EFFECTS OF BUILDING CONSTRUCTION NOISE ON RESIDENTS: A QUASI-EXPERIMENT

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Abstract

Noise pollution is an environmental problem in cities. Although recent field research has focused on transportation noises, the effects of exposure to building construction noise have not been studied. In a quasi-experiment, residents of a three-wing residence hall for female students located near a construction site served as subjects in three comparison groups. Information about their personal characteristics and perceived effects of construction noise on studying and other behaviours were gathered in a questionnaire (n = 94) and an activity log (n = 14). In addition, sound level measurements and records of resident turnover and systematic observations of windows open or closed were analysed. As expected, the results of chi-square tests, one-way ANOVAs and MANOVAs show significant wing effects (p < 0.05) on frequency heard, distractability, and several perceived behavioural effects, such as being awakened, difficulty with relaxation and studying-related activities, and interference with conversation and television-watching. These effects were significantly more severe for residents closest to the construction site than those further away. Residents coped with noise by speaking louder, keeping windows closed, and leaving the room.

Introduction

Noise pollution is an environmental concern in cities. Noise, defined as unwanted sound (Cohen & Weinstein, 1982), is likely to have certain physical characteristics (e.g. impulsive, high intensity, or high frequency) (Dunn, 1981). Sounds emitted from construction sites should meet these criteria quite well, and thus be considered as a noise by many city residents.

In decades of noise research, researchers have exposed people to white noise, artificial and unfamiliar sounds in the laboratory in an attempt to generalize any noise effects on human behaviours to their daily lives. Later on, the effects of transportation noises (i.e. aircraft, train, and highway traffic noises) have been studied in field settings to see if these laboratory results hold up (e.g. Bronzaft & McCarthy, 1975; Cohen et al., 1981; Weinstein, 1982; Smith & Stansfeld, 1986; Eberhardt, 1988; Matsumura & Rylander, 1991; Bronzaft et al., 1998).

More recently, other noise sources in the community or neighbourhood have received some attention from researchers (e.g. Kono & Sone, 1988; Levy-Leboyer & Naturel, 1991). In no studies, however, have the effects of building construction noise on residents been examined. The construction of a multi-purpose building right beside a student residence hall on a small university campus provided an opportunity to assess the effects of construction noise in a field setting.

Does construction noise interfere with learning and studying, degrade social interactions, disrupt speech communication, lead to emotional distress or annoyance, or lead to physical health problems? Current theories on noise effects and the research findings of field studies of transportation noises suggest that construction noise has some negative effects on emotional and physical well-being, speech communication, and academic performance.

Annoyance

Interviews or surveys of residents in communities have consistently shown that the mean annoyance rating or the proportion of highly annoyed residents
is directly related to noise levels (McKennell, 1973), although there is great variability in individuals' responses (Griffiths & DeLauzun, 1977). Ahrlin (1988) suggested that residents were annoyed apparently because of disruptions to their activities.

Behavioural interference

One of the disruptions to daily activities is interference with sleep and relaxation, and being awakened (Kono & Sone, 1988). Intermittent traffic noise at as low as 45 dB(A) is likely to induce changes in sleep stage towards lighter sleep and awakening, and to lead to subjective experience of poor sleep quality and bad mood (Eberhardt, 1988). In addition, residents living in areas of high aircraft noise exposure have reported having more frequent occurrence of everyday errors (e.g. forgetting why one goes from one part of the house to the other) than those in lower noise exposure areas (Smith & Stansfeld, 1986). Overt actions that people take to cope with noise include changing bedrooms, planting trees, installing double-pane windows, and taking sleeping pills (Appleyard & Lintell, 1972).

Another behavioural consequence is degradation of social behaviours, such as less helping (Mathews & Canon, 1975; Page, 1977) and less casual social interaction on the street with heavy traffic (Appleyard & Lintell, 1972).

Current research suggests that the emotional and behavioural effects are influenced by such psychological factors as controllability and predictability of the sound (Glass & Singer, 1972), sound sensitivity (Griffiths & DeLauzun, 1977; Weinstein, 1978), and the meaning people attach to the noise and the attributions given to the intentions of the noise-maker (Levy-Leboyer & Naturel, 1991).

Interference with speech communication

Noise can interfere with speech communication through direct masking of the message by noise (Dunn, 1981). The effect of masking of wanted sounds or signals by noise has been well-demonstrated in the laboratory (cf. Kryter, 1970). In the field setting, Kono and Sone (1988) have reported that residential neighbourhood noise interfered with radio and television listening, telephone conversation, and ordinary conversation.

