



Preliminary evaluation of the relative importance of acoustic, non acoustic and context related factors in reactions to noise at the individual level

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ABSTRACT

The reaction of an individual to a particular source of sound varies. This is dependant upon a number of acoustic, non acoustic and context related factors. This preliminary study considers the impact of noise arising from three sources of neighbourhood noise affecting people living in residential dwellings in the UK. The sources of neighbourhood noise include a blanking press, chiller units and drop hammers. In each case the noise was considered intrusive and at a sufficient level of interference, at the individual level, to result in complaints. This paper evaluates a number of acoustic, non acoustic and context related factors and how these rank, relative to the importance of those factors, in affecting noise reaction in each case. The preliminary findings demonstrate residents who were sufficiently annoyed to complain considered non acoustic and context related factors equally as important as acoustic factors. It would appear a greater emphasis on non acoustic and context related factors is necessary when assessing the likely negative reaction or affectedness arising from exposure to specific sources of neighbourhood noise. It is considered necessary to develop an internationally recognized questionnaire for assessing the impact of specific sources of neighbourhood noise.

Keywords: Annoyance, neighbourhood noise, non acoustic factors, context

Topics: T7.1 Community noise & ratings, T10.0 General (Noise & health)

1. INTRODUCTION

This paper considers three sources of neighbourhood noise including an industrial blanking press, chiller units serving a public house and a blanking press. All three sources, when occurring, dominate the internal acoustic environment of the residential dwelling. The sources considered within this paper are primarily single exposure situations during periods when the source noise dominates. Such sources are less commonly studied in comparison to sources of air, road and rail traffic noise. Importantly, the neighbourhood sources exhibit different characteristics that attract the listener's attention and are associated with a specific operator exercising control.

This paper follows a previous paper analyzing the limitations of the equal energy principle when applied to sources specific premises and sources neighbourhood noise (1).

1.1 Sources of noise

For the purposes of this study it is important to distinguish between different sources of noise that can affect humans living within dwellings. In England, 'noise' is recognized as falling into three categories:

- "environmental noise" which includes noise from transportation sources
- "neighbour noise" which includes noise from inside and outside people's homes; and
- "neighbourhood noise" which includes noise arising from within the community such as

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industrial and entertainment premises, trade and business premises, construction sites and noise in the street" (2)

It is clear people interpret noise differently according to its source. Within the "environmental noise" category, noise from road traffic is perceived differently than noise from aircraft with noise from "neighbors" and the "neighbourhood" also falling into distinct categories (3). This paper considers only "neighbourhood noise" which in all three cases was perceptible within habitable rooms of the affected dwelling.

2. Sound and noise in context

Sound is an aural sensation caused by pressure variations in the air. In a scientific sense, the pressure variations are waves of energy that pass through a medium such as air. Sound is the human perception of those pressure waves via the hearing mechanism (auditory physiology). The pressure variations are transmitted via the middle and inner ear and converted into nerve impulses within the cochlea. The neural impulses are detected and processed by the brain.

Noise is sound that is perceived as unwanted. Noise may arise when received in a variety of contexts e.g. a dripping tap, a loud telephone conversation or an intruder alarm. The term 'noise', therefore, introduces a subjective element to an individual's decision of whether or not a sound is wanted or unwanted. This 'decision' is effectively the perception, interpretation and reaction processing in response to the sound.

2.1 Perception, interpretation and reaction

Fig 1 shows some of the key factors that influence the perception, interpretation and reaction response of a human to a particular sound. The reaction depends on how the sound is interpreted by the brain e.g. is it wanted with positive connotations or unwanted with a decision as to how impact can be eliminated or if not reduced to limit adverse response by the receiver. Fig 1 concentrates on noise arising from a specific premises within the neighbourhood but is also relevant in some respects to sources of environmental noise e.g. arising from anonymous sources such as aircraft, road and rail.

It is important to note, whether a sound is noise and the subsequent reaction of the individual is dependant on:

- Acoustic factors (decibel level, frequency content etc.)
- Non-acoustic factors (time of day, regularity of impact etc.)
- Context or circumstances in which the sound is received (character of receiving area, activities interrupted, perception of noise producer etc.)

Using fig 1 and the examples above, a dripping tap may not be annoying but can disturb sleep if audible in a hotel room at night when it is otherwise quiet. Likewise, an audible intruder alarm sounding on the streets of towns and cities during the day may cause no adverse response/reaction to passers by but can become a serious annoyance when sounding at 2am at a neighbouring property affecting sleep. People can react with displeasure (annoyance) to a loud telephone conversation occurring when trying to read or concentrate on a long train journey. These aspects of reaction/affectedness are not determined by the decibel level but the constituents of the sound and how they are perceived in context. Historical research by Guski indicates that psychological factors often determine the amount of annoyance and that this is line with the concept of "noise" as a psychological, rather than acoustical, term (4).

