

EFFECTS OF SOUND IN OFFICES – SUBJECTIVE EXPERIENCE VS. OBJECTIVE ASSESSMENT

Pierre Chigot

Concept Developer - Modern Office, Ecophon, Hyllinge, SE - 260 61

E-mail: pierre.chigot@ecophon.se

Working conditions in the office are gaining attention, both in regards of the interaction of the office worker with the psycho-social environment and of the built environment, out of which sound is an important characteristic. Using criteria of specificity and applicability to the profession of facilities management, a selection of abstracts of studies addressing the effects of sound in offices and recorded in PsychInfo is made. Eleven abstracts are reviewed and discussed from the point of view of their approach, whether it is the assessment of sound itself, or the assessment of the effects of sound. Typical lacks afferent to each approach are discussed in regards of the usability of the abstract in supporting the building and management process of offices. The correlation between subjective experience and objective assessment of sound in offices is discussed, out of a categorised overview of the abstracts. Few of the abstracts use standardised assessment strategies. This impairs comparison between studies and their applicability to the task of accommodating office workers. Finally alternative acoustical concepts and measurement units to better assess the effects of sound on office work are proposed.

Key words: sound, noise, office, office design, facilities management

INTRODUCTION

Access to scientific research in order to support the decision making in the choice of building elements and systems is limited to the use of abstracts.

Turbulent business climate, adoption of new technology and new work patterns put raised expectations on the office. The adoption of innovative, open workplace design puts the acoustical environment in focus: a single sound source (speech, telephone ringing or office machine) can impact on a large number of workers at a time. The objective with this paper is to investigate to what extent there is a correlation between objective measurements and self-rating in the use and experience of office premises from the point of view of sound. Are measurements through tests and observations of office workers paralleled by the same individuals' perception of the sound environment? In other words, does the action/reaction law apply to offices? This is of particular interest for the professionals dealing with the accommodation of office workers.

The conclusions are important in the perspective of integrating research in the building process and, by that, help professionals to improve working conditions for the end-users.

The purpose of this review is to identify in what way results of office focused research can be applied within the field of Facilities Management.

By using abstracts here, the situation of the building- or refurbishment process of an office is simulated. Scientific research as a support to decision making (sometimes called "evidence based design") is mostly conveyed by summaries and overview matrix, such as in the case of GSA (2001). The intention with such tools is to provide decision-makers with an overview of scientific studies and case studies addressing in what way building- or work pattern characteristics affect office employees. Unfortunately, research on the interaction between physical and psychosocial environment is complex and leads seldom to linear correlation. As pointed out by Marans and Spreckelmeyer (1982), the objective effects of sound do not necessarily parallel the subjective experience of the same sound. This can be of critical importance in the planning, design and management process of offices. On the one hand, end-users express traditionally an opinion. They make a judgement on an existing situation or on what they can foresee of an alteration of their working environment (subjective experience).

On the other hand, designers and facilities managers will to a large extent relate their decisions to quantifiable features (objective assessment). By this way, they can easier refer the planned alteration of the environment to comparable studies or projects. These different approaches make communication difficult between users and professionals. Moreover, the discrepancy – sometimes contradiction - between the respective results of the two approaches might lead to inappropriate decisions in the accomodation of work.

In what way does a study of the concordance or discrepancy between subjective experience and objective assessment help in understanding the fundamentals of sound in offices? Hopefully, new insights in that field will contribute to increase the quality of office premises.

Method

Three successive searches were conducted in week 4/2002 in PsychInfo using the following key words: “office + environment + indoor + noise” respectively “office + noise”

It resulted in 87 abstracts of journal articles and books dealing with the topic. A read-through of the material with the specific intention of finding papers that dealt with “the effects of noise on office work” reduced the material to 36 posts. A selection of abstracts was made, by discarding records addressing specialised office settings were a main task, often computerised, is dominant under the working day. By eliminating studies dealing with for instance air-traffic control or data processing, the sample reflects more traditional office settings, where a complex mix of activities are taking place under a day. A final selection using the criteria “strict relevance to «noise in offices»” and “use of both subjective and objective assessment of the effect of sound” led to 11 studies. They are discussed below, from the point of view of their usability (itself dependant on reliability and validity) in supporting the decision making under the planning, design and management of offices.