The degree of interference with communication varies with the amplitude and frequency of background noise, the distance between speaker and listener, the speaker's vocal effort, and the hearing acuity of the listener. For normal face-to-face conversations, communication can practically be carried out at 50–65 dB between a male, articulate speaker with vocal power of 65 dB and a listener with perfect hearing acuity (Miller, 1974). Surveys of office workers (e.g. Beranek, 1956), however, suggest that 55 dB is the desired maximum noise level that allows telephoning and talking to take place without interference. The typical responses to the inability to clearly distinguish what is said is to move closer to the speaker, or for the speaker to raise the volume (Miller, 1974), or for the parties to reduce speech communication (Jones et al., 1981). The parties may, where possible, leave the setting and, when not possible, change the quality or nature of the communication (Becker et al., 1983).

Academic performance

According to the arousal theory (Broadbent, 1971, 1979), exposure to moderate or high intensity noise causes an increase in arousal. Heightened arousal leads to a narrowing of an individual's attention. As a result, inputs that are irrelevant to task performance will be ignored first. As arousal increases, attention is further restricted; task-relevant cues may be ignored as well. The relationship between arousal level and task performance is represented as an inverted U-shaped function, known as the Yerkes-Dodson Law. Performance is greatest at a moderate arousal level and gradually tapers off as the arousal level either increases or decreases. Further, the effects of arousal on performance vary with task complexity. The optimal arousal level is lower for complex tasks than for simple ones.

The findings of some laboratory studies are consistent with this theory. For example, Rabbitt (1968) reported that unpredictable or irregular noise may disrupt performance of mental tasks that require learning or short-term retention of new information. In Weinstein's (1974, 1977) studies, more complex tasks, such as detecting contextual and grammatical errors, were affected more by noise than are less complex tasks, such as detecting typing errors.

In field settings, there is increasing evidence that the effects of noise on children's academic performance persist outside the noisy environment (cf. a review by Evans & Lepore, 1993). For example, impairment of auditory discrimination and reading ability (Cohen et al., 1973) and lower reading achievement test scores (Bronzaft & McCarthy, 1975) have been reported in children exposed to noise long-term.

As these studies have been conducted on children, it is not clear if college students' studying and
learning are affected in a similar way. In the only study conducted on college students, Ward and Suedfeld (1973) observed less student participation and attention under simulated traffic noise broadcast outside a university classroom building. Their findings suggest that college students would have greater difficulty concentrating and studying in a noisy room than in a quiet room.

In summary, this study was designed to test, in a field setting, the following hypotheses. Building construction noise will: (1) cause emotional upset and affect residents' physical well-being negatively; (2) interfere with residents' activities that involve speech or sound communication; and (3) affect residents' studying negatively.

Method

Research design

A quasi-experimental research design was used, as in a few previous studies (e.g. Bronzaft & McCarthy, 1975; Bronzaft, 1981; Bronzaft et al., 1998). Students occupying rooms in the residence closest to the construction site (Near Wing, noisy side) formed the experimental group, and those occupying rooms farther away (Central Wing) and farthest away (Far Wing) formed two comparison groups. Such grouping of residents is justified by the sound level measurement data, as reported in the Results section later.

There were only two differences between the rooms in the Near Wing and the Far Wing. First, rooms in the Near Wing typically had movable furniture. Second, the first floor rooms in the Near Wing had just been renovated before construction started.

Participants

There were 157 students living in the residence hall for females at the small university in Atlantic Canada. Ninety-four students (30 Near Wing, 31 Central Wing, 32 Far Wing, and one unknown) completed the questionnaire. As shown in Table 1, 34.8 per cent had their own room and 62.2 per cent shared their room with a roommate. The majority were first-year (50.5%) and second-year university students.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Near Wing (n = 30)</th>
<th>Central Wing (n = 31)</th>
<th>Far Wing (n = 32)</th>
<th>Total (n = 93)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Occupancy</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Own room</td>
<td>33.3</td>
<td>33.3</td>
<td>37.3</td>
<td>34.8</td>
</tr>
<tr>
<td>Shared room</td>
<td>66.7</td>
<td>66.7</td>
<td>62.5</td>
<td>65.2</td>
</tr>
<tr>
<td>Floor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basement</td>
<td>10.0</td>
<td>0.0</td>
<td>0.0</td>
<td>3.2</td>
</tr>
<tr>
<td>First floor</td>
<td>20.0</td>
<td>32.3</td>
<td>37.5</td>
<td>30.1</td>
</tr>
<tr>
<td>Second floor</td>
<td>40.0</td>
<td>38.7</td>
<td>34.4</td>
<td>37.6</td>
</tr>
<tr>
<td>Third floor</td>
<td>30.0</td>
<td>29.0</td>
<td>28.1</td>
<td>29.0</td>
</tr>
<tr>
<td>Year in university</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>First</td>
<td>50.0</td>
<td>58.1</td>
<td>43.8</td>
<td>50.5</td>
</tr>
<tr>
<td>Second</td>
<td>36.7</td>
<td>32.3</td>
<td>43.8</td>
<td>37.6</td>
</tr>
<tr>
<td>Third</td>
<td>0.0</td>
<td>97.0</td>
<td>6.3</td>
<td>5.4</td>
</tr>
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<td>Fourth</td>
<td>10.0</td>
<td>0.0</td>
<td>6.3</td>
<td>5.4</td>
</tr>
<tr>
<td>Fifth or beyond</td>
<td>3.3</td>
<td>0.0</td>
<td>0.0</td>
<td>1.1</td>
</tr>
<tr>
<td>Sound sensitivity</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Very sensitive</td>
<td>0.0</td>
<td>3.2</td>
<td>9.4</td>
<td>4.3</td>
</tr>
<tr>
<td>Sensitive</td>
<td>30.0</td>
<td>97.0</td>
<td>18.8</td>
<td>19.4</td>
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<tr>
<td>About average</td>
<td>60.0</td>
<td>64.5</td>
<td>59.4</td>
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<tr>
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<td>0.0</td>
<td>6.5</td>
<td>3.1</td>
<td>3.2</td>
</tr>
<tr>
<td>Grade point average last year</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A</td>
<td>14.8</td>
<td>97.0</td>
<td>3.2</td>
<td>9.0</td>
</tr>
<tr>
<td>B</td>
<td>33.3</td>
<td>41.9</td>
<td>38.7</td>
<td>38.2</td>
</tr>
<tr>
<td>C</td>
<td>25.9</td>
<td>97.0</td>
<td>19.4</td>
<td>18.0</td>
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<tr>
<td>D</td>
<td>0.0</td>
<td>0.0</td>
<td>3.2</td>
<td>1.1</td>
</tr>
<tr>
<td>Not applicable</td>
<td>25.9</td>
<td>38.7</td>
<td>35.5</td>
<td>33.7</td>
</tr>
</tbody>
</table>

