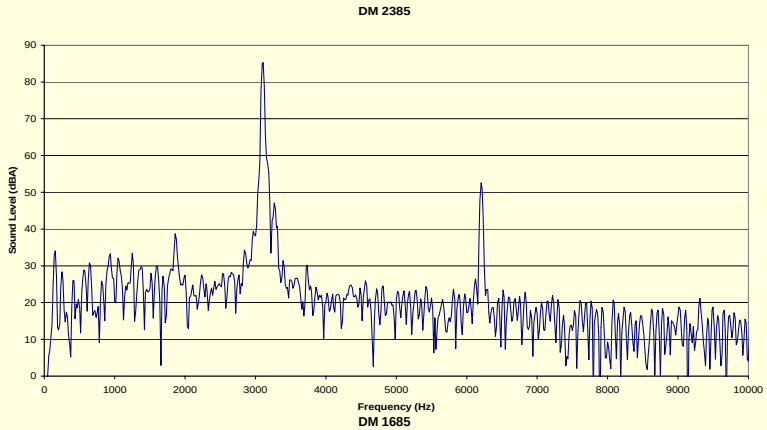
- detector response and reliability
- signal(s) emitted and reliability
- number of smoke alarms
- detector position(s) re fires resulting in fatalities and injuries
- emitter position(s) re locations of those able to respond appropriately
- influence of occupants on operation and reliability of smoke alarm(s)
- ability of occupants to become aware of signals emitted and react appropriately

Part 2.
"Waking effectiveness of alarms"

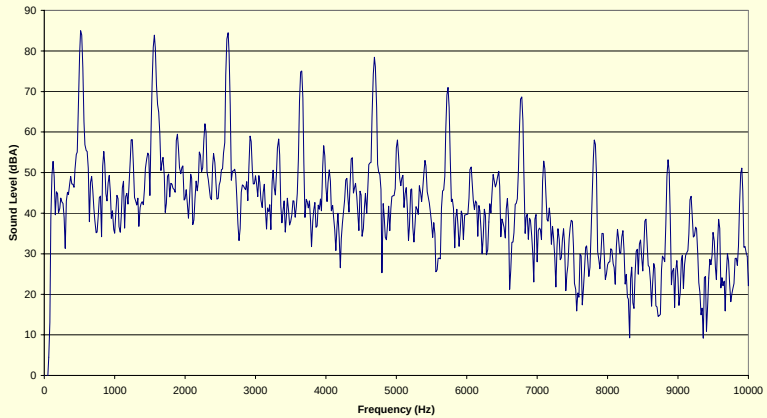
Sample group	age	number tested	Signals tested
children	6-10 yrs	14-20	auditory
young adults	18-26 yrs	12	auditory
older adults	65-85 yrs	42	auditory
0.08 BAC	18-26 yrs	12	auditory
0.05 BAC	18-26 yrs	32	auditory, visual and tactile
hard of hearing	18-77 yrs	38	auditory, visual and tactile

Main auditory signals tested

- Current auditory alarm
  High pitched, 3100 Hz



- 520 Hz square wave
  Mixed frequency



- Actor's voice
  (male voice better than female)

