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Office noise and employee concentration: Identifying causes of disruption and potential improvements

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A field study assessed subjective reports of distraction from various office sounds among 88 employees at two sites. In addition, the study examined the amount of exposure the workers had to the noise in order to determine any evidence for habituation. Finally, respondents were asked how they would improve their environment (with respect to noise), and to rate examples of improvements with regards to their job satisfaction and performance. Out of the sample, 99% reported that their concentration was impaired by various components of office noise, especially telephones left ringing at vacant desks and people talking in the background. No evidence for habituation to these sounds was found. These results are interpreted in the light of previous research regarding the effects of noise in offices and the 'irrelevant sound effect'.

Keywords: Open-plan offices; Noise; Distraction

1. Introduction

Background noise is the most frequent complaint about open-plan office environments. This is not surprising given that the concept of open-office planning always invites some level of acoustical compromise; since the conflicting requirements of good speech communication and good speech privacy are asked to co-exist in a single physical environment. Thus, where there is good communication, both formal and informal as in most open-plan offices, there is also a risk of interruption and distraction from background noise.

Previous research has identified office noise as a potential source of dissatisfaction with the work environment, both in terms of motivational deficits (e.g., Evans and Johnson, 2000), performance decrements (e.g., Veitch, 1990, Loewen and Suedfeld 1992, Banbury and Berry 1997) and annoyance (e.g., Sundstrom *et al.* 1994, Sailer and Hassenzahl 2000). The vast majority of the research conducted to date has concentrated on the last aspect,

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that of annoyance, using a variety of questionnaire-based methods. For example, Langdon (1966) found the most frequent complaint about office environments concerned noise, especially from people talking in the background. Boyce (1974) surveyed an open-plan office and found that out of 200 workers, 67% were disturbed by telephones ringing and 55% by people talking and about half of the sample by air conditioning and office machinery. Nemecek and Grandjean (1973) reported that more than a third of the 519 workers surveyed in 15 European offices, complained about the noise in their offices, particularly background conversations (although the mean ambient sound levels were unrelated to these complaints). Furthermore, Keighley (1970) assessed the 'acceptability' of noise in 40 offices and measured ambient sound level and peak level above background. The study found that acceptability was unrelated to the ambient sound level, but strongly, inversely correlated with peak levels above ambient, suggesting that distinctive or salient sounds were least acceptable. Sundstrom *et al.* (1994) found that out of over 2000 participants questioned, 54% said that they were often bothered by noise, especially by people talking and telephones ringing. Interestingly, this disturbance by noise correlated with dissatisfaction with the environment and job, but not with self- or supervisor-rated performance. In summary, these studies show that: firstly, the disruption reported by office workers was unrelated to the level of the ambient noise; secondly, distinctive or salient sounds, such as peaks of office noise, were reported to be highly unacceptable; and thirdly, background speech is reported to be the most bothersome noise source in the office environment.

The cognitive psychology literature has provided a wealth of data on the deleterious effects of background speech and the above observational findings go some way to support these laboratory findings (for a review see Banbury *et al.* 2001). The irrelevant speech effect was first identified by Colle and Welsh (1976), and has subsequently been replicated by a number of researchers using simple serial-recall tasks (e.g., Colle 1980, Salamé and Baddeley 1982, 1987, Jones *et al.* 1992, Jones and Tremblay 2000). Early studies established key features of the disruption by irrelevant speech, among them that the degree of disruption was not dependent on the intensity of the sound, at least within the range 48 – 76 dB(A) (Colle and Welsh 1976, Tremblay and Jones 1999). Moreover, recent research has found that the effect is not confined to speech, since the effect can be found with tones (Jones and Macken 1993) or pitch glides (Jones *et al.* 1993). Thus, it is now referred to as the 'irrelevant sound effect' (see Jones, 1999).