Note: p < 0.01.
students (37.6%). On average, students had lived in the residence for 14.35 months (S.D. = 9.44), and in the present room for 8.18 months (S.D. = 5.32).

Student room assignment was basically at random, according to the university administration. As evident in Table 1, this assumption is supported by non-significant chi-square tests, at \( p < 0.05 \), of demographic variables (occupancy, floor, year in university, sound sensitivity, and grade point average last year) with wing. A one-way ANOVA shows that time in residence was not significantly different across wings \( F(2, 90) = 0.10, p > 0.05 \).

The only exception is that, on average, Near Wing residents had lived in the present room for significantly fewer months \((M = 6.50, \text{ S.D.} = 4.00)\) than Central Wing residents \((M = 9.87, \text{ S.D.} = 6.18)\) and Far Wing residents \((M = 8.13, \text{ S.D.} = 5.13)\) \([F(2,89) = 3.21, p < 0.05]\). This is because the Near Wing was under renovation in the previous summer and no students occupied those rooms until the fall when construction started.

**Construction site and schedule**

The construction site was for a three-storey, 41,000 square-foot multipurpose academic building. One edge of the site was only 15 feet away from some of the rooms in the Near Wing. At times, the sound level at that end of the residence hall was as high as 80 dB. Construction started early in the morning and continued until late afternoon.

The construction work lasted for about a year, starting in August and continuing until the fall of the following year. Excavation and rock removal were carried out in August and early September. The foundation was laid between mid-October and early January. Structural steel and general steel works began in February and were completed by April. Exterior and interior works were done during the summer and the fall.

**Procedure**

At four Wing meetings in March and April, a research assistant explained the nature of the study and the tasks involved to those students present. Ninety-four students completed the questionnaire, 27 agreed to keep an activity log for a week, and 27 gave consent to have sound level measurements of their rooms taken. Introductory Psychology students were awarded research credit points for their participation.

Five sets of data were collected: (1) sound-level measurements; (2) questionnaires; (3) activity logs; (4) resident turnover records; and (5) systematic observations of windows open or closed.

**Sound level measurement.** In March and April, the sound levels of 27 rooms in various wings and floors of the residence hall were measured with a sound level meter (Bruel & Kjaer Model #2232) at 5 s intervals for 10 min at various times of the weekdays (Michael & Bienvenue, 1983). Measurements were taken in 22 of the rooms when construction works were going on, and to serve as a rough baseline check, in five of the rooms when no construction works were going on.

In each room, 120 readings were taken when the window was open and another 120 readings were taken when the window was closed. The sound level meter was placed on the window-sill, and the door to the room was kept closed. The residents were told to act as if the observer was not present.

**Questionnaire survey.** Students completed a questionnaire about the satisfaction with their room, their studying and social activities, their perception of the effects of various noise sources (including construction noise), and demographic variables.

**Activity log.** Twenty-seven students agreed to keep a diary of any noise sources and any associated interference with their activities for a week. Only 14 logs were completed and returned, with a biased sample of nine from Near Wing.

**Resident turnover record.** The records of change of rooms during the construction period were obtained from the administration. The reasons for room changes, if known, were noted.