Children:
Alarm sounded above bed, 1 - 4 am

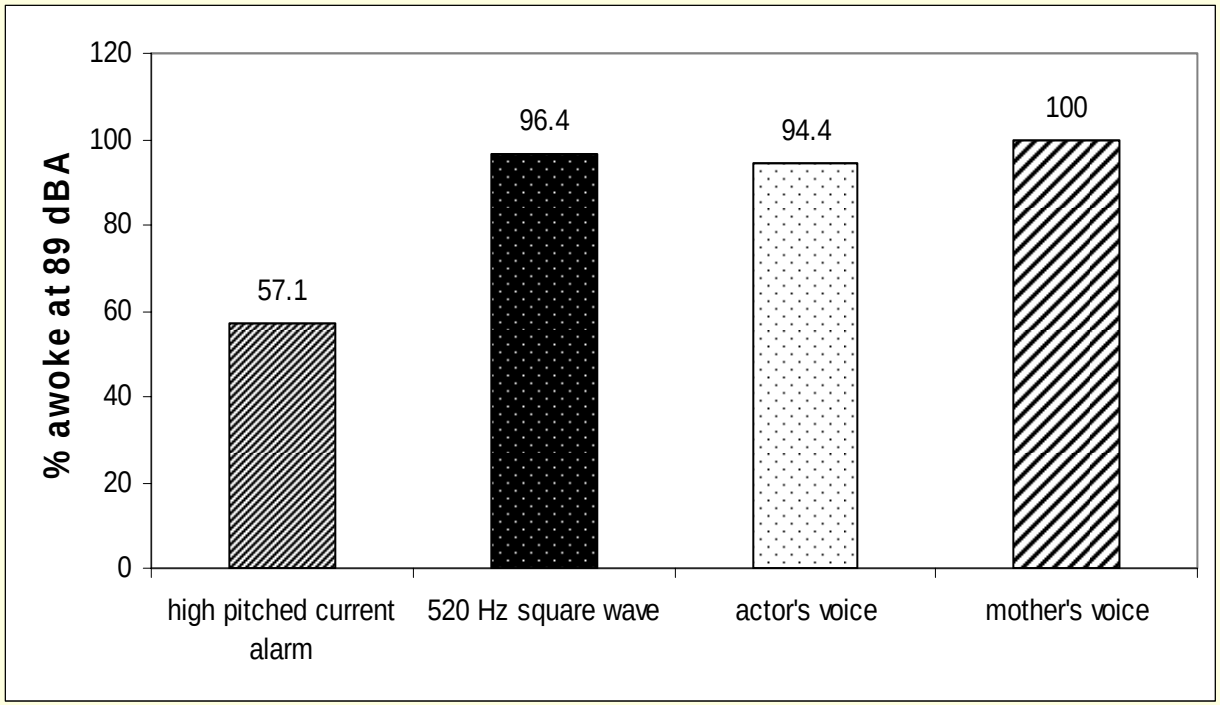
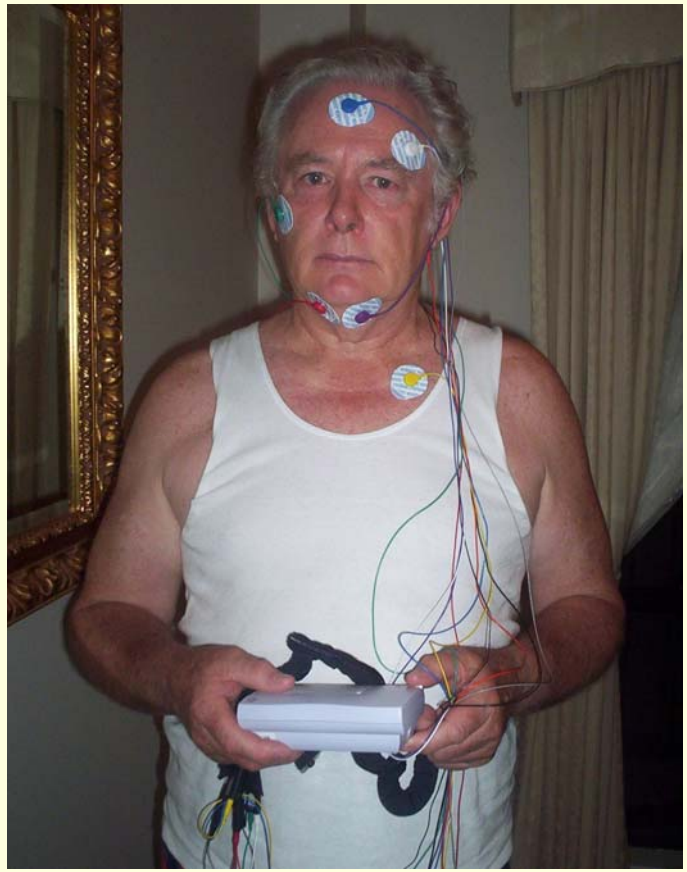


Figure 1: Waking to different signals in **children aged 6 to 10 years** of age *Source: Bruck et al 2004*

In all subsequent studies:

- Sleep stage was assessed (EEG) and signals presented in deep sleep (first third of the night)
- Signals presented at increasing intensities from a low volume, in 5 or 10 dBA increments
- 30 seconds at each volume (plus three minutes at 95 dBA)

NB: Benchmark is **75 dBA**, recommended as the minimum at the pillow (e.g. NFPA 72)