There has been less agreement over the question of whether non-speech sounds can disrupt performance on serial recall tasks. Based on the formulation of working memory by Baddeley and Hitch (1974), Salamé and Baddeley (1982) proposed that the effects of speech and non-speech sounds on serial recall can be understood in terms of a filter and detector system that selectively passes into memory only sounds that resemble speech. They suggested a mechanism in which the degree of disruption is proportional to the phonological similarity between the written material and the material that is heard. Thus only speech, they argued, can show an irrelevant speech effect. However, studies by Jones *et al.* (1995) using spatial memory tasks and Jones and Macken (1993) using random tones, suggested some other factor other than phonological confusion is responsible for the disruptive effects observed. The Changing State hypothesis advanced by Jones *et al.* (1992) argued that the sound has to show a particular variation over its time course, rather than the assumption that the sound has to be 'speech-like' before it disrupts serial recall. They argued that any sounds that conform to the criteria of changing-state have the potential to cause a disruption similar to those seen with speech (for further discussion see Macken *et al.* 1999).

Previous research by Banbury and Berry (1997, 1998) found that office noise, either with or without speech, significantly impaired performance on memory for prose and mental arithmetic tasks. They argued that the Changing State hypothesis advanced by Jones *et al*. (1992) is more successful in accounting for the disruptive effects of office noise, as the account by Salamé and Baddeley (1982) can not explain how office noise that does not contain speech disrupts cognitive processing. In addition, Banbury and Berry (1998) found that the effect was independent of the meaning of the sound. This finding supports a number of other studies using simple laboratory-based tasks and recorded speech and tones (e.g., Salamé and Baddeley 1982, 1987, Jones *et al*. 1990, Buchner *et al*. 1996, and LeCompte and Shaibe 1997).

One problem with generalizing the results of laboratory research of this kind to the real world is that, although the physical properties of the sound may be similar, background sound in the real world may carry some additional meaning. Indeed, participants in the laboratory are instructed to ignore the background sound, whereas office workers may be attending to the sounds in the office. A further problem is that the irrelevant sound used in these studies was a novel sound source to the participants, whereas office workers spend a large amount of time in their offices. Thus, the extent to which habituation occurs is of both theoretical and practical importance. The study of habituation within the irrelevant sound paradigm is both inchoate and inconsistent. For example, Banbury and Berry (1997) observed significant habituation effects after 20 min of continuous exposure. However, Tremblay and Jones (1998) found no evidence of habituation using a different methodology. One explanation for this disparity is that the process of habituation may be dependent on the locus of attention. In the study by Banbury and Berry, participants attended to the irrelevant sound, whereas in that by Tremblay and Jones, exposure was incidental (i.e., unattended). The discrepancy in the results can also be explained by the finding that a relatively short period of quiet restored the interference by irrelevant sound (Banbury and Berry 1997). Nevertheless, Banbury *et al*. (2001) argued that although the weight of laboratory evidence seems to indicate that the interference by irrelevant sound is not evanescent, further field studies are needed on this topic.

The present study attempts to validate these laboratory findings using a field study to assess disturbance by the various components of office noise in relation to subjective reports of environmental satisfaction and job performance. The content of the questionnaire included questions concerning the respondents' satisfaction with their work environment, how their concentration was affected by the noise in the office and the amount of exposure respondents had to it, in order to determine any evidence of habituation. It was hoped that any significant negative correlations found between the time spent in the office and the reported disruption from noise would indicate that respondents were able to habituate to the noise in their office.

In addition, more direct questions regarding other distractions in the office, such as speech privacy and people passing through the office, were included. Finally, respondents were asked how they would improve their working environment and to rate examples of improvements with regard to their job satisfaction and performance.

2. Method

2.1. *Research design*

Office employees at two sites completed a questionnaire regarding the noise in their office environment, and their reactions to it. In addition, questions pertaining to

potential improvements to the office were included. Finally, sound level measurements were taken throughout both offices on the same day as the questionnaires were administered.

2.2. *Research settings*

Participating organisations were two private corporations in the United Kingdom, whose management consented to the research. They were selected on an 'opportunity basis'. The research sites included accounting, administration, human resources, customer services, and sales departments. Both offices were a similar size and used completely open-plan layouts. They differed in relation to the amount of internal partitioning; one office used five-foot acoustic screens, whereas the other used office furniture to separate work-stations. The number of personnel was 150 and 130 in the two offices respectively.

Office 1 was located within the headquarters of a large banking organization. The office was arranged in a circular manner around a central services core. The management was located around the outside of the office next to the windows, and the other employees situated within. A single coffee area and separate interview rooms, (located elsewhere in the building), were allocated for all employees to use. The tasks undertaken in this office were mostly secretarial-clerical, related to the company's banking role. The sound level of the office was approximately 55 dB(A).

