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Arousal from Sleep with a Smoke Detector in Children and Adults

FCRC Project 4
Fire Safety System Design Solutions
Part A – Core Model & Residential Buildings

Fire Code Reform Research Program
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important Notice

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Background

The Fire Code Reform Research Program is funded by voluntary contributions from regulatory authorities, research organisations and industry participants.

Project 4 of the Program involved development of a Fundamental Model, incorporating fire-engineering, risk-assessment methodology and study of human behaviour in order to predict the performance of building fire safety system designs in terms of Expected Risk to Life (ERL) and Fire Cost Expectation (FCE). Part 1 of the project relates to Residential Buildings as defined in Classes 2 to 4 of the Building Code of Australia.

This Report was relevant to the project activities in support of the Model's development and it is published in order to disseminate the information it contains more widely to the building fire safety community.

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Arousal from sleep with a smoke detector alarm in children
and adults

by

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Brief report

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INTRODUCTION

The impetus for this study arose from the need to investigate whether children would awaken to a 60 dB alarm. A volume of approximately 60 dB is expected with a placement of an alarm in a hallway of a house with a bedroom door left open. This is the placement widely recommended and implemented. Previous field studies have suggested that adults will awaken within 21 seconds to a smoke detector alarm received by the sleeper at 55 dB (Nober et al 1981). However, a sleep laboratory study of a younger adult population (18 to 24 years) found that 30% did not reliably awaken to a smoke alarm of 60 dB (Bruck and Horasan 1995). This study suggested that younger subjects may be harder to arouse than middle aged adults and is consistent with the fact that there are age-related differences in the amount of deep sleep (slow wave sleep), with younger individuals having more deep sleep. However, there has been no previous published studies on the likelihood of children waking up to an alarm signal. This issue is particularly important in view of the fact that in many newer home designs the children's bedrooms may be a considerable distance from adult sleeping areas. It is thus essential to know whether children would have a high chance of awakening to a smoke alarm located in the standard hallway position.

Thus the following study aimed to determine whether children would awaken to a 60 dB alarm placed within their own homes. Their parents were also monitored to provide confirmatory (or otherwise) data on the reliability of adult arousal.

METHOD

Subjects:

Thirty six subjects aged between 6 and 59 participated in the study. The group was considered within two age groupings: 20 'juniors' aged 6-17 years (9M, 11F, mean of 11.6 years); 16 'adults' aged 30-59 years (8M, 8F). Participants were recruited predominantly from among University students and staff and their families.

All potential participants were interviewed to ensure that they considered themselves to have normal hearing, normal sleeping patterns, *no heavy snoring*, no daytime sleepiness, no chronic illness, no ongoing medications affecting sleep/wake behaviour and were prepared to remain free of specified medications, alcohol and drugs for the duration of the experiment. A sketch of

the house layout was also made to ensure the location of the bedrooms would meet the requirements of the experiment.

Prior to participation all subjects were also required to pass a (free) hearing test (including air conduction and bone conduction) conducted by a professional audiology agency. The required thresholds values were taken from the International Standard (ISO) 7029 and a 90% percentile criterion was adopted for each age level.

Apparatus:

A special portable smoke detector alarm on a stand was constructed for the experiment. The alarm could be positioned at ceiling level. This was connected to a timer that could be preprogrammed for two separate activations of three minutes duration each within a five day period.

Each subject was required to wear an actigraph (*Minimitter Mini-logger 2000*) on each of the four nights throughout the experiment. This is a small device worn on the wrist which monitors activity and can **detect** the **difference** between sleep and wake. Each actigraph was set to collect activity data in time 'bins' of 16 sec intervals, whereby it was possible to identify at what time during the night a subject awoke (within a parameter of 16 seconds).

Two brief questionnaires were devised for the experiment. The 'Evening Questionnaire' consisted of two questions asking for a rating of the quality of the previous night's sleep and the level of daytime sleepiness on the day just completed. Both questions required ratings compared to normal for them. The 'Upon Awakening Questionnaire' asked questions pertaining to their experience of awakening **when** the alarm went off and included five point ratings of how clear-headed they felt at three points of time after the alarm was activated. The Karolinski Sleepiness Scale (9 points) was also included. A synchronised clock was placed in the living room for precise identification of how much time had elapsed at the end of completing the questionnaire.