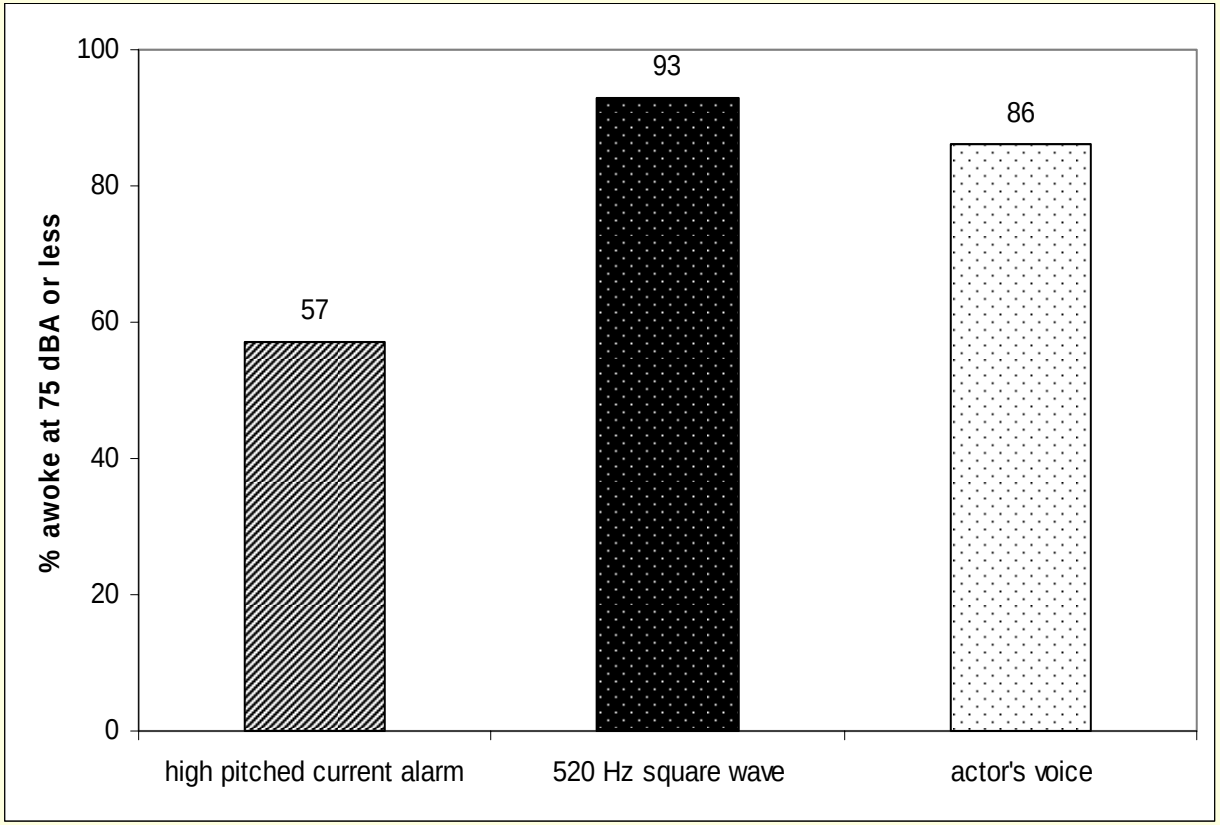


Figure 2: Waking to different signals in **young adults, aged 18-26 years** of age *Source: Ball and Bruck 2004*