2.2 Reaction to unwanted sound

The reaction to unwanted sound, at the individual level, varies. One type of reaction to noise is annoyance which is a negative attitude or feeling of displeasure. Annoyance is likely the most widespread adverse effect of noise (5). The same type of noise can evoke completely different degrees of annoyance when we are engaged in different activities e.g. physical tasks like riding a bike, or concentrating in order to understand a difficult discussion (6). Annoyance is a psychological response to a noise. It is an emotional response that can manifest as anger or frustration. Annoyance is used as a descriptor in many 'environmental' noise studies to formulate dose-response curves. The dose-response curves relate 'average' annoyance and sleep disturbance of the population to measured sound levels.

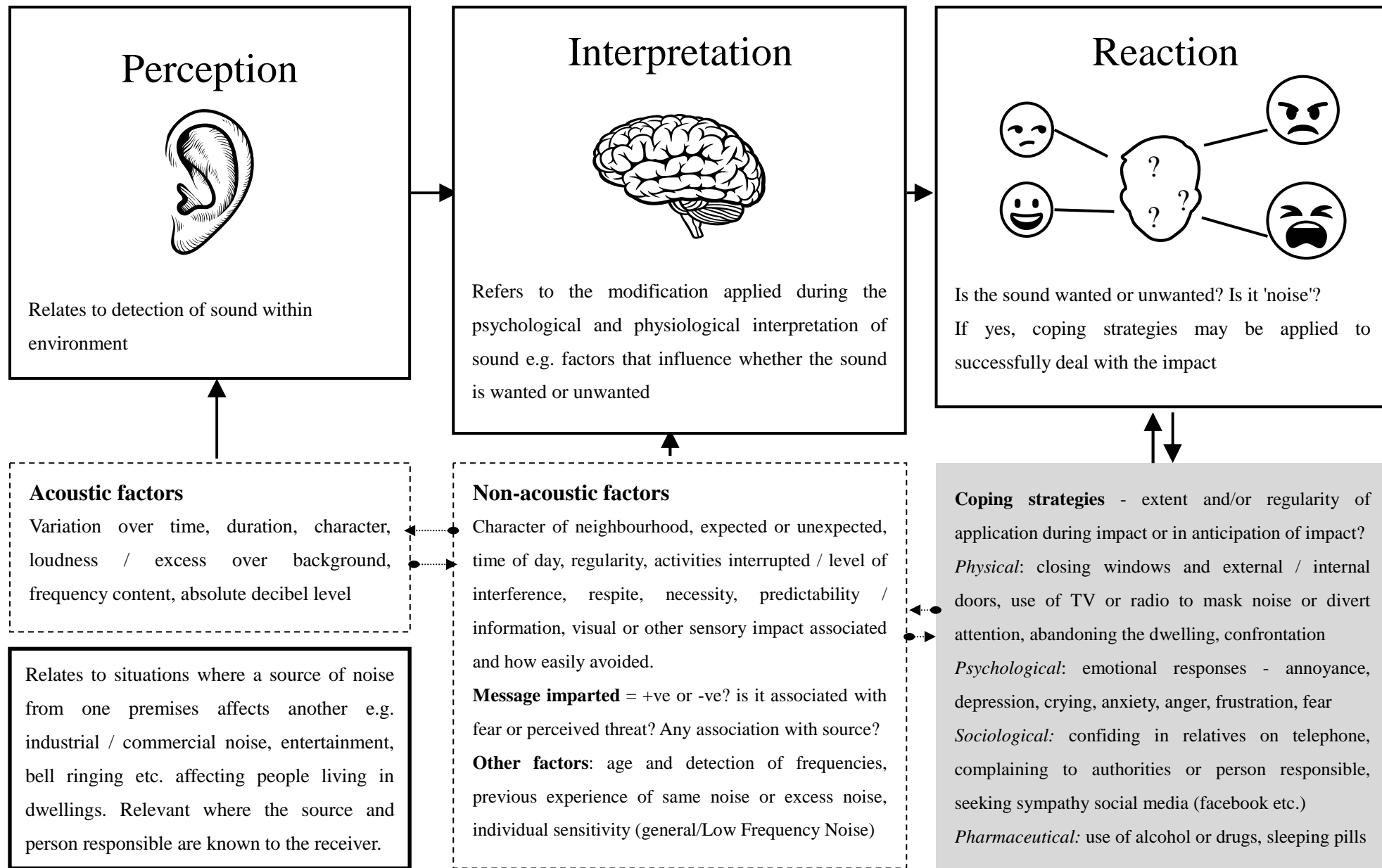


Figure 1 - Human response to specific neighbourhood sound

Furthermore, Job et al (2001) show psychological reactions, other than annoyance, can include anxiety, distraction, exhaustion, anger frustration, disappointment and fear (7). Furthermore, the research by Job et al (2001) identifies that psychoacoustic investigations and surveys that include questions only about annoyance fail to measure many possible and important reactions to noise. It is, therefore, necessary to consider other reactions such as affectedness, dissatisfaction and activity disturbance.