Office 2 was located within the divisional headquarters of a large computing organisation. The office was arranged in a rectangular manner and, in contrast to the previous office, the management was located evenly around the office floor. A single coffee area and separate interview rooms, (both on the same floor), were allocated for all the employees to use. The tasks undertaken in this office were mostly sales and on-line customer support related to the company's IT support role. The sound level of the office was approximately 60 dB(A).

2.3. *Participants*

Participants were 88 employees (45 from office 1 and 43 from office 2) who volunteered to complete a questionnaire. Overall, the sample was 65% male and 35% female, and had been working in their current office for a mean of 9 months. Ages ranged from 20 – 59 years, with a mean of 33 years. Finally, 22% of the sample were managerial, 22% were supervisory and 56% were involved in clerical-secretarial duties.

2.4. *Procedure*

On the day of the visit, questionnaires were delivered to participants' desks, to be completed when convenient and returned to a designated location using a stamped-addressed envelope. A memorandum accompanied each questionnaire from the management, encouraging employees to participate in the study. It was stressed that participation was strictly on a voluntary basis and employees were under no obligation to complete the questionnaire. The response rate was approximately 75%.

On the same day, sound level measurements, in dB(A), were taken using a Digital Sound Level Meter (manufactured by RadioShack, Fort Worth, TX, USA) in various locations in the office in order to reflect, as closely as possible, the mean ambient noise level of the office. The same readings were taken an hour later and an aggregate reading was recorded. Each measurement took approximately 5 min to complete.

2.5. *Questionnaire*

The questionnaire examined employee reactions to office noise. It also asked respondents to rate various methods of noise control. Respondents were asked to complete the questionnaire at their 'regular workspace/workstation'. The questionnaire took approximately 10 min to complete.

2.6. *Variables*

2.6.1. Demographic details and habituation to office noise: The questionnaire contained questions concerning age and sex, and asked respondents to describe their office layout, (either as open-plan with partitions, open-plan without partitions, closed office, or other), and estimate how many people they share an office with. Finally, the questionnaire contained questions concerning how long respondents had worked in their current office (in months), how long they spent in the office each day (in hours), and the percentage of the day they spend at their usual workspace or workstation. These questions should provide some measures of the respondents' exposure to the noise in their office.

2.6.2. Disturbance by noise: The questionnaire examined eight noise sources;

- Telephones ringing,
- Telephones left ringing at vacant posts,
- Other people's telephone conversations,
- Printers,
- Typewriters and keyboards,
- Computers,
- External sources,
- Other people talking.

Using a five-point rating scale, (1 = Major improvement , 2 = Slight improvement, 3 = Not at all affected, 4 = Slight deterioration and 5 = Major deterioration), respondents were asked to indicate how their *concentration* was affected by each noise source. Other studies examined how 'bothered' (Sundstrom *et al.* 1994), 'disturbed' (Nemecek and Grandjean 1971), or 'annoyed' (Sailer and Hassenzahl 2000) respondents were by the noise of their office. The wording of the present study (i.e., effect on *concentration*) was chosen because it was felt to be both representative of the irrelevant sound literature, and, perhaps more importantly, would not predispose respondents to view office noise in a negative light. Indeed, Ellermeier and Zimmer (1997) found that the effects of noise on participants' performance ranged from disruption to slight facilitation.

Disturbance by combined sources of noise was calculated in a manner similar to that of Sundstrom *et al.* (1994), in which each individual's disturbance score was averaged for the eight separate noise sources.

Three other sources of distraction were investigated. Using the same rating scale, respondents were asked to rate;

- How their concentration was affected by people passing through the office,
- The thought that other people could overhear their telephone conversations,
- The thought that other people could overhear their conversations with colleagues.

These three measures were not included in the combined noise source score. Finally, there was an open-ended question regarding the respondents' job title. Job titles were used to classify participants into one of three job categories: managerial, supervisory, clerical-secretarial, so that any reported disturbance to certain background noises could be scrutinized.