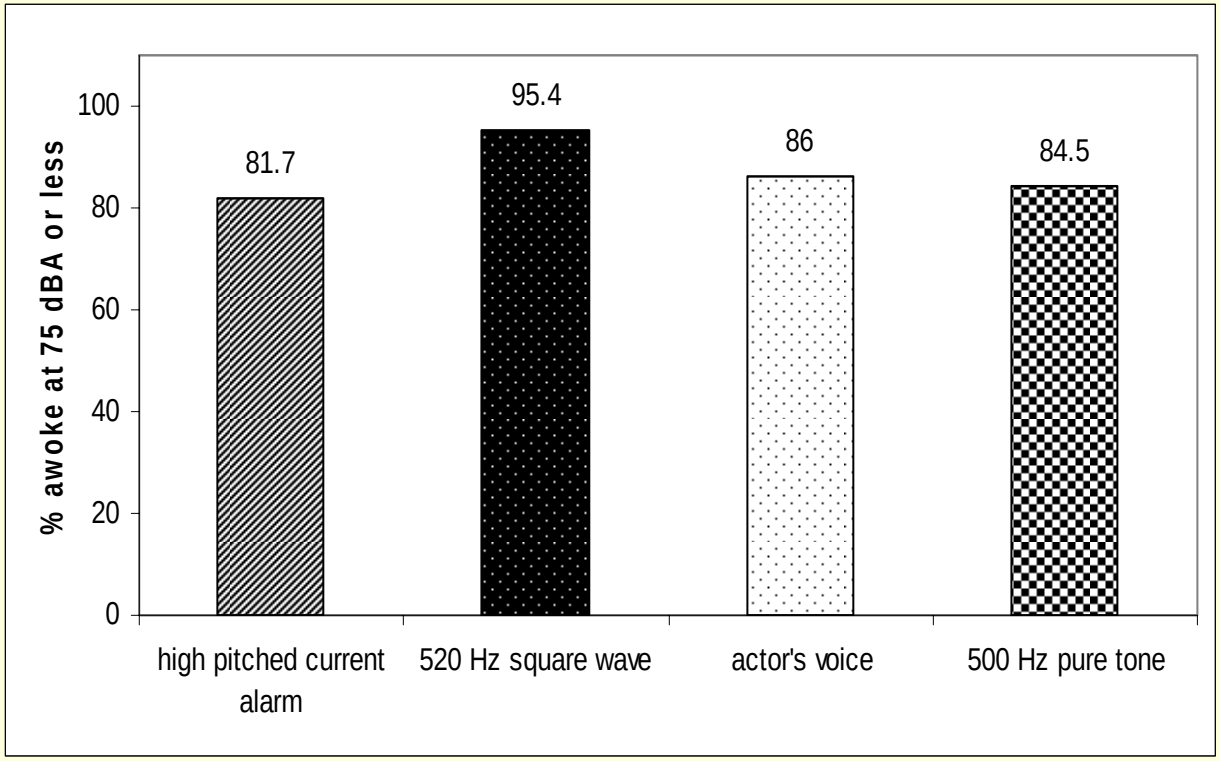
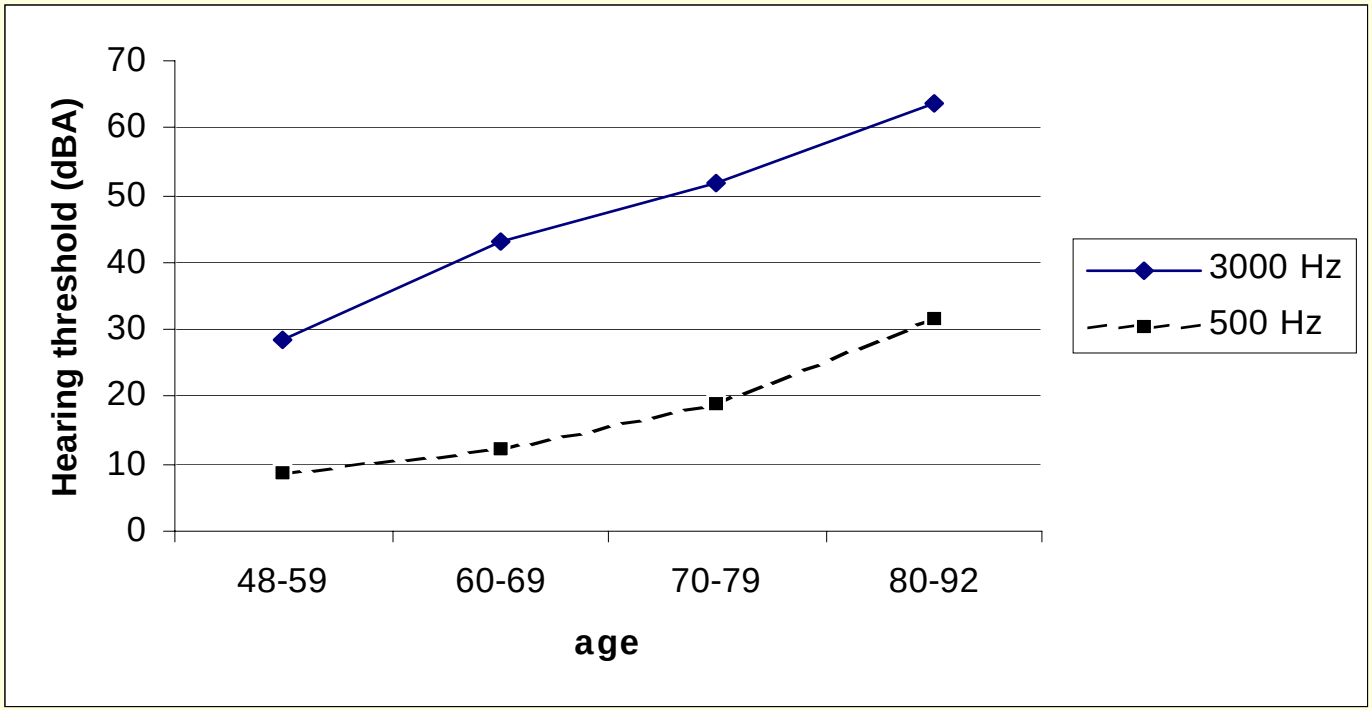


Figure 3: Waking to different signals in **older adults aged 65 to 83 years** *Source: Bruck & Thomas 2007a*

Main hearing loss with age is at higher frequencies
(graph shows males)



From US normative data for hearing thresholds when awake, Cruickshanks *et al.* 1998.