**Systematic observation of windows open or closed.** Whether a window was open or closed was observed from outside the building between 3.30 pm to 4.00 pm for 45 weekdays between late January and early April. The mean temperature was \(-2^\circ \text{C}\) and the range was from \(-13^\circ \text{C}\) to \(+16^\circ \text{C}\).

**Results**

**Manipulation check: sound level measurements**

The average sound level when construction works were going on was calculated for each of the 22 rooms. The results support the assumption that when construction works were being carried out, there was a substantial sound level difference between the three wings. The results of an one-way ANOVA indicate a significant wing effect on sound
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level when the window was open \( F(2,19) = 8.01, p < 0.05 \). An LSD test, \( p < 0.05 \), indicates that the mean sound level at Near Wing \( (M = 65.75 \text{ dB}, \text{S.D.} = 10.43) \) was significantly higher than that at both Far Wing \( (M = 50.18 \text{ dB}, \text{S.D.} = 4.42) \) and Central Wing \( (M = 57.63 \text{ dB}, \text{S.D.} = 10.00) \).

Likewise, a one-way ANOVA indicates a significant wing effect on sound level when the window was closed \( F(2,19) = 3.95, p < 0.05 \). The Scheffe test, \( p < 0.05 \), indicates that mean sound level at Near Wing \( (M = 50.69 \text{ dB}, \text{S.D.} = 9.02) \) was significantly higher than that at Far Wing \( (M = 40.73 \text{ dB}, \text{S.D.} = 4.48) \).

When construction works were not going on and based on a very small, inadequate sample of five rooms, the sound level at Near Wing was lower than that at Central Wing and at Far Wing. When the windows were open, the mean sound levels at Near Wing, Central Wing, and Far Wing were 39-90 dB, 48-36 dB, and 51-57 dB, respectively. When the windows were closed, the mean sound levels were 31-15 dB, 44-64 dB, and 43-03 dB, respectively. In addition, measurements taken outside the building on several occasions indicated that the sound levels at various wings were fairly consistent, at 45-50 dB.

Validity of measures

Several validity checks were incorporated in the design of this study. First, there were three pairs of very similar questions in the questionnaire. The responses (on five-point scales) to ‘How often do you close or keep your window closed to keep the noise out?’ and to ‘How often do you close your window or keep the window closed?’ are significantly correlated \( r(90) = 0.69, p < 0.01 \). The responses to ‘How often do you notice sounds of construction works in your room?’ (on a five-point scale) and to ‘Do you notice noise from the construction site?’ (on a two-point scale) are significantly correlated \( r(92) = 0.45, p < 0.01 \). The responses (on five-point scales) to ‘If woken up by noise in the morning, how difficult or easy is it for you to return to sleep?’ and to ‘How often do the noises you hear in your room wake you from your sleep?’ are significantly correlated \( r(93) = 0.28, p < 0.01 \). The fairly low, although significant, correlation suggests that different factors influence the ease with which people wake up and fall back to sleep.

Second, self-reports of room changes are consistent with room changes indicated on the resident turnover records. In the questionnaire, ten students indicated that they had asked for a change of room in response to noise. Of the seven students who could be identified by their room numbers, six appeared on the residents turnover records to have changed rooms. It is not clear if noise was a reason because no ‘noise’ category appeared on the turnover records.

Third, for residents who could be identified by their room numbers, self-reports of how often residents closed their windows and observational records of whether a window was open or closed were analysed. The results indicate that the rating of how often a resident closed her window was not significantly correlated with the number of days on which the resident’s window was open \( r(58) = 0.14 \). One possible explanation is that the residents were wrong in their estimates. Another explanation could be that the window opening condition during the obervational period was not the same as that during the rest of the day.

Fourth, responses to questions about interference with activities could be compared with descriptions in the activity logs. However, as the sample of activity logs completed is small and biased, it is difficult to use these data for validity check purposes.

Noises in college dormitories

Noisiness. The mean sound levels in rooms in the separate wings were different. Did residents’ subjective reactions match the objective data of sound level measurements? The answer appears to be no. The results of an one-way ANOVA indicate that ratings of noisiness in their rooms were not significantly related with wing \( F(2,89) = 0.55, p = 0.58 \). The mean ratings for Near Wing, Central Wing, and Far Wing residents were 2.63, 2.53, and 2.72, respectively; nor were ratings of noisiness in the residence hall significantly different across wing \( F(2,89) = 0.09, p = 0.92 \). The mean ratings for Near Wing, Central Wing, and Far Wing residents were 2.37, 2.35, and 2.31, respectively. A possible explanation for the results is that residents may have interpreted the questions to mean noises coming from inside the room or the residence hall.