2.6.3. Environmental satisfaction: Respondents were asked to write down what they most *liked* and *disliked* about the design of their current working environment. Using a five point rating scale, (1 = Major improvement , 2 = Slight improvement, 3 = Not at all affected, 4 = Slight deterioration and 5 = Major deterioration), respondents were then asked to rate potential ways of reducing the noise in their office, in terms of how their *satisfaction with their working environment* would be affected. The suggested improvements were;

- The use of better sound absorption materials on ceilings, and partitioning to reduce the overall noise level,
- To have a designated area where non-work related conversations were permitted (e.g. a coffee area),
- To have enforced areas of quiet (to allow quiet, contemplative work),
- To have a separate enclosed interview room where private, work-related conversations can be held.

Finally, respondents were asked to rank the above improvements in order of preference, from 1 (highest) to 4 (lowest), considering their experience of the background noise in their office.

2.6.4. Improvements to job performance: Considering their answers to the above category, respondents were asked to speculate how their *job performance* would be affected by each of the four improvements. Enough space on the questionnaire was given to accommodate their written responses.

3. Results

Preliminary analyses indicated no substantive differences between the data from the two offices. As a result, it was decided to collapse the data-set and calculate descriptive statistics and Pearson product-moment correlation coefficients (r) from the data of both offices together.

3.1. *Disturbance by office noise*

The mean combined 'disturbance score' for the two offices was 3.6, which corresponds to a 'slight deterioration' in the respondents' concentration caused by the eight noise sources. In fact, 99% of respondents reported that at least one of the eight noise sources disrupted their concentration to some extent, and 82% reported that their concentration was impaired by three or more sources of noise. Finally, 57% of respondents indicated that at least one noise source caused a 'major deterioration' to their concentration. Table 1 shows the mean disturbance ratings for each of the eight noise sources, as well as for the three other distractors.

A one-way within subjects analysis of variance showed an overall significant difference between the ratings for the eight noise sources $F(7,609) = 53.98$, $p < 0.001$. These effects

Table 1. Mean ratings (and standard deviations) of noise sources and other distractors.

	Mean ratings
Sources of noise	
Combined noise score	3.60 (0.32)
Telephones ringing	3.73 (0.71)
Telephones left ringing	4.33 (0.74)
Printer noise	3.45 (0.68)
Typewriter / keyboard noise	3.10 (0.48)
Computer noise	3.24 (0.43)
Outside noise	3.06 (0.49)
Other people's conversations	3.99 (0.67)
Other people's phone conversations	3.82 (0.74)
Sources of distraction	
People passing through the office	3.58 (0.67)
Own phone conversation privacy	3.93 (0.79)
Own conversation privacy	3.68 (0.77)

(1 = major improvement/5 = major deterioration to concentration).

were followed up by Bonferroni-corrected paired comparisons and revealed that telephones left ringing at vacant posts were reported to have significantly more disruption to concentration than any of the other sources of noise, including telephones ringing ($p < 0.05$). Noise from telephones was reported to be significantly worse than the noise from computers, typewriters and keyboards, and noise from outside the building ($p < 0.05$). Disruption from printer noise was reported to be significantly worse than typewriters and keyboards, and noise from outside the building ($p < 0.05$). Disruption from other people talking in the background was reported to be significantly worse than the noise from printers, computers, typewriters and keyboards, and noise from outside the building ($p < 0.05$). Disruption from other people's telephone conversations was reported to be significantly worse than the noise from printers, computers, typewriters and keyboards, and noise from outside the building ($p < 0.05$). Finally, outside noise was reported to have significantly less disruption to concentration than any of the other sources of noise ($p < 0.05$), except typewriter and keyboard noise, and computer noise.

Table 2 shows correlations between the ratings of the eight noise sources and three other distractors, and the job category of the respondents. Significant, albeit modest, correlations were found between participant job category and annoyance from other people's telephone conversation, ($\rho = 0.241$, prob < 0.05), the combined noise rating, ($\rho = 0.352$, prob < 0.001), annoyance from telephones left ringing at vacant posts, ($\rho = 0.246$, prob < 0.05), people passing through the office ($\rho = 0.239$, prob < 0.05), and the thought that other people can overhear their conversations with colleagues ($\rho = 0.266$, prob < 0.05). The nature of the correlations was such that, the higher the respondents were in the organisation, the more disruptive these sources of noise were reported to be.