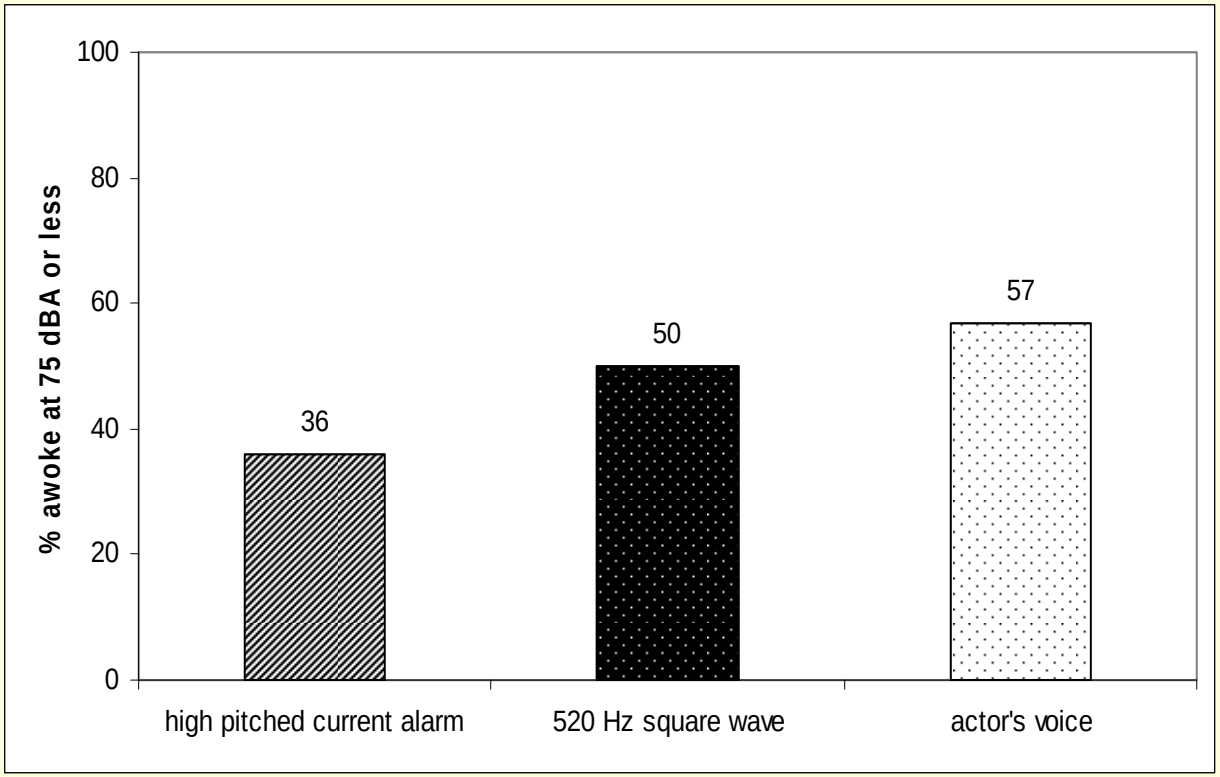


Figure 4: Waking to different signals in young adults (aged 18-26 years) with 0.08 Blood Alcohol Content *Source: Ball & Bruck 2004*

Next two studies also included tactile and visual alarms

Bed and pillow shakers

- **Benchmark** was intensity level as purchased (level 3)
- Levels 1-5 were tested

Strobe lights

- For wall placement 110 cd is the standard (NPFA 72).
- Minimum intensity presented was 177 cd (i.e. one light activated)

  = **benchmark**
- Maximum intensity presented was 420 cd (i.e three lights)