2.3 Complaints

Complaining about noise to the relevant authority (or other e.g. operator, family etc.) is recognized as one coping mechanism. It is generally the easiest method of expressing concern. There are other factors/moderators that affect complaint reaction which include expectation of quiet within a locale, past complaint experience, the assumption nothing will be done or a positive association with the source e.g. noise generated by employer carries a positive message regarding employment security and financial stability. Therefore, it is recognized noise levels are not the crucial factor for complaining or not complaining and consequently complaint data cannot be accepted as an accurate measure of public annoyance (8).

3. Methodology

3.1 Selection of neighbourhood noise sources and respondents

This preliminary study considers sound perceived as being unwanted from three sources. The noise sources chosen were originally subject to regulatory (statutory nuisance) or (potential) civil litigation (private nuisance action) investigation in the UK (9). All sources of neighbourhood noise, with the exception of the storeroom were, when operational, the subject of noise complaint. This study presents noise levels from real-life situations where humans were exposed to neighbourhood noise sources causing ongoing annoyance, affectedness and dissatisfaction. In all three cases noise exposure has been eliminated through engineering measures or site relocation (blanking press).

When occurring, all three noise sources were perceptible, discernible, dominant for significant periods and recognizable as emanating from a specific site where the operator was known i.e. a person or body was responsible for noise emissions. Residents could identify, perceive and attribute noise emissions as arising from the site, specifically related to the activity undertaken. In all three cases the author had observed and measured noise affecting use of the receiver's dwelling. None of the locations were close to continuous or dominant transportation noise sources during the periods of greatest impact.

The respondents to the questionnaire were chosen as the noise exposure to which they had been subjected was no longer occurring. It was hoped this would allow reflection and a more considered response rather than an ongoing set of circumstances and, potentially, a state of heightened stress or other emotional affects.

3.2 Questionnaire

The questionnaire was drafted with regard to the work completed by The International Commission on the Biological effects of Noise ("ICBEN") regarding the reporting of core information from community reaction surveys. This paper follows the minimal guidelines for the three levels of information disclosure i.e. level I: Limited (9). For the preliminary study three respondents were chosen. In two of the three cases the sources of neighbourhood noise affected only one household.

The questionnaire is provided in figure 2 and is designed, primarily, to rate the importance of acoustic, non acoustic and context relevant factors in reactions to noise at the individual level. The first half of the questionnaire (Qs 1-5) are included to acquire general information about health, chronic illness, character of the neighbourhood and contentment with the area in which the respondent lives. The second half of the questionnaire (Qs 6-8) require responses when considering one specific element of the acoustic environment i.e. the specific source of neighbourhood noise where a person responsible can be identified. For Qs 7a-7l, a total of twelve factors were chosen for the preliminary study. The aim was to provide 4 questions on acoustic factors, 4 questions on non acoustic factors and 4 questions relating to the context. Qs 7a-7l is based on the 5 point verbal answer scale and numeric answer scale designed and recommended noise reaction questions in community noise surveys (10).

Questionnaire

The information collected will be kept confidential by MAS Environmental Ltd for the purposes of research. This information will not be published. The information will only be published in an anonymised form i.e. County of residence, age and sex etc.

Name _____ Age____ Sex_____ Date____
 Occupation _____ Nationality_____
 UK Area/County_____

This section includes questions about you

Q1. In general, would you consider your health is:

1 Very Good 2 Good 3 Average 4 Poor 5 Very poor

Q2. Do you suffer from a chronic illness or disability? 1 YES 0 NO

Q3. Does chronic illness or disability restrict your daily work / activities?

1 Not at all 2 slightly 3 Moderately 4 very much 5 Extremely

This section includes questions about your environment

Q4. What best describes the area surrounding your home?

City
 Suburban (outskirts of City)
 Countryside / rural
 Other (please state) _____

Q5. How content are you with the area surrounding your home?

1 Very happy 2 Happy 3 Neither happy or unhappy 4 Unhappy 5 Very unhappy

This section includes questions relating to the specific source of neighbourhood noise and how it affects you

Q6. How long have/did you experienced the noise?_____

Q7a to Q7l - To what extent are the following 12 factors important in your reaction to the specific noise received at your dwelling?