A. ABSTRACTS REVIEW

As a consequence of the development of office landscapes during the 50'es and 60'es in Western countries, numerous studies have been conducted on the effects of sound in offices, regarding both sound from machines or equipment and sound from the presence of several workers in the same room. Some studies address the issue by specifically asking office workers to rate and judge the sound environment, which we call “Assessment of sound”. Other studies address the effects of sound by looking at the incidence of sound on work characteristics, performance or well-being both subjectively and objectively. They propose an indirect approach to the assessment of sound, where sound is looked at through its influence on activities (mental and physical), emotional states or behaviour. We call it “Assessment of the effects of sound”.

A.1. Assessment of sound

Primarily these studies' validity can be affected by the fundamental choice of isolating the sound environment from other environmental factors, such as light, temperature or airflow. The evaluation of the acoustical environment through a questionnaire addressing sound, as in Tang (1997), might capture other negative elements of the working environment such as dissatisfaction on job content.

On the other hand, focusing on sound and its perception by the office employees can be a necessity, due to the complexity of the sound environment in offices, where key sound parameters (reverberation time, sound propagation) can vary significantly in the same large room.

A.1.1. Bias

In some of the studies, office workers participate actively to the investigation, like Spieth (1956). This puts requirements on study design to secure that no Hawthorn effect is found. Study design including only questionnaires, as in Tang (1997), might be biased as it provides opportunities to the office workers to express complaints or thankfulness regarding other elements than sound. Also, study design where office workers are actively involved might require control to avoid bias. For instance, Spieth (1956) would gain to be repeated with a measurement of annoyance at a control group passively submitted to the identified sound pressure thresholds.

A.1.2. Metrics

Although they are based on standardised acoustical measurement procedures, the presentation of the material is weakened by the use of non-standardised, often imprecise terminology, such as “noisiness” (Beranek, 1956). This can partly reflect the lack of metrics by which to describe qualitative aspects of sound in rooms. Comparison of objective measurements over time with perceived characteristics of the sound environment (“noisy”, “loud”...) indicates that duration plays a role on the judgement of the acoustical environment. The continuous aspects of the sound environment (equivalent sound pressure level) seem to correlate better with the subjective judgement (Tang, 1997). Also, studies show a convergence of some noise characteristics. Beranek (1956) identifies for instance a strong correlation between "noisiness" and "speech interference level" indicating that the perceived disturbance of sound would be linked to its speech contents. Furthermore, the same study questions the ability of the psycho-acoustic loudness to reflect an overall judgement on the sound environment in the office, whereas there would be a strong correlation between loudness level and perceived “noisiness”. Obviously, the validity of sound assessment studies is highly dependent on the thorough analysis of the noise characteristics, mainly spectrum characteristics and changes over time. This is based on the assumption that the metrics and subjective perception will vary depending on the frequencies. Spieth (1956) suggests that annoyance at respective frequency parallels the response of hearing functions reflected in the loudness rating. This study partly questions Baranek’s, assumed that “annoying” and “noisiness” would reflect the same characteristics of the sound environment.

The integration of studies on “Assessment of sound” in the building and management process of offices requires obviously a thorough understanding of acoustics. The lack of appropriate general metrics and measurement procedures can make the interpretation of the results difficult for the designer or the facilities manager. Moreover, although the focus on sound might be a way to overcome the complexity of the indoor environment in offices, the risk of bias should be carefully taken in account.

A.2. Assessment of the effects of sound

Obviously, such studies are not looking as deeply in acoustics as studies assessing sound. Nevertheless some indications on the sound environment are needed to not weaken the usability of the study at large. Sundstrom (1982) omits to mention in the abstract the objective measurements of the acoustic environment, indicating that sound is used as a stressor, like any other, more than for its specificity.