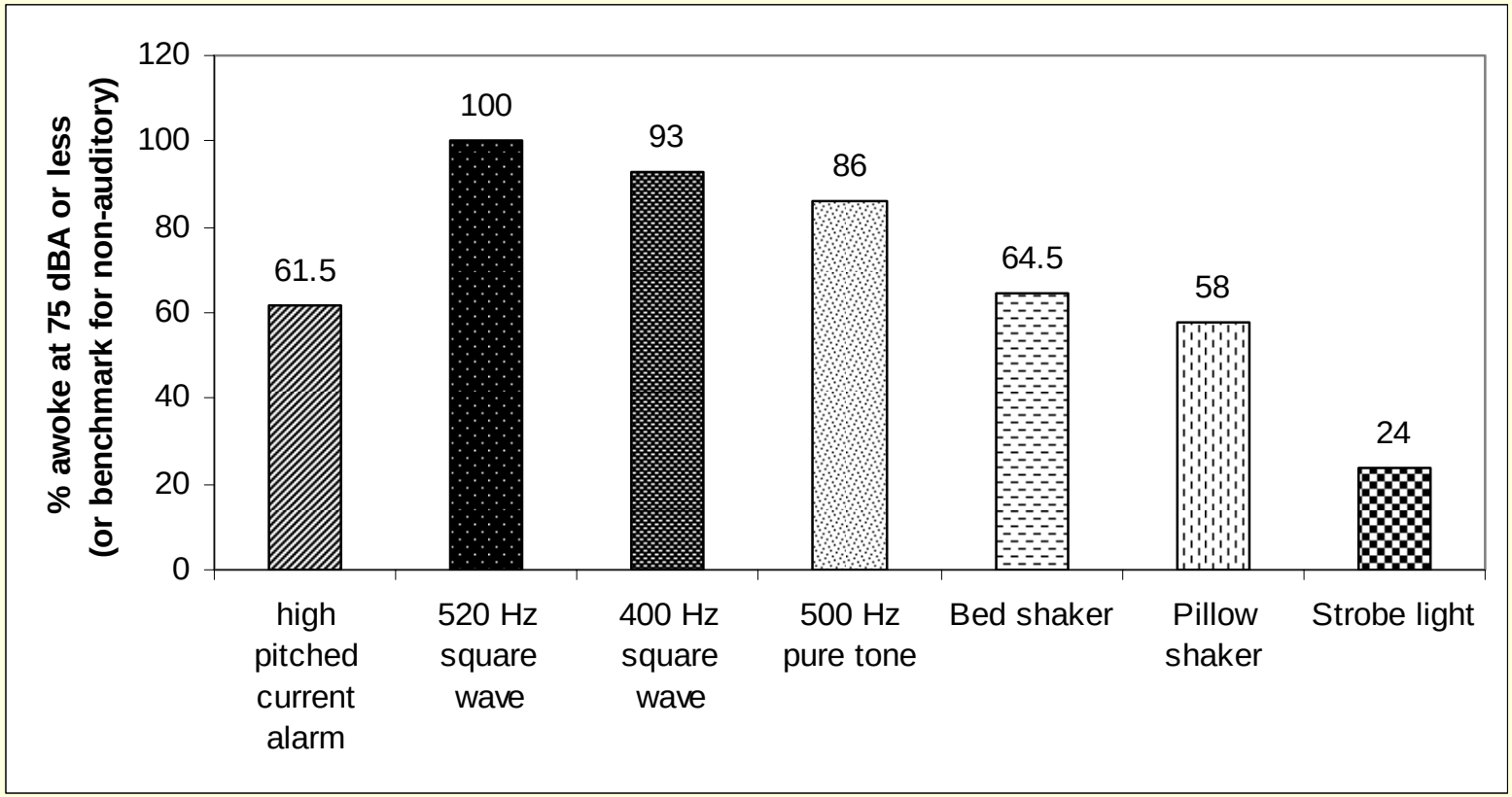


Figure 5: Waking to different signals in young adults (aged 18-26 years) with 0.05 Blood Alcohol Content *Source: Bruck, Thomas & Ball 2007*

Participants aged 18-77 years, with hearing loss in each ear of 25-70 dBA. Most wore hearing aids. None were deaf.

