OBJECTIVE ACOUSTICAL EVALUATION OF HEALTHCARE OFFICE FACILITIES

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1 Introduction

The work reported here evaluated the acoustical quality of healthcare office facilities by way of physical measurement. The objectives were to determine the quality of the environments, the relationships of design features to it and how to design better environments?

2 Site descriptions

The study sites consisted of 17 healthcare office facilities on 30 floors in 17 buildings. In these, administrative staff employed by four local health authorities work. The floors were generally 2.7-m high from the carpeted floor to the suspended acoustical-tile ceiling (SAC). All buildings were mechanically ventilated. On five of the floors, professionally-designed sound-masking systems were installed in parts of the floors, and were in operation during testing. The spaces studied in these facilities included private offices (PO), shared offices (SO), open-plan offices (OPO), meeting rooms (MR), breakout and telephone rooms (B/TR) and lunchrooms (LR). OPOs varied considerably in size, shape and the number of cubicles/workstations. They had workstations arranged in various configurations, some separated by barriers, some separated by partial width or height barriers with heights varying from 1.2 – 1.8 m. In many cases these were located in cubicles of various configurations surrounded by partitions with heights varying from 1.5 - 2.0 m. While exact details of the construction of many of the internal partitions (IP) separating spaces in the facilities were not known, evidently many were of conventional gypsum wall board, metal-stud, usually with glass-fiber insulation, in some cases of modular construction as opposed to built-in-place. Some IP, particularly around enclosed offices, meeting and breakout rooms had glass sections; in one or two cases the entire IP was glass. Some IP rose to the ceiling slab, but many stopped at the SAC. Entrance IP contained hinged or sliding, solid wooden doors which closed against a jamb at the tops and sides, but with a gap of 0.5 to 2 cm at the bottom; in one or two cases, there was a door sweep.

3 Acoustical measurements

The following acoustical measurements were performed:

• back-ground noise levels: these were measured throughout the occupied spaces (BNLo); levels were measured in octave bands from 16-8000 Hz; from these total, A-weighted and NCB levels were determined.

• in selected unoccupied spaces the following parameters were measured in 125 to 8000 Hz octave bands:

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- Reverberation time (RT): average EDT and T20 values were determined from average impulse responses measured between 2 and 4 pairs of source and receiver positions. Values relevant to verbal-communication quality (vcq) were calculated by averaging values at 500, 1000 and 2000 Hz;

- Speech levels (SL), Speech Intelligibility Index (SII): sound-pressure levels generated by an omnidirectional source of pre-calibrated output-power levels were measured at selected receiver positions in the same and/or in adjacent spaces. From these, the source powers and the output powers of talkers using ‘normal’ voice level (SLn) [1], realistic octave-band and total, speech and A-weighted SLs (SLAn) were calculated. At each receiver position, the source-receiver distance, speech levels, EDTs and BNLo levels were used to calculate normal-voice speech-intelligibility indices (SIIn) [1, 2]. These were used to rate the speech intelligibility or speech-privacy quality at the receiver;

- Sound reduction with distance doubling (DL2): in 33 selected open-plan offices, DL2SA was determined from speech and A-weighted sound-pressure levels measured at available and convenient distances of 1 to 30 m from a calibrated omni-directional loudspeaker along lines crossing workstations;

- IP noise isolation (NI): the NIs of 99 selected IPs were measured as the difference between the sound levels on the source and receiver sides; from these Noise Isolation Class (NIC) values were determined.

4 Results

• Variation of BNLo with room type: Figure 1 shows the variation by room type of BNLo. Average noise levels were similar in SO, OPO and LR (LAtot = 50-53 dBA; NCB 45-50), and were slightly higher than in PO, BR/TR and MR, which were similar (LAtot = 45-47 dBA; NCB 40-43), as expected given the number of occupants in each type of room.

• Variation with RT with room type: Figure 2 shows the variation of average EDT and T20 with room type. All

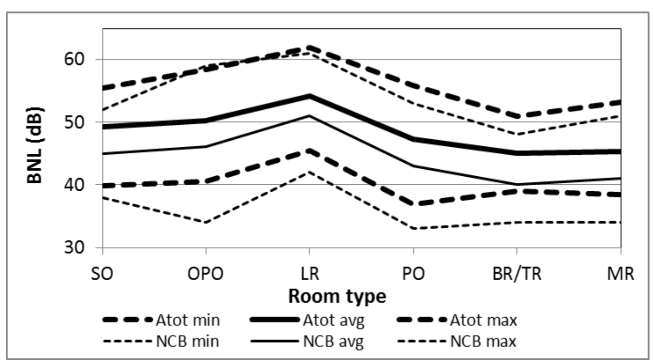

Figure 1: Variation by room type of the overall BNLo.