[Please insert a number between 0 and 10 using the scale below]

Not at all important		Slightly important			Moderately important		Very important		Extremely important	
0	1	2	3	4	5	6	7	8	9	10

- Q7a. The decibel level of the noise _____
- Q7b. The duration of the noise _____
- Q7c. The acoustic characteristics of the noise _____
- Q7d. The variation in noise level over time _____
- Q7e. The time of day the noise occurred _____
- Q7f. The regularity of noise intrusion _____
- Q7g. The amount, or lack of, respite from the noise _____
- Q7h. The message imparted by the noise _____
- Q7i. The activities interrupted by the noise _____
- Q7j. The ability to escape the noise within the dwelling _____
- Q7k. Your expectation of the noise in your neighbourhood _____
- Q7l. Any visual or sensory impact accompanying the noise _____

Q8. Are there any other factors you consider were important to how the noise affected you in this particular case?

Thank you for your time undertaking this survey. The results will be published in the proceedings of Internoise 2017.

Figure 2 - Preliminary questionnaire assigning importance of acoustic, non acoustic and context relevant factors in reaction to noise

3.2.1 Telephone interviews

Three telephone interviews were conducted in May 2017. The questionnaire was read as provided in figure 2. Further explanation and/or question repetition was provided on request. The respondents were asked to relate their responses to their previous experience of the specific neighbourhood noise to which they were exposed. The length of interview varied between 25-50minutes.

3.3 Limitations

A summary of the limitations are provided below:

- Respondents were not currently affected by the source of neighbourhood noise. The cessation of impact varied between two months for the storeroom and 4 years for the drop hammers and blanking press.
- A small sample was acquired due to the limited presence and availability of respondents.
- Limited number of questions on acoustic, non acoustic and context related factors are provided. There are 20-30 different factors that could be included but 12 factors is considered reasonable for a preliminary study.
- There is a degree of in-built bias within the study. The respondents are known to be dissatisfied to the point external help was sought e.g. local authority complaints or independent advice. This is a necessity of the survey to gauge the importance of different factors in noise reaction (site specific single exposure scenario).
- Given the presence of regulatory involvement and respondent sensitivity only general and anonymised information has been reported i.e. month of noise monitoring and county area within the UK.
- Use of non harmonized questions i.e. lack of similar or comparative research.
- Limited opportunity to compare non noise related factors e.g. housing density, geographic factors, socio-demographic influences etc.

4. Results

This section begins with a reporting of the background information for respondents A to C. Point 4.2 onward provides an overview of the neighbourhood noise experienced by each respondent followed by their survey responses. A summary of the rating scores for all sources is provided at the end of this section.

4.1 General questionnaire responses

Key to respondents:

- Respondent A - blanking press
- Respondent B - storeroom
- Respondent C - drop hammer

The respondents rated their general health to be either average (two responses) or good. Respondent B (good general health) cited chronic asthma as a chronic illness but this did not restrict daily work or activities. Respondent C suffered from arterial heart disease (ischemic heart disease) but did not consider this a chronic illness and it did not restrict daily activities.

Respondents A and C lived in suburban areas while respondent B lived near the sea. Both respondents A and B were happy with the area surrounding their home. Respondent C was neither happy or unhappy.

4.2 Noise monitoring and specific questionnaire results

Snapshots of noise monitoring are shown in the graphs below. The graphs contain the key noise

data analyzed for each source with a summary description of the inherent acoustic features. The graphs show extracts from longer term noise monitoring and A-weighted decibel levels. The snapshots selected represent typical and commonly occurring worst case noise impact. Noise measurements were undertaken with a positive wind vector from source to receiver and wind speeds below 5m/s. Noise measurements for the storeroom were undertaken internally within the centre of the room. Sample graphs are provided but extensive periods of similar impact were observed.

4.2.1 How to read the graphs

The X axis represents absolute time and Y axis the A-weighted decibel level. Levels are of average noise over time denoted by the $L_{Aeq,125ms}$ index. The varying profile shows how the noise changes over time.

4.3 Blanking press

The location of the dwelling and blanking press resulted in noise affecting only one dwelling. The blanking press operated intermittently and unpredictably through the day. There was no indication when the noise disturbance would cease between Monday to Saturday. Early starts, pre 7am and impact into evenings post 7pm were common. Press impacts also occurred before 7am on Saturday morning. Figure 3 shows free field noise levels external to the dwelling dominated by repetitive and impulsive peaks of noise from the blanking press. The period $L_{Aeq,T}$ was 55dB arising from a combination of road traffic and press activity. The specific contribution from the blanking press was 50dB $L_{Aeq,15min}$. Figure 3 shows a 5 minute period from 6:50pm containing approximately 230 individual blanking press impacts that were clearly audible at the dwelling.