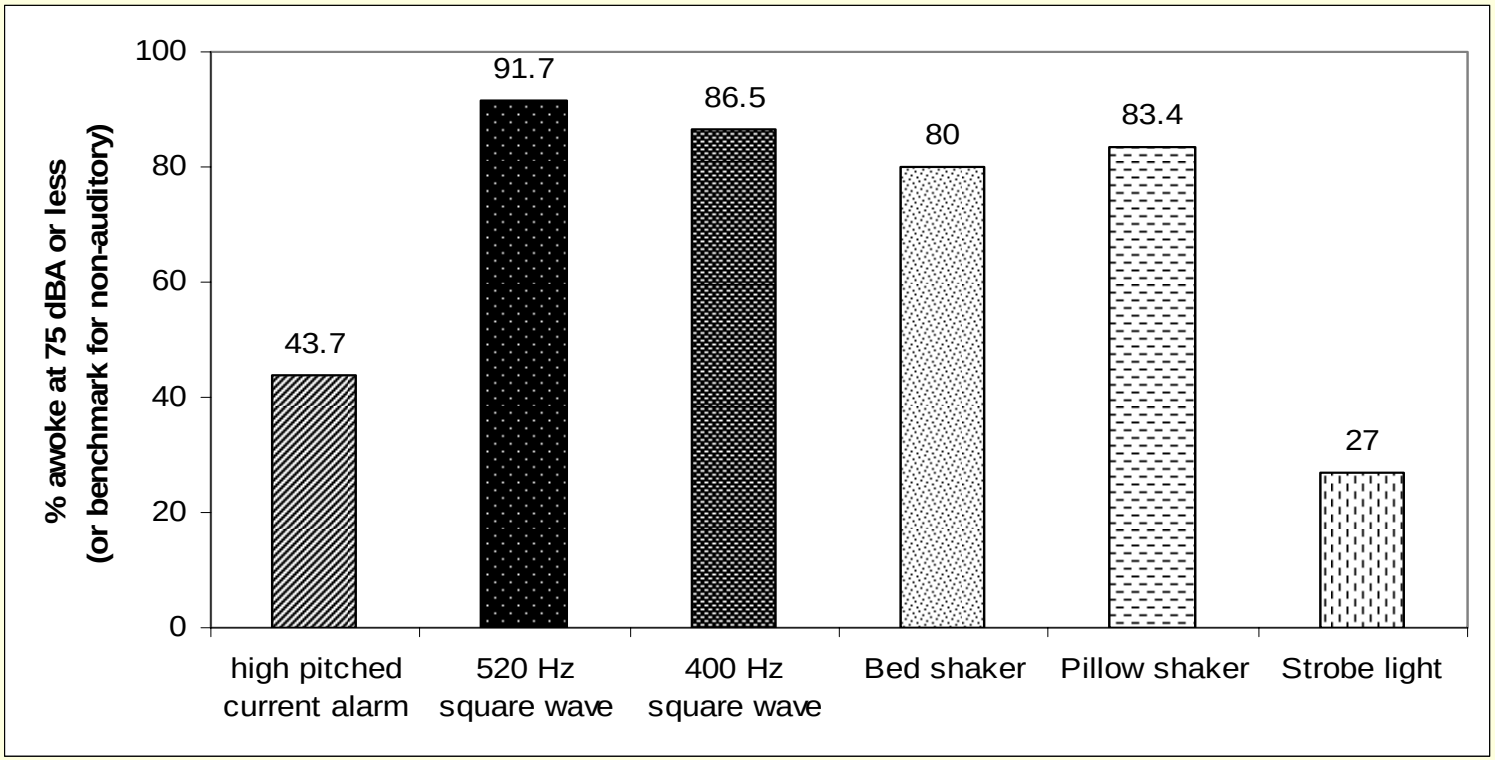
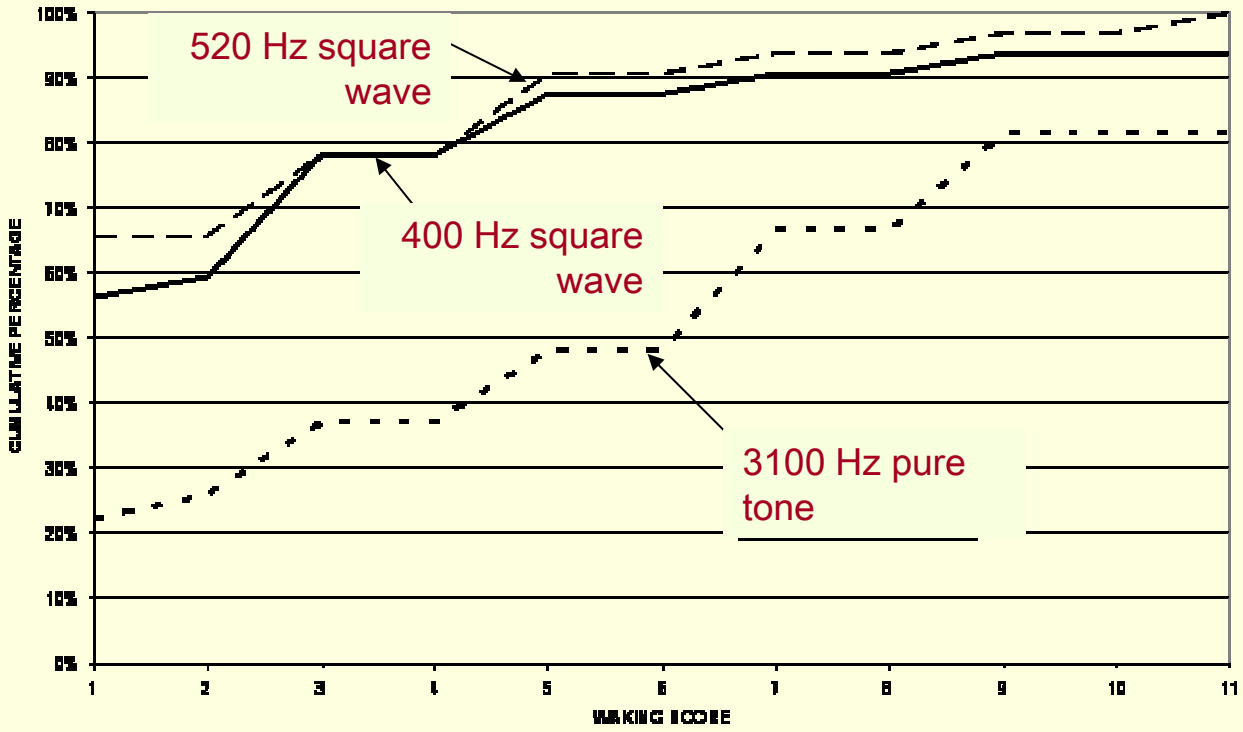