3.2. *Habituation to office noise*

Pearson product-moment correlation coefficients (r) were conducted to determine the strength of any relationship between the length of time employees spent in the office each day, the percentage of the time spent at their desk, and how long they had been working

Table 2. Pearson's ρ correlations ($n = 88$) among exposure factors, noise sources and other distractors

	Pearson's ρ correlations (listed by variable numbers)															
Variable	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.
1. Position in company (job category)																
2. How long in current office (months)	0.17															
3. Daily office hours (hours)	0.25[a]	0.29[b]														
4. Time spent at desk (% of day)	−0.26[a]	−0.01	0.28[b]													
5. Combined noise score	0.35[b]	0.00	0.13	0.03												
6. Telephones ringing	0.22[a]	0.03	0.21	0.06	0.59[b]											
7. Telephones left ringing	0.25[a]	−0.11	0.08	−0.11	0.64[b]	0.53[b]										
8. Printer noise	0.14	−0.07	−0.19	0.16	0.38[b]	0.05	0.09									
9. Typewriter/keyboard noise	0.15	0.26[a]	0.09	0.09	0.54[b]	0.12	0.10	0.42[b]								
10. Computer noise	0.07	0.00	−0.07	0.01	0.22[a]	0.10	0.18	0.06	0.10							
11. Outside noise	0.08	0.06	0.18	−0.09	0.31[b]	0.01	0.01	−0.11	0.22[a]	−0.07						
12. People passing through the office	0.24[a]	0.14	0.18	−0.12	0.39[b]	0.24[a]	0.26[a]	−0.06	0.13	0.11	0.25[a]					
13. Other's conversations	0.18	−0.09	0.19	0.05	0.57[b]	0.16	0.15	−0.04	0.15	−0.11	0.22[a]	0.35[b]				
14. Other's phone conversations	0.24[a]	−0.03	0.00	0.02	0.67[b]	0.19	0.28[b]	0.05	0.28[b]	−0.04	0.19	0.29[b]	0.57[b]			
15. Own phone conversation privacy	0.20	−0.02	0.21	−0.07	0.13	0.03	0.10	0.02	0.08	0.02	0.01	0.16	0.06	0.22[a]		
16. Own conversation privacy	0.27[b]	−0.04	0.17	0.06	0.15	−0.01	0.01	0.17	0.18	0.02	−0.07	0.14	0.13	0.14	0.71[b]	

[a]$p < 0.05$. [b]$p > 0.01$.

in their current office, with the ratings from the eight noise sources in the questionnaire, and the three other distractors.

Table 2 shows correlations among disturbances by the eight noise sources and three other distractors, and the three factors relating to the length of time exposed to the noise in the office. Only one significant correlation was found, which was between the time (in months) spent working in their current office and annoyance from keyboard and typewriter noise (i.e. the longer they had spent working the more disruption they reported, $\rho = 0.26$, $p < 0.05$).

The absence of any negative correlations, or indeed zero correlations, between the time spent in the office and the reported disruption from office noise suggests that respondents have not habituated to the noise in their office.

3.3. *Environmental satisfaction*

Verbal reports from respondents indicated that the spaciousness of the office (37%), ease of communications and access (36%), and friendliness (15%) were the most liked aspects of the offices. Distractions from various office noises (35%), lack of privacy (24%), poor lighting (15%), tatty furnishings (12%), ventilation and air-conditioning (7%), and desk arrangement (6%) were the most disliked aspects of the office.

Table 3 shows the mean estimated satisfaction ratings for each of the four suggested office 'improvements'. A one-way within subjects analysis of variance showed significant differences between the ratings for four improvements and their effect on respondents' satisfaction with their working environment $F(3,261) = 15.80$, $p < 0.001$. These effects were followed up by Bonferroni-corrected paired comparisons and revealed that the provision of quiet areas was rated significantly worse than all other solutions ($p < 0.05$).

Finally, when asked to rank each suggestion for preference, respondents favoured sound absorption and partitioning, followed by quiet areas, interview rooms and finally coffee areas. It is interesting to note that interview rooms and a separate coffee area were already allocated for employees' use in both offices.