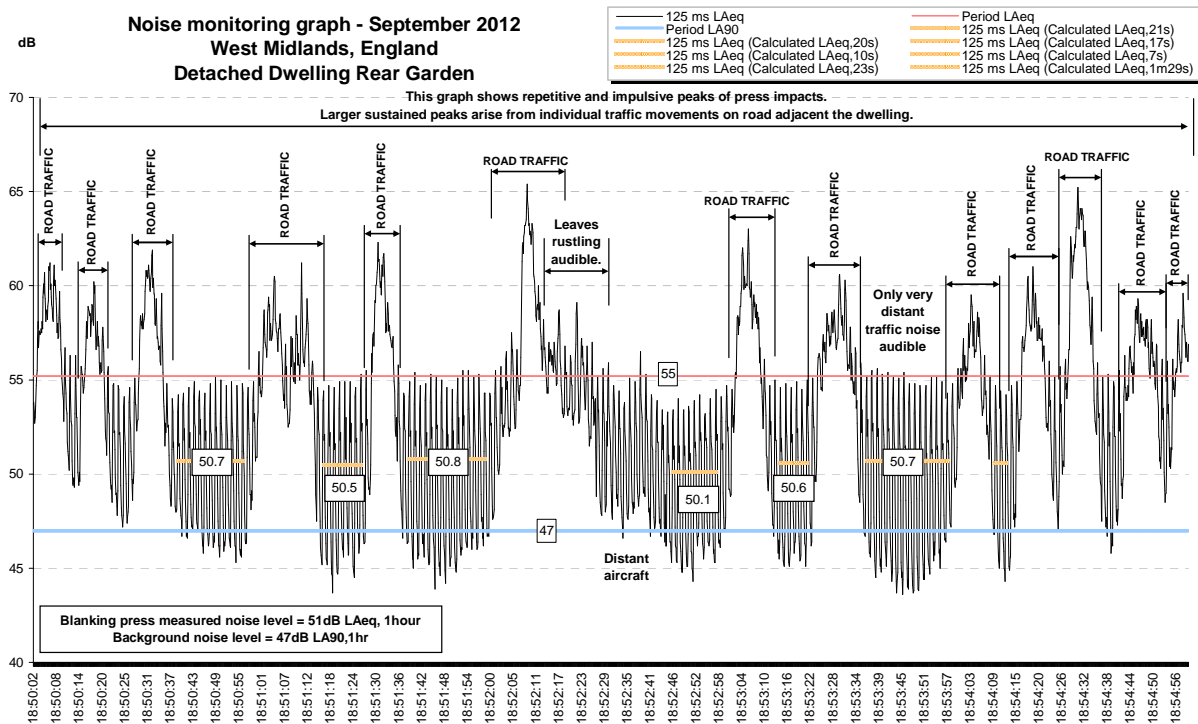


Figure 3 Graph showing typical worst case noise levels from blanking press

The repetitive and impulsive peaks of noise were clearly audible within the garden and affected the living room and bedrooms within the dwelling. The rate of change in decibels had been measured up to 90dB per second. Noise impact at the dwelling was substantial, inescapable when occurring and considered unacceptable by the author.

4.3.1 Blanking press questionnaire results

Respondent A experienced noise from the blanking press for 8 years between 2005-2013 with her partner. However, the partner of respondent A suffered a stroke with an almost complete loss of speech and function on one side of the body. This was reported as a significant factor due to the inability of escape the noise even within the dwelling due to constant care responsibilities.

For Qs 7a-7l, 9 of the 12 factors were rated "extremely important" with a score of 10 out of 10. Qs

7h 'message imparted by the noise' was rated a 9 and Qs 7c 'acoustic characteristics of the noise' rated an 8. Qs 7l 'visual or sensory impact' was rated 1 "not at all important". However, there was no odour or visual impact accompanying the noise due to conifer trees. A forklift truck could be seen occasionally but this was not considered significant.

In response to Qs 8 'any other factors considered important', the following points were reported:

- Longer duration of noise exposure (years) the more annoying it became
- People don't understand noise unless they have been affected themselves
- Felt was going mad due to lack of respite
- Felt trapped and vulnerable
- Lack of help from local authority made it worse
- No escape from and no control over the noise were massive factors

4.4 Storeroom

The residential dwelling (flat) was located directly above a storeroom. The storeroom was associated with a public house ("pub") serving food and drinks. Respondent B purchased the flat and experienced noise on first occupation of the property. The storeroom contained fixed plant with at least 2 different fan units containing at least 2 fans. The storeroom also contained an old pump to supply soft drinks to the pub ("soft drink maker"). The storeroom and pub consisted of two buildings separated by an alley. The residential flat is located directly above the storeroom and was the only dwelling affected.