Noise sources. To see what noises other than building construction noise residents heard when in their rooms, they were asked how often they heard a list of 12 common noises in residential settings. The results of one-way ANOVAs, \( p < 0.05 \), show that residents across wings did not differ significantly in how often they heard music from other rooms, talking and yelling, telephone ringing, sounds of domestic activities, footsteps, door banging, car starting, domestic appliances sounds, outside traffic, and other sounds. There is, however, a significant wing
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effect on how often residents heard plumbing noises [\(F(2,88)=5.66, p<0.01\)], although the differences were not significant across any pair of groups.

**Construction noise**

*Frequency heard.* As expected, how often residents in the three wings heard construction noise differs significantly [\(F(2,89)=3.55, p<0.05\)]. An LSD test, \(p<0.05\), shows that Near Wing residents heard construction noise significantly more often (\(M=4.07, \text{ S.D.}=1.11\), on a five-point scale, with 1 indicating ‘rarely’ and 5 indicating ‘always’) than Far Wing residents (\(M=3.29, \text{ S.D.}=1.40\)) and Central Wing residents (\(M=3.29, \text{ S.D.}=1.40\)). Similarly, a significantly higher percentage of Near Wing residents noticed noise coming from the construction site (93.3%) than Central Wing residents (54.8%), \(\chi^2(1, n=61)=11.68, p<0.001\), and Far Wing residents (59.4%), \(\chi^2(1, n=62)=9.74, p<0.01\). The percentages between Central Wing residents and Far Wing residents were, however, not significantly different, \(\chi^2(1, n=63)=0.13, p=0.72\). These results are consistent with the sound level measurement data that Near Wing was the noisiest.

*Pleasantsness.* Of the 12 noise sources, residents rated construction noise as one of the two most unpleasant noises. The mean rating was 2.58 on a scale of 10, where 1 indicates ‘very unpleasant’ and 10 indicates ‘very pleasant’. How unpleasant construction noise was is not related to how often it was heard, as ratings of pleasantness are not significantly correlated with ratings of how often construction noise was heard [\(r(91)=-0.17\)].

**Physical and emotional effects.** Apart from being very unpleasant, construction noise was distracting to about one-third of the residents. As shown in Table 2, the percentages of residents who reported being distracted differ significantly across wings. Specifically, a significantly higher percentage of Near Wing residents (48%) than Central Wing residents (16%) reported being distracted, \(\chi^2(1, n=59)=6.75, p=0.01\). However, the percentages of residents feeling irritable, being startled, or getting a headache were not significant across wings.

**Perceived behavioural effects.** As Table 2 reveals, residents reported that construction noise affected their speech communication and social interactions, daily enjoyment of life, and their study-related activities, as expected.

On speech communication, about 10 per cent said that construction noise made conversation difficult for them both in hearing others and in being heard, on the phone and in the room. The results of chi-square tests show significant differences across wings in difficulty with telephone conversation, hearing conversation, and in being heard in their rooms. The percentage of Near Wing residents reporting difficulty with conversations on the phone (32.1%) was significantly higher than that of Central Wing residents (0%), \(\chi^2(1, n=57)=11.07, p<0.001\), and of Far Wing residents (3.4%), \(\chi^2(1, n=57)=8.11, p<0.01\). Similarly, the percentage of Near Wing residents reporting difficulty in hearing conversations (28.6%) was significantly higher than that of Far Wing residents (4.8%), \(\chi^2(1, n=57)=15.26, p<0.001\). A significantly higher percentage of Near Wing residents (48%) than Central Wing residents (16%) reported being distracted, \(\chi^2(1, n=59)=6.75, p=0.01\). However, the percentages of residents feeling irritable, being startled, or getting a headache were not significant across wings.