Procedure:

Upon establishing the eligibility of each member of a volunteer household to participate a visit to the home was made. The smoke alarm stand was carefully placed in such a position that the decibel reading at the pillow of each participating member of the household was 60 dB +/- 3 dB. This was achieved through various manipulations such as the position of the bedroom door or some minor movement of furniture. The stated duration of the experiment was four nights but the alarms were always set to activate on the second and third

nights of the study. The time of night of the alarms was determined by taking the midpoint of the shortest sleeper in the house and setting the alarm on one night for one hour prior to the midpoint and the other night for one hour after the midpoint (order counterbalanced across all subjects). All activations were between 1 am and 4.30 am.

Prior to retiring to bed at night each subject was required to put on the wrist actigraph and complete the Evening Questionnaire. Participants were instructed that upon hearing the alarm they were to immediately begin moving the wrist with the actigraph back and forwards while remaining in bed. Once the alarm stopped sounding (after three minutes) they should quietly get out of bed, go to the living room and complete the Upon Awakening Questionnaire. Parents were asked to help their children. Those who slept through the alarm were not required to do anything during the night.

The study was approved by the Victoria University Human Experimentation Ethics Committee.

RESULTS

Behavioural response to alarm:

Of the 36 subjects, 2 were not asleep on one of nights of the alarm activation (one junior, one adult) and these nights were excluded from all subsequent analyses.

in the junior age group over two thirds (69.3%) slept through the three minute alarm (this is an average across both nights). By contrast, all adults awoke on both alarm nights.

Another way to consider this data is to look at the *reliability* of awakening. In the juniors only three of the twenty children woke on both nights while six awoke on one night only and the majority (11) slept through both nights. Thus 85% of the children tested did not reliably awaken to the 60 dB alarms. Interestingly, both the 16 and 17 year old participants awoke on both nights. 100% of the adults reliably awoke.

The Evening Questionnaire was scored to identify any subjects reporting that their previous night's sleep was "a lot worse than normal" or they were "a lot more" sleepy during that day than normal. This was to identify whether the previous night of participating in the experiment may have affected their

arousal behaviour. The 5 people (3 juniors and 2 adults) who ticked one of these boxes all awoke the subsequent night so no sequential confounding effects were evident. (Interestingly these three juniors seem to have sleep that is both less refreshing and lighter than the other juniors.)

Time to arouse to the alarm:

Precision in latencies was not possible both because the actigraphs only yielded data at 16 sec time intervals and because of technical difficulties achieving exact synchrony between the internal clock of the actigraph and the alarm. Nevertheless, the data clearly showed that most subjects who awoke responded very quickly to **the onset** of the alarm. Where reliable actigraph data was available, 95% of the subjects awoke within 32 seconds of alarm activation. The remaining 5% awoke between 32 and 64 seconds of the alarm onset and these were both juniors. This data is in accord with the subjects' own self-report which consistently reported prompt arousal and movement of the relevant wrist within a few seconds.

Clearheaded Ratings:

Subject's ratings of how clearheaded they felt at three different time points were taken'. A rating of 1 indicated "extremely" clearheaded with 3 being --moderately" and 5 "not at all". The first and second ratings are retrospective evaluations with the **first** being at the time the alarm was first heard and the second when the subject got out of bed (when the alarm stopped after 3 **minutes**). The third was a "right now" rating and recordings of exact time of night suggest this was 4-7 minutes after the alarm sounded.

Predictably the ratings show improvement over the time period and the difference between all time points was significant ($p < .05$). The greatest period for improvement was within the first three minutes. The ratings suggest that most subjects felt "moderately" clear headed immediately upon hearing the alarm.

Further analyses were undertaken to determine whether there were differences between the different age groups in their ratings of clear headedness or **sleepiness** at different time points. No significant differences were found ($p > .05$)

CONCLUSION

This is the first study to demonstrate that children will not reliably awaken to a smoke alarm located in the standard hallway location within the home. In fact 85% of this sample of children did not awake on both nights.

The study also provides further support for the findings of Nober et al (1981) which indicates that adults *will* reliably awaken within *half* a minute. The *study* also found that those who awoke reported feeling moderately clearheaded within the first three minutes and improved thereafter.

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