3.4. *Improvements to job performance*

Verbal reports from respondents indicated that sound absorption and partitioning (40%) and quiet areas (19%) would be likely to offer some *improvement* to their job performance due to the reduction in noise. No respondents thought that sound absorption and partitioning would reduce their job performance, but 16% thought that quiet areas would do more harm than good and would be difficult to enforce. Out of the respondents, 23% reported that interview rooms already existed and 25% reported that a coffee area was provided. Clearly these facilities were either not widely known about or were simply not used.

Table 3. Mean ratings (and standard deviations) of improvements to office.

Improvements to office	*Mean ratings*
Sound absorption and partitions	2.16 (0.76)
Provision of coffee areas	2.47 (0.87)
Provision of quiet areas	2.93 (1.05)
Provision of interview rooms	2.24 (0.92)

(1 = major improvement/5 = major deterioration to environmental satisfaction).

4. Discussion

Overall, 99% of respondents reported that at least one of the eight noise sources caused a 'slight deterioration' in their concentration, with 82% of the sample reporting that three or more sources led to a slight deterioration. Furthermore, 57% of respondents reported that one or more noise sources caused a 'major deterioration' in their concentration. This prevalence of disturbance by noise in the present study is comparable to previous studies, with 54% reporting to be 'often bothered' (Sundstrom *et al*. 1994), and 35% 'greatly disturbed' (Nemecek and Grandjean 1971). In addition, the present study found no evidence for habituation to the deleterious effects; there were no significant negative correlations between time spent in the office and degree of disruption reported.

4.1. *Theoretical implications*

The findings of the present study indicate that telephones left ringing at vacant posts were rated to impair concentration significantly more than the other sources of noise in both offices. Indeed, this noise source was rated to be significantly more bothersome than disturbance from other people talking in the background. These results have a number of implications for current accounts of the irrelevant sound effect. At first consideration, the formulation by Salamé and Baddeley (1982) (i.e., that only speech can cause disruption) has difficulty in accounting for the reports of disruption by non-speech sounds. Indeed, the present results seem to be more in line with the changing state hypothesis advocated by Jones and his colleagues. In other words, the telephone and non-speech sounds in the offices met the criteria for changing state leading to reports of impairments to concentration.

It is not clear why telephones left ringing at vacant posts were perceived to be so disruptive. Respondents in both offices indicated that telephones left ringing at vacant posts impaired their concentration significantly more than the noise from telephones ringing per se. One possible explanation is that, in the former case, additional annoyance was caused by the fact that workers were not at their desks when they should have been. However, it may simply be that the duration of the disruption was greater in the case of the telephones left ringing at vacant desks.

The present study has a number of implications for the study of habituation to irrelevant sound. Although Banbury and Berry (1997) found that recorded office noise could be habituated to when performing a memory for prose task, the weight of evidence suggests otherwise (see Banbury *et al*. 2001). This position is supported by the present study, in that no evidence of respondents habituating to the noise in their offices was found. In fact, the reverse was observed—the one significant correlation that was obtained indicated that the longer respondents had spent in the office the more they reported disruption from typewriter and keyboard noise (although one needs to be wary of type 1 error when interpreting this result).

A number of explanations for the lack of effect of habituation can be put forward; specifically, a process of dishabituation, or locus of attention. Firstly, Banbury and Berry (1998) found that a relatively short period of quiet restored the interference from office noise. Thus, one possibility is that such periods of quiet may occur spontaneously throughout the working day, thereby reinstating the negative effects of office noise. Secondly, Tremblay and Jones (1998) found no evidence for habituation using a similar paradigm to Banbury and Berry, differing only in the locus of attention. Participants in the earlier study were asked to attend to the irrelevant sound in the habituation period,

whereas participants' exposure to the irrelevant sound was incidental (i.e., unattended) in the experiments by Tremblay and Jones. In the present study, office workers may not be habituating to the noise in their office because they are simply not attending to (i.e., ignoring) it.