### Table 2

**Construction noise effects: percentages of residents by wing**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Near Wing (n = 30)</th>
<th>Central Wing (n = 31)</th>
<th>Far Wing (n = 32)</th>
<th>Total (n = 93)</th>
<th>(\chi^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interferes with television watching</td>
<td>33.3</td>
<td>6.7</td>
<td>27.6</td>
<td>22.5</td>
<td>6.77*</td>
</tr>
<tr>
<td>Interferes with radio listening</td>
<td>26.7</td>
<td>6.7</td>
<td>23.3</td>
<td>18.9</td>
<td>4.50</td>
</tr>
<tr>
<td>Interrupts thoughts</td>
<td>60.0</td>
<td>20.0</td>
<td>33.3</td>
<td>37.8</td>
<td>10.59**</td>
</tr>
<tr>
<td>Makes reading difficult</td>
<td>50.0</td>
<td>20.0</td>
<td>33.3</td>
<td>34.4</td>
<td>6.00*</td>
</tr>
<tr>
<td>Makes you irritable</td>
<td>50.0</td>
<td>20.0</td>
<td>36.7</td>
<td>35.6</td>
<td>5.92</td>
</tr>
<tr>
<td>Distracts</td>
<td>48.3</td>
<td>16.7</td>
<td>33.3</td>
<td>32.6</td>
<td>6.72*</td>
</tr>
<tr>
<td>Makes relaxing difficult</td>
<td>48.3</td>
<td>13.3</td>
<td>43.3</td>
<td>34.8</td>
<td>9.37**</td>
</tr>
<tr>
<td>Makes studying difficult</td>
<td>51.7</td>
<td>20.0</td>
<td>37.9</td>
<td>36.4</td>
<td>6.46*</td>
</tr>
<tr>
<td>Makes you use</td>
<td>53.6</td>
<td>16.7</td>
<td>37.9</td>
<td>32.2</td>
<td>15.26***</td>
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<td>Makes telephone conversation difficult</td>
<td>32.1</td>
<td>0.0</td>
<td>34.4</td>
<td>11.6</td>
<td>17.17***</td>
</tr>
<tr>
<td>Makes hearing conversion difficult</td>
<td>28.6</td>
<td>0.0</td>
<td>9.3</td>
<td>18.27***</td>
<td></td>
</tr>
<tr>
<td>Makes conversion difficult to be heard</td>
<td>25.0</td>
<td>3.4</td>
<td>6.9</td>
<td>11.6</td>
<td>7.39*</td>
</tr>
<tr>
<td>Gives you an headache</td>
<td>32.1</td>
<td>10.3</td>
<td>13.8</td>
<td>18.6</td>
<td>5.14</td>
</tr>
<tr>
<td>Startles or scares you</td>
<td>17.9</td>
<td>3.4</td>
<td>10.3</td>
<td>10.5</td>
<td>3.16</td>
</tr>
<tr>
<td>Makes thinking difficult</td>
<td>42.2</td>
<td>17.2</td>
<td>41.4</td>
<td>33.7</td>
<td>5.33</td>
</tr>
<tr>
<td>Affects other activities</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>- - -</td>
</tr>
</tbody>
</table>

Note: *\(p<0.05\), **\(p<0.01\), ***\(p<0.001\).
Effects of Building Construction Noise on Residents

Central Wing residents (0%), $\chi^2(1, n=57)=9.64$, $p<0.01$, and of Far Wing residents (0%), $\chi^2(1, n=57)=9.64$, $p<0.01$. In addition, the percentage of Near Wing residents reporting some difficulty in being heard (25%) was significantly higher than that of Central Wing residents (3.4%), $\chi^2(1, n=57)=5.48$, $p<0.05$.

On daily living, about one-fifth reported interference with television watching. Interference with television watching was significant across wings, as indicated in Table 2. A significantly lower percentage of Central Wing residents (6.7%) reported interference with television watching than Near Wing residents (33.3%), $\chi^2(1, n=60)=6.67$, $p=0.01$, and Far Wing residents (27.6%), $\chi^2(1, n=59)=4.58$, $p<0.05$.

As for resting, about one-third of the residents reported that construction noise made relaxing difficult or it woke them up. These effects were significant across wing. The percentage of Central Wing residents reporting being woken up (67%) was significantly lower than that of Near Wing residents (53.6%), $\chi^2(1, n=58)=15.38$, $p<0.001$, and that of Far Wing residents (37.9%), $\chi^2(1, n=59)=8.39$, $p<0.01$. If woken up by noise in the morning, residents found it ‘somewhat difficult’ to ‘neither difficult nor easy’ for them to return to sleep ($M=2.31$ on a scale of five, where 1 indicating ‘very difficult’ and 5 indicating ‘very easy’). In addition, a significantly lower percentage of Central Wing residents reported difficulty relaxing (13.3%) than Near Wing residents (48.3%), $\chi^2(1, n=59)=8.49$, $p<0.01$, and Far Wing residents (43.3%), $\chi^2(1, n=60)=6.65$, $p=0.01$.

On studying and its related activities, about one-third of the residents reported that construction noise interrupted their thoughts, and made reading and studying difficult. The results of chi-square tests show significant differences across wings, $p<0.05$, in interruption of thoughts, difficulty in reading and studying. The percentage of Near Wing residents reporting interruption of thoughts (60%) was significantly higher than that of Central Wing residents (20.0%), $\chi^2(1, n=60)=10.00$, $p<0.01$, and that of Far Wing residents (33.3%), $\chi^2(1, n=60)=4.29$, $p<0.05$. A significantly higher percentage of Near Wing residents reported difficulty in reading (50.0%) and studying (51.7%) than Central Wing residents (reading: 20.0%; studying: 20.0%), $\chi^2(1, n=60)=5.93$, $p=0.01$ and $\chi^2(1, n=59)=6.47$, $p=0.01$, respectively.

Of the 14 residents who completed an activity log, ten indicated that noise from the construction site interfered with their activities; eight of these ten were Near Wing residents and two were Central Wing residents. The Near Wing residents mentioned that construction noise interfered with their activities as many as 11 times in the week. The effects included in decreasing number of mention, woken up or hard to sleep (14), difficult to concentrate or study (8), impossible to hear the television, music, or other people (6), impossible to relax (4), and feeling annoyed (4). These results are consistent with the questionnaire data presented in Table 2.

