# ISO 3382-3 Round Robin test in an open-plan office

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**Abstract**

Our purpose was to experimentally determine the precision of ISO 3382-3. An accuracy experiment was set up in an open-plan office where nine independent participants independently conducted the measurements according to ISO 3382-3. The reproducibility standard deviations, $s_R$, were 0.3 dB, 1.1 dB, 0.6 dB, 16%, and 21% for spatial decay rate of speech ($D_{2,S}$), A-weighted *SPL* of speech at 4 meter distance ($L_{p,A,S,4m}$), A-weighted *SPL* of background noise ($L_{p,A,B}$), distraction distance ($r_D$), and comfort distance ($r_C$). The values depended mainly on between-laboratory differences while within-laboratory differences were marginal. Our findings benefit the development of standard revision and planning of future accuracy experiments.

**Keywords:** open-plan offices; room acoustics; measurement uncertainty; precision, accuracy.

## 1 Introduction

International standard ISO 3382-3:2012 [1] describes the method for measuring the room acoustic quality of open-plan office. The method focuses on spatial decay of standard speech unlike ISO 3382-2 [2], which can also be applied in open-plan offices, but it is limited to reverberation time. It describes the temporal decay of sound in a fixed position. ISO 3382-3 is under revision in ISO TC 43 SC 2 WG 34. Currently, the main reported single-number quantities (SNQs) of the revised draft standard, ISO FDIS 3382-3:2021 [3], are

- spatial decay rate of speech in decibels ($D_{2,S}$),
- A-weighted *SPL* of speech at 4 meter distance in decibels ($L_{p,A,S,4m}$),
- A-weighted *SPL* of background noise in decibels ($L_{p,A,B}$),
- distraction distance in meters ($r_D$), and
- comfort distance in meters ($r_C$).

Lack of knowledge related to measurement uncertainty was the most important technical reason to begin the revision of ISO 3382 in 2018. Operator's path choice is known to affect the measurement result but there is very little knowledge, how largely. Measurement uncertainty of a single measurement is possible to assess using the principles of GUM [4]. However, GUM cannot consider the effect of operator's choices on results since there is no mathematical expression for them. Operator is given a freedom to choose the measurement path and source & receiver positions in ISO 3382-3.

Increasing number of international standards report the precision based on accuracy experiments (AE) also known as Round-Robin test, inter-laboratory test, or inter-comparison test. AEs are conducted according to the rules of ISO 5725 [5, 6] and the reported quantity is the reproducibility standard deviation (SD).

Hongisto et al. [7] conducted the first AE of ISO 3382-3 to fill the gap in knowledge. The purpose of this paper is to summarize their findings.

## 2 Materials and methods

An AE was arranged in an open-plan office involving 12 workstations in Turku, Finland (Fig. 1). ISO 5725 suggests that 8–15 participants should participate an AE. Therefore, 12 participants were invited to join. Finally, nine participants conducted the measurements according to ISO 3382-3 and provided the required data to the AE managers. Each participant conducted the measurement independently during different days.
Each participant conducted the measurement in two Settings A and B having different screen heights (117 and 147 cm, respectively) between workstations (see dashed line of Figure 1). Manager of the AE changed the screen heights. Since the office was relatively small, we advised the participants to choose a single path and then to conduct the measurement to both directions along the same path in both Settings. In both Settings, the reported value was the mean of the two opposite directions.

Outlier analyses revealed that 1–2 participants reported deviations from the mean of the other participants. Therefore, the reported results are based on either seven ($L_{p,A,S,4m}$, $r_D$, and $r_C$) or eight ($D_{2,S}$ and $L_{p,A,B}$) participants.

The main outcome of the work is the reproducibility SD, $\boldsymbol{s_R}$ [dB]. It is defined by

$$s_R = \sqrt{s_r^2 + s_L^2} \tag{1}$$

where $s_L$ [dB] is the between-laboratory SD, and $s_r$ [dB] is the repeatability SD. The former is based on the values reported by the seven or eight participants of the AE. The latter is based on five repeated measurements along the same path conducted by a single participant. It is expected that $s_L > s_r$, because $s_r$ depends only on the variations in the physical measurements while $s_L$ depends also on path choice.

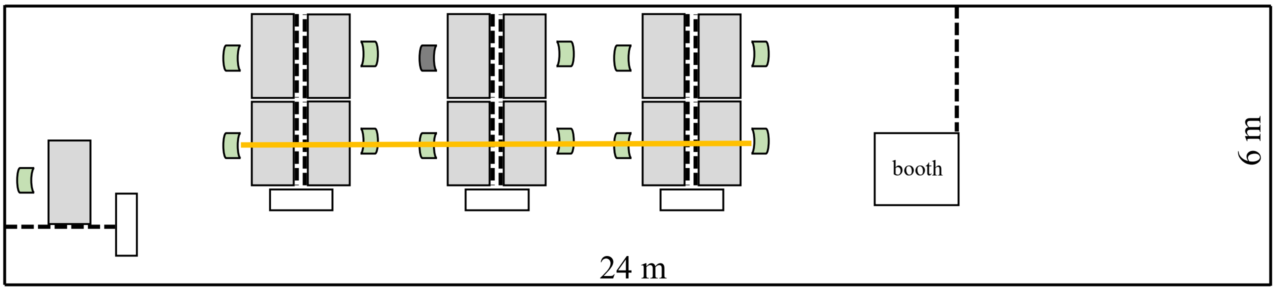


Figure 1 – Principal layout of the open-plan office. Orange line represents the most usual measurement path.