Figure 6: Waking to different signals in **adults with mild to moderately severe hearing loss** *Source: Bruck & Thomas 2007b*

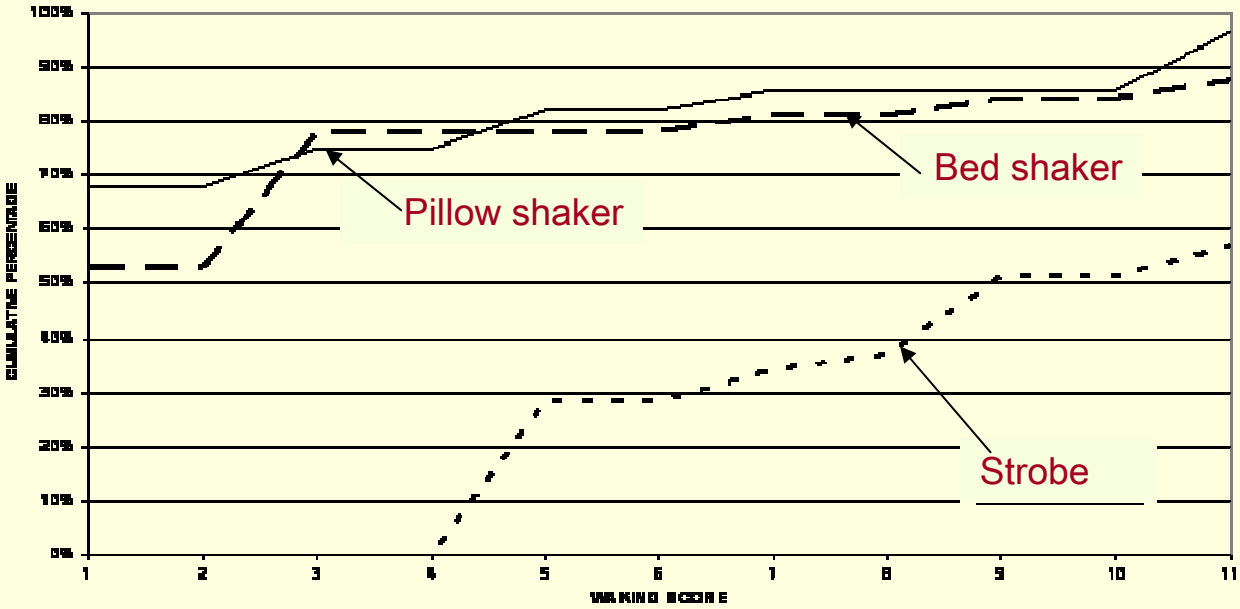
Hard of hearing – auditory signals



16% slept through 3 min of 95 dBA of current smoke alarm

0% slept through 3 min of 95 dBA of 520 Hz square wave

Hard of hearing – tactile and visual signals



43% slept through 3 minutes of 420 cd strobe lights
(NFPA standard requires 110 cd)

Hard of hearing –

Questionnaire on alerting devices in the home

Administered to 44 hard of hearing participants.

Results:

- 98% did not have a non-auditory device for fire emergency (84% did not feel the need for one)

- High level of misplaced complacency. Hence, desirable that smoke alarm for general population emit a signal that maximises chances of awakening for the hard of hearing (if also effective for overall population).

Recommendations

That the technical feasibility of replacing the current high frequency smoke alarm T-3 signal with a low frequency square wave T-3 signal (with a fundamental frequency of 520 Hz or thereabouts) for the entire population be investigated as a matter of priority.

That any recommendations for the use of strobe lights solely as an emergency alarm to awaken sleepers who are hard of hearing or of normal hearing be withdrawn as soon as possible.

That bed shakers and pillow shakers, presented alone, are not an adequate alternative emergency alarm for people who are hard of hearing or alcohol impaired.

That further study be undertaken with people who are deaf to determine the best signals, or combination of signals, that will reliably awaken this population from deep sleep.

This should include bed shakers and pillow shakers and could include strobe lights.

Thank you

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•Onesteel

Reports

The reports on which this presentation is based are available at the NFPA Fire Protection research Foundation website at:

http://www.nfpa.org/assets/files//PDF/Research/hardofhearing&alarms.pdf
http://www.nfpa.org/assets/files//PDF/Research/alcohol&alarmsreport.pdf
http://www.nfpa.org/assets/files//PDF/Proceedings/Consideration_of_Domestic_Smoke_Alarms_as_a_Sytsem_-_I.Thoma.pdf

Many of the reports referenced in the above are also available on the NFPA FPRA website or on the VU website (e-repository).