Effects other than noise

Overall, 71.7 per cent of residents noticed some effects of the construction site. A much higher percentage of Near Wing residents (93.3%) noticed some effects of the construction site than Far Wing residents (62.5%) and Central Wing residents (60.0%), $\chi^2(2, n=92)=10.29$, $p<0.01$.

In addition to noise and interference with watching television described above, building vibration was reported by 25.8 per cent of the residents to be another effect of the construction works. Again, a significantly higher percentage of Near Wing residents (46.7%) reported feeling building vibration than Central Wing residents (19.4%), $\chi^2(1, n=61)=5.16$, $p<0.05$ and Far Wing residents (12.5%), $\chi^2(1, n=62)=8.77$, $p<0.01$. In addition, a significantly higher percentage of Near Wing residents reported smoke or dust (13.3%) than Far Wing residents (0%), $\chi^2(1, n=62)=4.56$, $p<0.05$.

Attitudes toward construction

Despite significant differences across wings in self-reported, negative effects of the construction works, a chi-square test shows no significant differences in degree of approval across wings. Overall, residents approved of the construction of the building: 37.6 per cent of residents strongly approved, 34.4 per cent approved, and 25.8 per cent neither approved or disapproved. In response to whether the construction works should be done in the summer, 30.1 per cent of the residents said yes, 44.1 per cent had no opinion, and 25.8 per cent said no. Again, the responses do not differ significantly across wings.

Coping with noise

How did residents cope with the noise in their rooms? Residents were asked to rate how often they used each of eight coping behaviours on five-point scales, with 1 indicating ‘rarely’ and 5 indicating ‘always’. The results of a MANOVA with eight coping
behaviours as dependent variables and wing as the independent variable were significant, $\lambda = 0.70$, $F(16, 164) = 2.03$, $p < 0.05$. As indicated in column 5 of Table 3, univariate $F$-tests show that speaking louder and asking their friends to speak louder when in the room, keeping the windows closed, and going somewhere else to study were significant.

**Increasing effort in speech communication.** As shown in Table 3, residents indicated that they spoke louder in the room ‘once in a while’ to ‘sometimes’ ($M = 2.34$) and they asked their friends in the room to speak louder ($M = 2.11$). The Scheffe tests, $p < 0.05$, show that Near Wing residents reported speaking louder when in the room ($M = 2.67$) and asking their friends in the room to speak louder ($M = 2.37$) more often than did Central Wing residents ($M = 1.90$; $M = 1.65$, respectively).

**Keeping windows closed.** When asked how often residents closed or kept their windows closed, residents reported doing so ‘once in a while’ to ‘sometimes’ ($M = 2.41$). In another question in which residents were asked specifically about how often they closed or kept their windows closed to keep the noise out, again they reported doing so ‘once in a while’ to ‘sometimes’. A Scheffe test, $p < 0.05$, shows that Near Wing residents reported closing their windows ‘sometimes’ to ‘often’ ($M = 3.07$), significantly more often than Central Wing residents ($M = 2.06$) and Far Wing residents ($M = 2.13$) (Table 3, row 6).

The systematic observational data indicate that 25 per cent of the windows were open across all wings. A $3 \times 2$ (wing $\times$ construction) ANOVA with percentage of windows open as the dependent variable was run. The results show that there is a significant effect of wing [$F(2,42) = 11.57$, $p < 0.001$]. The mean percentage of windows open in the Near, Central, and Far Wings was $19.33$ (S.D. = 13.41), 27.88 (S.D. = 24.05), and 32.01 (S.D. = 25.83), respectively. The main effect of whether construction works were going on or not was nonsignificant [$F(1,43) = 1.33$, $p = 0.26$]; nor was the interaction effect significant [$F(2,42) = 1.65$, $p = 0.20$]. The results suggest that residents kept their windows open or closed for reasons more than just for noise; the most obvious one is the outside temperature. Indeed, the total number of windows open was significantly correlated with the outside temperature [$r(45) = 0.87$, $p < 0.01$].
Flight behaviour. To avoid the setting, residents went somewhere else to study 'sometimes' \((M=3.1)\). As indicated in Table 3, a Scheffe test, \(p<0.05\), shows that Near Wing residents reported going somewhere else to study significantly more often \((M=5.0)\) than Far Wing residents \((M=2.7)\).

Actions desired or taken. The most common action that residents desired to take or had actually taken to combat noise in their rooms were contacting the noise source (77.2% of residents desired; 66.2% had taken) and complaining to friends and family (73.7% of residents desired; 87.5% had taken). Thirty per cent had desired to take other actions, and 70 per cent had actually taken other actions.