Figure 4 shows a 15 minute period of noise monitoring between 13:15 and 13:30pm. The graph shows a repeating pattern/cycle of noise also experienced during the day and night. Noise from the soft drink maker occurs during the evening but not during night time when the pub is closed. The Refrigeration Fan Continuous ("RFC"), Refrigeration Fan Loud ("RFL") and soft drink maker are present. The graph shows three occurrences of the RFL and two occurrences of the soft drink maker within the 15 minute period. The two occurrences of the soft drink maker increase noise levels within the lounge by 11dB. This equates to a doubling of loudness and was highly perceptible within the lounge. The occurrence of noise from the soft drink maker in combination with RFL appears intermittent and relative to drink orders. Therefore, during any 15 minute period there is a combination of either the RFC or RFC and RFL but also the RFC, RFL and soft drink maker all in operation at the same time adding to the intrusion.

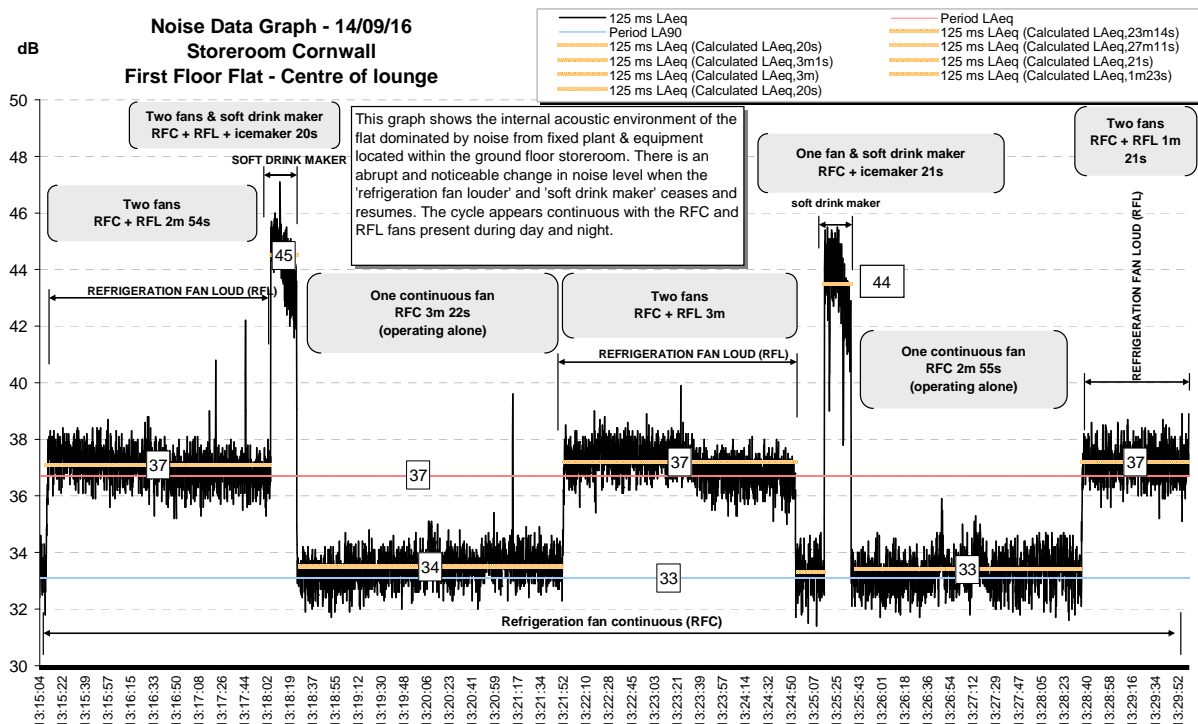


Figure 4 Noise monitoring of fixed plant within lounge of flat above

The internal $L_{Aeq,T}$ was dominated by the RFC and RFL. Specific noise levels within the lounge were typically around 37dB $L_{Aeq,1hr}$. The noise was clearly audible and constant during monitoring occurring throughout the night. The change in temporal variation from the RFC and soft drink maker represent stark increases and decreases in loudness. The noise from plant was accompanied with vibration passing through shared structural elements. The vibration could be felt underfoot and could be 'heard' transmitting through the walls². The unacceptability of the noise was accepted following the submission of an acoustic report to the building management company.

4.4.1 Storeroom questionnaire results

Respondent B had experienced the noise for 10 months but had not been affected since March 2017. Respondent B still lives within the same dwelling with partner and child. Respondent B described all 12 factors as either "very important" or "extremely important" providing ratings of 9 or 10 for all factors (six 9 and six 10 ratings).