The assessment of the effects of sound provides a wider frame for assessing the long-term effects of sound in offices. Jackson (1999), for instance, investigates mental workload and fatigue as dependent variables. The disadvantage can be the resulting complexity of the study design. The demands it puts on co-ordination of disciplines and operations to be conducted on the sample can question the reliability and, by that, the usability of the study. This applies in particular to Evans (2000). Furthermore, the wide range of variables used in the different

studies is reflected by the unclarity of definitions. For instance, Loewen (1992) establishes a distinction between arousal and perceived stress that others Evans (2000) do not make. The wide range of variables used in the different studies is reflected by the unclarity of definitions. For instance, Loewen (1992) establishes a distinction between arousal and perceived stress that others Evans (2000) do not make.

Improved understanding of the situation of the office worker tend to integrate multiple factors in the assessment of the environment: outdoor view (Young, 1979) air quality (Klitzman, 1989) or illumination (Veitch, 1990). The scope of factors can be enlarged to include psychosocial aspects of work. These are used as dependent variables, like job satisfaction (Sundstrom, 1994) or on collaborative skills and interpersonal functioning (Mathews, 1975).

The contradictions that are subjacent in the reviewed abstracts' conclusions (whether they are discrepancy between subjective experience and objective assessment or between subjective evaluations only) reflect the complexity of the office environment, especially in the interaction between the physical and the psychosocial environment.

A.2.1 Sampling

For obvious practical reasons, young subjects (undergraduate students mostly) are sometimes chosen to perform tests addressing office work (Loewen, 1992, Veitch, 1990, Willner, 1986). The age of the subjects and the lack of reference to office tasks can affect the validity of the study and the pertinence of the conclusions. In studies where task performance is measured, potential intervening variables, like skill level or experience of work in noisy environment, are not satisfyingly discussed, such as in Loewen (1992). Sometimes, as in Jackson (1999), neither the sampling nor skill level of the subjects is mentioned, complicating the use of the study.

A.2.2. Time frame

The duration of the investigation seldom reflects the situation of the office worker. Time frame of exposure is particularly important when coping capacity with continuous sound, such as sound masking, is investigated (Loewen, 1992). As artificial background noise constitutes a supplementary environmental load, study design should be accommodated consequently.

Psychosocial factors related to long-term changes have been assessed in before-and-after move/refurbishment studies (Brookes, 1972; Sundstrom, 1982; Sundstrom, 1994). Brookes (1972) suggests for instance that there would be a discrepancy between the subjective judgement on architectural quality and the assessment of physical factors' impact on the office environment. Sundstrom (1982) indicates that the personal history of the office worker (former occupants of walled offices) influences satisfaction with privacy while the perception of noise itself was not affected. The question is to what extent the time factor that is subjacent to both studies (reshaping of the environment (Brookes) and move (Sundstrom) can justify the discrepancy. This asks for a further understanding of the reference frames used in the judgement of office environments by workers: are expressed expectations coherent? Are all characteristics judged and evaluated in regards of the same reference environment?

Furnham (2002) and Veitch (1990) suggest that personal characteristics such as introvert/extrovert traits can be intervening variables in the perception of effects of sound. A trend suggests that there would occur an inversion of performance when shifting from low to high sound level (Veitch, 1990), although this single study is not sufficient to see if personal characteristics can justify the discrepancy.

Kjellberg (1996) proposes that the necessity of the noise and control of the source would determine the level of annoyance and by that influence the match between subjective experience and objective assessment of the effects of sound. Specific aspects of control are also addressed in Willner (1986), where it is suggested that habituation to the negative impact

of sound on cognitive processes can be achieved, assumed that an intermittent quiet period is offered to the subjects. This abstract is not sufficient to see if habituation and learning strategies could be altered over time. On the other hand, Evans (2000) indicates that realistic duration of three hours can be achieved. The resulting inconvenient is the complex and extensive analysis of the recorded sound data, explaining the lack of information on the objective characteristics of the sound environment in the abstract.