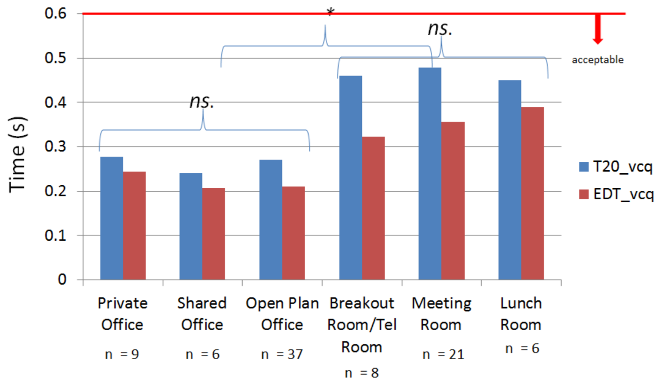

Figure 2: Variation of average EDT/T20 with room type.

average RTs were low – less than 0.5 s. Average RTs were similar in PO, SO and OPO (EDTvcq = 0.2-0.25 s; T20vcq = 0.24-0.28 s), and were slightly higher in BR/TR, MR and LR, which were similar (EDTvcq = 0.32-0.39 s; T20vcq = 0.45-0.48 s), The results are explained by the room volumes and shapes and, for OPOs, the high density of furnishings.

- Variation with room type of speech intelligibility, privacy: Figure 3 shows the variation with room type of the average SIIn at receiver positions 1 m from the source within one room or OPO workstation (SIIn,1m) and of the normal-voice speech privacy at the workstation in an adjacent room or OPO nearest to that containing the source (SIIn,nws). Excellent/acceptable speech intelligibility corresponds to SII > 0.75 / 0.6. Acceptable speech privacy corresponds to SII < 0.2. In all room types, speech intelligibility is acceptable (e.g., in SO, LR) or excellent (e.g., in PO, OPO, BR/TR, MR). Speech privacy is acceptable in PO, BR/TR and MR, but unacceptable in SO, OPO and LR. In the former rooms the receiver is separated from the source by an IP, in the latter there is no IP. Clearly acceptable speech privacy between a source and a receiver requires them to be separated by an IP.
- DL2SA: In the 33 cases measured, DL2SA varied from 5.9 - 14.0 dBA/dd (average = 9.0 dBA/dd; standard deviation = 2.1 dBA/dd). ISO 3382-3 standard [3] suggests that values above 11 / 9 / 7 dBA/dd represent 'excellent' / 'good' / 'fair' conditions for speech privacy, respectively, and values below 7 dBA/dd represent 'poor' conditions. If correct, then 2 (6%) / 11 (33%) / 13 (39%) / 7 (21%) of the OPOs measured have 'excellent' / 'good' / 'fair' / 'poor' conditions, respectively. In OPOs, conditions for speech privacy – and DL2SA –

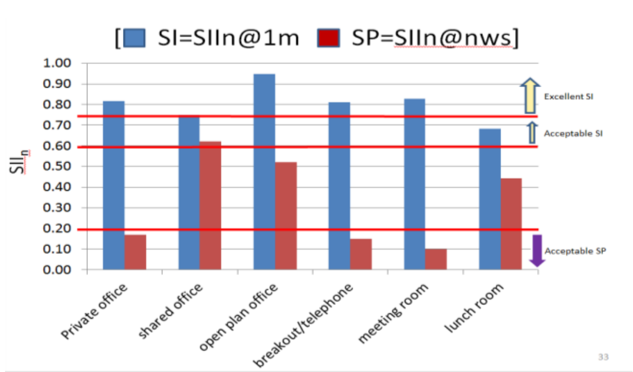

Figure 3: Variation with room type of SIIn,1m and SIIn,nws.

increase with lower ceiling height, sound-absorptive floors and ceilings, increased room lateral dimensions and increased height of partitions separating workstations, among other factors. All OPOs measured had low ceiling heights and absorptive ceilings and floors; partition heights, and room shapes varied.

- The noise isolations of the 99 IP varied from NIC 18-41. Structural concrete or brick walls had the highest values, a glass partition with doors with bottom gaps had the lowest.
- Empirical NIC prediction model: In preparation for developing NIC prediction models using multi-variable regression, all IPs were categorized with respect to the following features: absence or presence of a door; IP rises to SAC or to structural slab; percentage of glass; sliding or hinged door; absence or presence of door sweep; non-structural or structural IP; absence or presence of cavity insulation; modular or built-in-place construction; absence or presence of a flanking path. The only variables that were statistically significant in the analysis were: absence (0) or presence (1) of a door, non-structural (0) or structural (1) IP, absence (0) or presence (1) of cavity insulation, and modular (1) or built-in-place (0) construction. In particular, IP rises to SAC or to structural slab and percentage of glass in partition were not statistically significant. The optimal regression model, which explained 65% of variance, was:

$$\text{NIC} = 31.0 - 8.2\ \textit{door present} - 2.0\ \textit{modular construction} + 7.7\ \textit{structural partition} + 2.2\ \textit{insulation present}$$

According to this model, on average, a non-structural, non-modular IP without insulation or door has NIC 31. The presence of a door and of modular construction reduce the partition noise isolation by NIC 8.2 and NIC 2, respectively. Structural construction and cavity insulation increase noise isolation by NIC 7.7 and 2.2, respectively. Surprisingly, constructing the IP to rise to the structural slab instead of to the SAC did not make a statistically-significant difference in the noise isolation.

5 Conclusion

The results of this objective evaluation provide valuable information on the contributions of design features to workplace quality, and how to optimize it.

Acknowledgments

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