To get out of the situation altogether, 20.5 per cent of the residents had desired to ask for a change of room and 17.5 per cent had actually done so. About one-fifth (18.8%) indicated a desire to move out, but only 7.3 per cent had actually moved out. The discrepancy is likely due to a lack of alternative affordable housing in convenient locations. During the construction period, 33 changes in assignment of rooms were on record. The reasons for change of rooms on the resident turnover records included preference for roommate, preference for single room, conflict with roommate, and request by administration. Seven students moved from the Near Wing to other wings, with no reasons specific to the construction noise given. Privately, three residents indicated that noise from the construction site was the reason for change of room.

Academic performance

As reported above, construction noise distracted residents, interrupted their thoughts, and made reading and studying difficult. Some coped by going somewhere else to study. Are these negative effects large enough to affect their academic performance during the construction period? The answer appears to be no. The results of an one-way ANOVA show a nonsignificant effect of wing on self-reported change in grade point average between last year and last term \([F(2,86) = 0.43, p = 0.65]\).

**Discussion**

This study has two significant contributions. First, it is the first field study to focus on the effects of exposure to noise emitted from a building construction site. Second, it is one of the few studies that use observational data and archival data in addition to self-reports.

Like studies of train, highway, and aircraft noise, the results of this study indicate that there are some negative effects of exposure to loud construction noise. Student residents found construction noise highly unpleasant; in fact, one of the two most unpleasant of a list of 12 commonly heard noises in the community. Students living closest to the construction site reported being distracted more frequently than those farther away from the construction site—a finding consistent with Smith and Stansfeld's (1986) study that subjects made more everyday errors. They also reported interference with and disruption of a number of their daily activities. Among these are those related to their academic activities, i.e. interruption of thought, difficulty in studying, and difficulty in reading. These results are consistent with the Yerkes-Dodson Law and the findings of Weinstein's (1974, 1977) studies that noise impairs performance of more complex, intellectual activities. Some residents indicated that they coped by going somewhere else to study. In this study, the negative effects on academic activities are not strong enough to produce a significant change in their grade point average. The most likely explanation is that the self-report measure of grade point average is not a sensitive enough measure; the percentage grade should have been used instead.

That construction noise woke residents up and made sleeping and relaxing difficult was the primary concern of residents. Students close to the construction site also reported interference with speech communication on the phone and in their rooms. Raising the voice is one way of coping but it obviously lowers the quality of social interaction. Construction noise also affects residents' enjoyment of life in general. Students living near the construction site had to turn up their television in order to be able to hear. These results are consistent with the effects reported by residents exposed to train and aircraft noise (Ahrlin, 1988; Bronzaft et al., 1998).

The use of a quasi-experimental approach makes this study as valid as it could be in a field setting. Assignment of residents to the different groups was mostly at random, although there were a few differences in the room design. The baseline sound level seemed fairly consistent across the wings. The wing closest to the construction site was perhaps even quieter than the wings further away when no construction works were going on. As in any other quasi-experiment, the presence of noises other than
construction noise and the occurrence of uncontrolled events, such as a brief construction project near the Far Wing, have made some of the results more difficult to interpret.

As Cohen and Weinstein (1982) pointed out, behavioural indicators should be used in addition to self-reports to assess noise annoyance in the community. In this study, sound level measurement, observational, and archival data were used in addition to self-reports.

Comparisons between questionnaire responses and a small sample of activity logs and between self-reports of room changes and turnover records indicate consistency across data sets. The sound level measurement data are consistent with residents’ reports about how often they heard construction noise, but not with their subjective evaluation of noisiness in their rooms and noisiness in the residence hall. Nor are the observational data of windows open consistent with residents’ self-reports of how often they kept their windows open. These inconsistencies in data may indicate that residents are not very accurate estimators of their behaviours.

Previous studies suggest that attitudes towards the noise source and sound sensitivity may be important moderating variables. In this study, residents were generally positive about the construction of a new academic building on campus. There was too little variation in their attitude or sound sensitivity ratings to affect residents’ reactions to noise significantly.

Note that the participants in this study were young, female college students. No harmful health effect was reported. However, caution needs to be taken in generalizing the results to males or older people who are more sensitive to noise (Matsumura & Rylander, 1991). This study was conducted during winter and spring when residents tended to close their windows to keep the heat in. Students may report different effects had the study been conducted in the summer.

In conclusion, the results of this study suggest some negative impact of building construction noise on residents’ home life. Being distracted, having difficulty with relaxing and, in particular, being woken up by construction noise can affect the mental health of residents. Having to leave the residence or to keep the window closed, would mean one’s home is no longer one’s haven. University administration contemplating constructing new buildings near occupied dormitories should, therefore, take every possible measure to minimize the effects on student residents.

Acknowledgements

Funding for this project was provided by St Thomas University, where the author was on the faculty and data were collected. The author acknowledges the assistance of Doreen Vatour and Renae Agrey in data collection.

References