In response to Q 8, any other factors considered important, some additional points were reported including:

- Felt powerless and helpless - no clear or definitive way to sort it out
- Attitude of pub was one of not willing to help
- Was kept awake by stress of noise impact but also noise itself
- Made my heart race

4.5 Drop hammers

Noise from the drop hammers was generated as a by-product of the manufacturing of car parts. Metal was heated and repeatedly struck with the drop hammer to mould into shape. The intensification of activity at the factory over a number of years resulted in night time operation and activity.

Figure 5 takes a 1 minute period to better show the temporal variation of noise from hammer impacts and fixed plant. The 1 minute graph demonstrates 31 hammer impacts over a 1 minute period. This is approximately 1 hammer impact every 2 seconds.

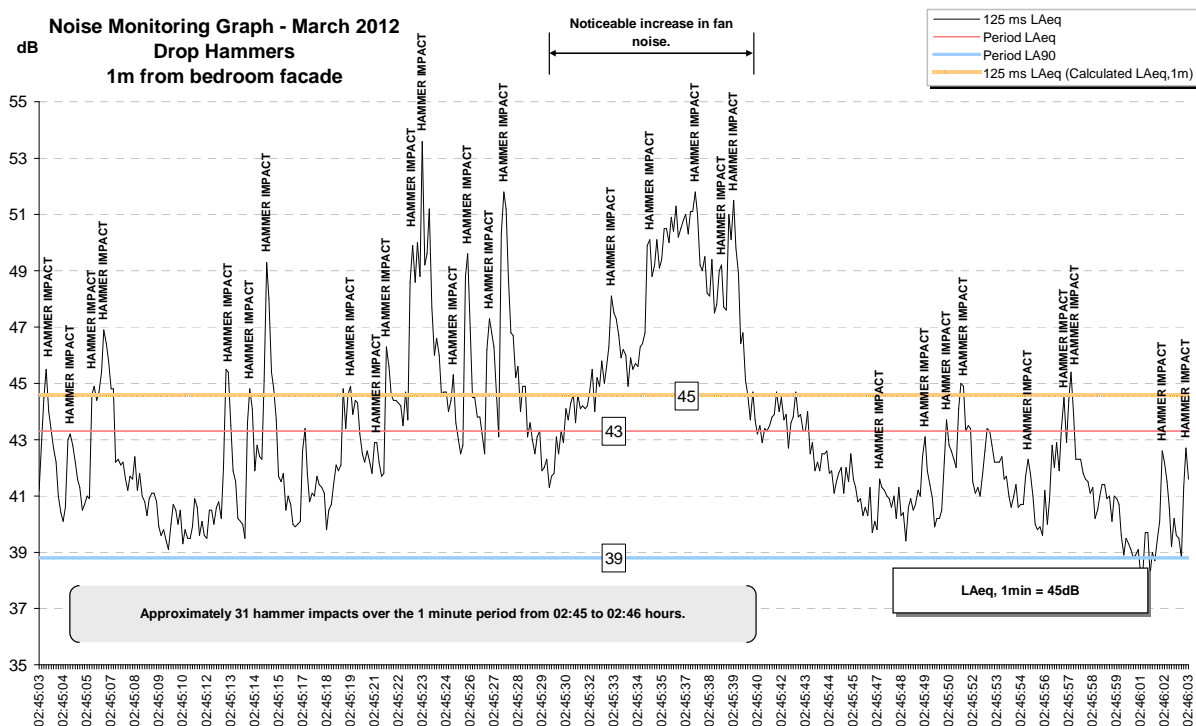


Figure 5 Night time monitoring of drop hammers and plant

The operation of the drop hammers generated a number of complaints from the local community

² 'Heard' through pressing ear against 3 different walls within the lounge.

located at a distance of approximately 820-900m. Typically daytime noise was not a source of community complaint due to higher ambient masking noise levels primarily from road traffic. However, the introduction of night working and lower background noise levels led to a number of complaints. The building containing the drop hammers was incapable of preventing noise breakout. After many years of complaint and negotiation, regulatory intervention initiated the installation of a comprehensive noise mitigation scheme and upgrading of the sound insulation of the building.

4.5.1 Drop hammer questionnaire results

Respondent C had lived at the dwelling for about 10 years. Noise impact gradually increased and intensified. Respondent C moved house in 2013 to escape the noise. Respondent C described 11 of the 12 factors as "extremely important" and provided a rating of 10 out of 10 in all those cases. Q71 relating to visual or sensory impact was "not at all important" with a rating of 0.

Respondent C commented that the noise "impacted on everyday life" and there was a perception that residents were expected to "put up with it". Respondent C noted that not being able to escape from the noise was an important factor.

4.6 Summary of questionnaire responses

Table 1 below provides an overview of the survey responses. Collectively, all numerical ratings were very similar varying between 28-30 points. The exception was Qs 7l which scored 11 points. This is expected as only the storeroom was accompanied by sensory impact i.e. feel able vibration in parts of the floor and on three walls.