4.2. *Implications for noise abatement in open-plan offices*

When asked to rate the effectiveness of a number of possible improvements to their office environment (from a reduction of noise perspective), the provision of enforced areas of quiet to allow uninterrupted work was rated the least popular. Although the reduction in the level of office noise to below the threshold of audibility is both impractical and prohibitively expensive (as well as seemingly unpopular with occupants), other methods can be utilized to reduce the disruption from a number of noise sources identified in the present study. Firstly, telephones can be diverted to a central answering service if they are left unanswered, and equipment noise can be appropriately quietened. Secondly, more care in the planning of the office area can be taken to ensure that those needing to work quietly are not located near noisy office equipment or co-workers.

Less obvious, however, is the reduction in the variability of the sound in line with the changing state hypothesis advanced by Jones and his colleagues. For example, Jones and Macken (1995), using auditory babble, have shown that the magnitude of the irrelevant speech effect can be increased if multiple voices are used. However, over six voices, the effects are greatly reduced, almost to a level similar to that seen in quiet. They argued that this is due to the voices becoming increasingly less discernible from one another, resulting in a lack of cues of segmentation. In other words, the sound no longer meets the criteria for changing-state. Jones and Macken postulated that they would expect that the noise from a smaller office to have a greater capacity to disrupt work than a larger office with more inhabitants, as the few sources of sound present do not mask each other. Indeed, Keighley and Parkin (1981) observed that the smaller the office, the more bothersome its noise climate was to its occupants.

Furthermore, Boyce (1974) found that the larger and noisier the office was, the more content its inhabitants were about the noise in their office. At first consideration, these findings have profound implications for noise abatement in the office because they suggest that attempts to reduce noise may exacerbate the problem rather than alleviate it. This is because disruption is related to the changing state properties of the sound; any reduction of some aspects of the background sound may make the remaining sound more discernible (by making the cues of segmentation more salient), thereby increasing the level of disruption. Indeed, Keighley (1970) found that distinctive or salient sounds were least acceptable to occupants. However, the use of sound absorbing materials on floors and suspended ceilings can dampen down the overall ambient sound level and make it less intelligible. By altering the acoustics of an office, it may be possible to reduce the cues of segmentation in this manner.

Alternatively, Jones and Macken (1995) suggested adding noise to reduce cues to segmentation. By adding a continuous noise signal, it is possible to mask most of the speech so that it becomes less audible and most importantly, they argued, the cues to segmentation become inaudible. This 'noise perfuming' (for a discussion see Northwood *et al*. 1979), seems very promising in theory, but when introduced into the office environment it has had indifferent results. Office inhabitants have been reported to mistake the 'hiss' of the concealed speakers for air conditioning and to complain about being too cold (Vischer 1989), or even go to great lengths to disconnect the system, even

when housed in metal ducting (Day 1969). Indeed, the literature pertaining to the efficacy of such systems is contradictory. Loewen and Suedfeld (1992) found that participants in masked office noise performed better those in unmasked office noise on a simple attention task. Research by Ellermeier and Hellbrück (1998) explored the role of signal-to-noise ratio in the irrelevant sound effect directly. They found that adding pink noise to the irrelevant speech signal produced a linear improvement in performance with decreasing speech-to-noise ratios. However, this effect was only manifest at signal to noise ratios greater than − 4dB(A), with levels of performance approaching that of quiet only at − 12dB(A). The implication of these findings is that levels of white noise masking capable of reducing disruption are impractical for use in offices.

In drawing the above implications, it must be remembered that the reports by the respondents in the present study were subjective reports on their perceived disruption from these sources of noise, and were *not* objective measures of performance. As such, it is important not to place too much emphasis on the findings, however helpful they may appear. Instead, the pressing practical need, coupled with the scarcity of work conducted in office and call centre settings, points to the need to research the problem of office noise in a more objective manner using robust psychological techniques and principles.

5. Conclusions

The present study has provided a useful support for the laboratory findings on the irrelevant sound effect and the utility of its application to work settings. The benefits of such an approach are manifold. Firstly, respondents' perceived deterioration in concentration in the presence of extraneous noise provides some quantification of the perceived cost of extraneous noise, both to the individual office worker and to the corporation as a whole. Secondly, using existing psychological theories it is possible to understand why particular office sounds disrupt particular office tasks. Thirdly, with such knowledge the efficacy of potential solutions to the problem of office noise, specifically the acoustic treatment of office ceilings and the provision of low levels of white noise, can be evaluated objectively.

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