B. CORRELATION BETWEEN SUBJECTIVE EXPERIENCE AND OBJECTIVE ASSESSMENT OF THE EFFECTS OF SOUND

The discrepancy between between subjective experience and objective assessment of sound as identified earlier in Beranek (1956), Tang (1997) and Spieth (1956) is also found here. A study like Jackson (1999) states that “irrelevant speech appeared to increase false alarms and completion rates. Subjective workload ratings were higher in the irrelevant speech conditions”. This illustrates a negative correlation (a mismatch) between the effect of the environmental load (irrelevant speech) on completion rate of the proposed exercise (objective assessment) and perceived workload rating (subjective experience). This can reveal the office worker’s adoption of a coping strategy (Marklin, Holmberg, 1999), by which the environmental stressor “speech” leads to an acceleration in the work, to the detriment of quality. Still, according to Jackson’s (1999) abstract, the correlation seems to be positive overall (see Table 1).

The same negative correlation can be found between different items of subjective experience. Evans (2000) concludes his abstract saying, “although participants in the noise condition perceived their work setting as significantly noisier than those working under quiet conditions did, the groups did not differ in perceived stress”. This suggests a discrepancy between two subjective experiences of the effects of sound (perceived noisiness and perceived stress), although the overall correlation is not possible to tell from the abstract.

On the other hand, correlation can occur for certain variables. For instance, disturbance parallels dissatisfaction with the environment and the job, but does not parallel performance (Sundstrom, 1994). Other studies, like Kjellberg, (1994), indicate that the cause of noise correlates stronger with annoyance than it does with distraction (attention loss). In Veitch (1990), the opening towards personality aspects of the office worker are interesting, and could be enlarged to reactional tendencies under noise exposure, such as motivation and collective aspects.

B.1. Categorisation

Indexing of research is often mentioned as a necessity when it comes to its integration in the building process. This is probably motivated by the need of quick access to information, and the opportunity to parallel a specific issue with a study addressing the same or a similar topic. Indexing requires that a single descriptive word is found, helping to accurately and quickly point out a limited amount of abstracts to be used. This helps to conceptualise the problem or issue to be decided upon, facilitating the communication with other parties involved. Out of the sampled abstracts, following categories of effects can be identified when it comes to the assessment of the effect of sound in offices. These categories reflect or a subjective experience or an objective assessment of the effects of sound in offices.

Subjective experience: Noisiness, Loudness, Arousal/stress, Attention, Disturbance/annoyance, Privacy, Control, Perceived productivity

Objective assessment: Cognitive performance/memory, Behaviour alteration

Table 1 – Overview of the eleven abstracts according to the correlation between objective assessment and subjective experience of the effects of sound