Extent to which factors are important in reaction to specific noise received at dwelling (0 not at all important to 10 extremely important)			Respondent rating			
			A	B	C	Total
7	a	The decibel level of the noise	10	9	10	29
7	b	The duration of the noise	10	9	10	29
7	c	The acoustic characteristics of the noise	8	10	10	28
7	d	The variation in noise level over time	10	9	10	29
7	e	The time of day the noise occurred	10	9	10	29
7	f	The regularity of noise intrusion	10	9	10	29
7	g	The amount, or lack of, respite from the noise	10	10	10	30
7	h	The message imparted by the noise	9	10	10	29
7	i	The activities interrupted by the noise	10	10	10	30
7	j	The ability to escape the noise within the dwelling	10	10	10	30
7	k	Your expectation of the noise in your neighbourhood	10	9	10	29
7	l	Any visual or sensory impact accompanying the noise	1	10	0	11

Table 1 Overview of survey responses relating to factors important in noise reaction

5. Discussion

For all 3 respondents, elaboration or repetition of Qs 7a-7l was necessary to aid understanding. This would indicate a degree of modification is required to the wording. However, with no prior knowledge of the survey content this is expected.

As shown within table 1, the results show that factors 1-12 were rated similarly. Three factors top scored with a rating of 30 points. These were Qs 7g, Qs 7i and Qs 7j. All three factors relate to the importance of non acoustic or context moderators to the respondent's reaction. The three factors relate to the lack of respite, activities interrupted and the inability to escape from the noise.

It was anticipated there would be a variety of responses for all factors and ratings between 0 and 10.

However, all 3 respondents had a tendency to rate each factor towards the top of the scale indicating that once there is a negative perception of the noise all factors are considered important to a similar degree. In other words, once there is dissatisfaction each factor is considered equally important and there may also be an overlap between factors i.e. the activities are interrupted because there is no escape within the dwelling.

There was a tendency to relate experience and responses to the worst case scenario or recollection of impact considering the overall context. This is perhaps a point of human psychology but in noise assessment it is always necessary to consider the worst case impact (assuming this would, in fact, occur in practice).

All 3 respondents described the importance of "not being able to escape" from the noise and the "lack of control" as high. This is expected as this effectively removes an important coping strategy from the receiver. In my experience, lack of control and lack of escape from noise are significant factors in how noise impacts on humans in dwellings.

Respondent B, affected by continuous and varying plant noise, described sleep disturbance in terms of direct effects (awakenings) but also indirect sleep disturbance effects due to stress. This would appear to support both the toxicological and psychological stress response health models.

6. CONCLUSIONS

The reaction of an individual to a particular source of sound varies depending on the physical attributes of the sound but also non acoustic and context related factors. Typically, the majority of factors that influence an individual's reaction to sound are psychological (interpretative) and situational (context) rather than physical (sound pressure).

Historical research and personal experience shows that for specific sources of neighbour or neighbourhood noise there is not a simple relationship with exposure (decibel level) to sound and reaction at the individual level. The equal energy principle applied as a daily or long term noise dose, when assessing an individual source or the total noise dose (intrusive source plus environmental noise) appears to understate the impact. A degree of weighting or adjustment to the noise dose is typically required to reflect inherent acoustic characteristics.

One reaction to noise is annoyance which is an emotional response. It is also necessary to consider other reactions including affectedness, dissatisfaction and the activities interrupted.

This preliminary study rates the importance of a number of acoustic, non acoustic and context relevant factors to reactions to noise at the individual level. All 3 respondents rated 12 factors as similarly important in their reactions to neighbourhood noise. Of the 12 different factors considered, the lack of respite, activities interrupted and inability to escape from the noise were rated the most important. The lack of control was also highlighted as an important factor in noise reaction which was not included within the survey.

6.1 Further work

There is a dearth of research into the health and other effects of non transportation noise sources. Qualitative rather than quantitative epidemiological studies which focus on primarily 'single exposure' scenarios are required. Research into the short and long term effects of site specific neighbourhood noise is needed. This should, potentially, include combinations of neighbourhood noise with other sensory contributors e.g. odour/dust/light etc.

The next stage of the research involves refining the questionnaire and selecting sources of neighbourhood noise affecting more than one individual/household. The progression includes increasing the number of respondents who are affected by noise to complete the survey and assessing any differences in responses i.e. comparing different reactions to similar exposure patterns.

A standardized questionnaire that specifically considers individual sources of neighbourhood noise including acoustic, non acoustic and context related factors is necessary to harmonize the methodology and increase the consistency of findings from future research.

Collaboration is required with researchers undertaking community noise surveys to identify knowledge gaps and our collective understanding of the factors that affect human response to specific sources of neighbourhood noise.

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