## 3 Results

The mean and standard deviation in Settings A and B is shown in Table 1. The single-number values reported by the participants in Setting B are visualized in Fig. 2. Setting A is not shown due to very similar values. The main outcomes of the AE are shown in Table 2. The values are the maximum SDs of either Setting A or B. That is, the larger value was chosen to avoid any underestimation of precision.

Table 1 – The mean ($M$) and the SD ($s_L$) over the N participants in Settings A and B.

| Setting | Quantity | $D_{2,S}$[a] | $L_{p,A,S,4m}$[b] | $L_{p,A,B}$[a] | $r_D$[b] | $r_C$[b] |
|---|---|---|---|---|---|---|
| A | $M$ | 3.7 | 52.4 | 37.9 | 15.3 | 16.8 |
| A | $s_L$ | 0.3 | 0.9 | 0.4 | 2.3 | 2.8 |
| B | $M$ | 3.7 | 52.5 | 37.6 | 14.7 | 16.8 |
| B | $s_L$ | 0.3 | 1.1 | 0.6 | 1.5 | 3.4 |

[a] N=8. [b] N=7

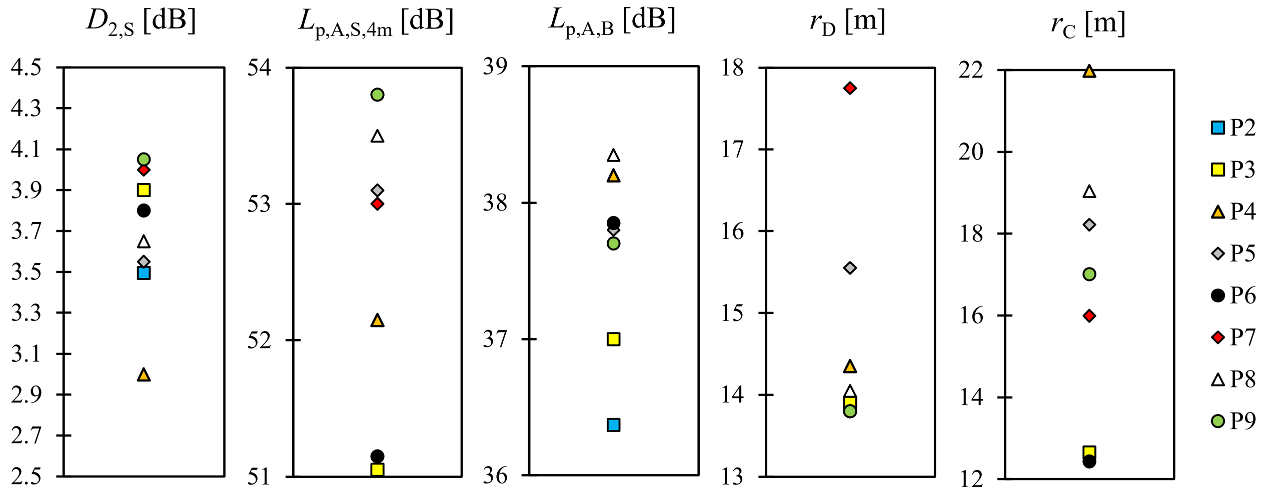


Figure 2 – Single-number values reported by the participants in Setting B. Each value represents the mean of two single-number values obtained in two opposite measurement directions along the same path.

Table 2 – The main results of the AE, i.e., between-laboratory SD ($s_L$), repeatability SD ($s_r$), and reproducibility SD ($s_R$).

| Single-number quantity | $s_L$ | $s_r$ | $s_R$ |
|---|---|---|---|
| $D_{2,S}$ [dB] | 0.3 | 0.03 | 0.3 |
| $L_{p,A,S,4m}$ [dB] | 1.1 | 0.04 | 1.1 |
| $L_{p,A,B}$ [dB] | 0.6 | 0.19 | 0.6 |
| $r_D$ [%] | 15 | 3.9 | 16 |
| $r_C$ [%] | 20 | 3.7 | 21 |

# 4 Discussion

Our study summarizes the first AE concerning international standard ISO 3382-3. More detailed information is found in Ref. [7]. We believe that our results represent the precision of revised ISO 3382-3 well and our results can be applied in the revision of ISO 3382-3 standard.

However, further research is needed because ISO 5725 recommends that AEs should preferably be conducted using two extreme levels of each SNQ. This means that the AE should involve at least two offices: one with poor performance and the other with extremely high performance. Although we attempted to solve this by using two Settings (A and B), their performances (Table 1) were too similar: they do not represent extreme levels obtained with ISO 3382-3.

Hongisto and Keränen [8] have surveyed the single-number values of ISO 3382-3 in global level. The distribution is shown in Table 3. In this light it is evident that the open-plan office used in the AE had a relatively weak spatial attenuation ($r_C$ = 17 m). There is a need for another Round Robin test in an open-plan office having significantly stronger spatial attenuation (e.g., $r_C$ < 7 m).

Table 3 – Range of single-number values reported in different articles according to [8]. Min is the smallest and Max is the largest value reported in the literature.

| | $D_{2,S}$ [dB] | $L_{p,A,S,4m}$ [dB] | $L_{p,A,B}$ [dB] | $r_D$ [m] | $r_C$ [m] |
|---|---|---|---|---|---|
| Min | 1.5 | 40 | 26 | 2.1 | 2.1 |
| Max | 12 | 60 | 54 | 21 | 43 |

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## References

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