Abstract	Category	Sample	Independent variable(s)	Objective assessment	Subjective experience	Comment	Subjective experience / Objective assessment correlation
Tang, 1997	Noisiness, loudness	26 air-conditioned landscaped offices		Sound level	Human auditory sensation (Loudness?)	L _{Aeq,T} = 5 min correlates best with human auditory sensation.	+
Beranek, 1956	Noisiness, loudness	190 Ss		Loudness level (not loudness)	Speech interference level	Linear relation	+
Spieth, 1956	Noisiness, loudness	Non-specified	Habitude to office noise	Adjusted noise level	Adjustment of threshold of annoyance	15 dB lower threshold for non office workers	+/-
Loewen, Suefeldt, 1992	Arousal/stress	45 undergraduate volunteers	No-noise	Performance	Least disturbed and stressed	Performed best on a measure of cognitive complexity	+
	Arousal/stress		Masked-noise	Performance	Felt more aroused but less disturbed or stressed	Performed better than those in the unmasked condition on integrative complexity/simple cognitive task	-
Guski, 1975	Arousal/stress	202 office workers	White noise ranging from 45 to 110 db, and in quiet	Sound pressure level Performance	Experienced situation	Subjective experience of noise affects the performance significantly more than the actual noise level	-
Jackson, 1999 (Study 2)	Attention	Unspecified	Effects of irrelevant speech on performance of a real-world verbal task (computer editing task)	Focused attention: misspelled words, homonyms, and spoilers (miscellaneous words)	Mental workload	Main effects of noise were found on two performance measures and on subjective workload Subjective workload ratings were higher in the irrelevant speech conditions	+
Sundstrom, 1982	Privacy	70 employees at 4 job levels in a large corporation	Questionnaire on their office environments 6 mo before and 6 wks after moving from a conventional to an "open-plan" office	Grade of enclosure	Satisfaction with communications, Perceptions of noise, satisfaction with privacy	Neither satisfaction with communications nor perceptions of noise changed after relocation, but satisfaction with privacy declined among former occupants of walled offices	+
Veitch, 1990	Control	48 male and 52 female Ss (aged 17-20 yrs)	Illumination and office noise	Reading comprehension	Rotter's Internal-External Locus of Control Scale	Ss with external locus of control (LOC) significantly outperformed those with internal LOC in low noise; the trend in high noise was the reverse, although the latter trend did not reach significance.	
Kjellberg, 1996	Disturbance, annoyance	439 persons (aged 17-65 yrs; 292 women and 147 men) working in offices, laboratories, or industries		Sound level, sound source type	Annoyance, distraction	Annoyance was found mainly to be related to sound level, self-rated "necessity" of the noise, hearing status, and gender. Distraction was most strongly related to degree of self-control of the noise and noise predictability.	+/-
Willner, 1986	Cognitive performance	30 female undergraduates (aged 19.6-33.5 yrs)	Memory, learning	Memory bias	Mood, tension	Exposure to loud, uncontrollable noise caused a substantial increase in the proportion of negative trait words recalled from the 2nd list and a worsening of mood, particularly an increase in tension.	+
Evans, 2000	Behaviour	40 female clerical workers	3-hr exposure to low-intensity noise designed to simulate typical open-office noise levels	Urinary epinephrine, norepinephrine and cortisol levels, motivation, posture adjustments	Perception, perceived stress	Although participants in the noise condition perceived their work setting as significantly noisier than those working under quiet conditions did, the groups did not differ in perceived stress	+/-

B.2 Discussion

Aware of the fact that the validity can be affected by the fundamental choice of isolating the sound environment from other environmental factors, this sample provides a scope when it

comes to correlation between subjective experience and objective assessment. Six abstracts out of eleven in the present review present or suggest a concordance between the way effects of sound are perceived and the actual objective measurements that can be made to describe them. Moreover, three abstracts do not provide enough information to evaluate that correlation. Anyway, there seems to be no simple, linear correlation between objective assessment and subjective experience of the effects of sound in the office. This suggests that workplace adjustments can be difficult to conduct in harmony between the end- users (subjective experience, perception) and external design consultants (objective assessment, measurement).

Few of the abstracts used standardised assessment strategies. This impairs comparison between studies, and in some way the benchmarking of the knowledge and insights found in each. Even fewer abstracts reflect realistic, continuous conditions where office work is more than individual performance. In regards of the expectations put presently on offices when it comes to support collective processes and knowledge spreading, it is surprising to see that interaction and collective performance are not more used as dependant variables when it comes to the effects of sound. After all, office work is intimately related to the capacity of organising and managing people towards collective goals, in interaction with the workplace. This could be more taken into account in the reviewed abstracts.

CONCLUSION

This review stresses out the need of higher understanding of the psychosocial processes occurring in offices and their impact on the perception of sound. Beyond traditional acoustical concepts and measurement units, it suggests that alternative approaches are needed to better assess the effects of sound on office work. Three main fields can be identified:

- influence of the acoustic environment respectively psychosocial environment in the achievement of the objectives of a company or an organisation: to investigate in what way workplace management strategies can influence the behaviour of office workers and their perception of the workplace. Integrated field studies conducted under a realistic duration could bring knowledge regarding individual vs. collective cognitive processes, knowledge building and collective behaviour.
- assessment strategies, measurement procedures and metrics that better correlate to the subjective experience of indoor factors: laboratory studies aiming at defining/standardising objective assessment of sound and sound perception in order to increase the accuracy and reliability of studies addressing the effects of sound and to facilitate comparison between field studies
- basic elements of design and usage practices supporting noise control in offices: laboratory and field studies on the outcome of different noise control measures in the overall improvement of the acoustical environment in offices. This would also contribute to increase the understanding between office workers and workplace designers.

Such efforts could support beneficially the design and management of offices.

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