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Evaluation of measures for the reduction of impairment by background speech at office workplaces: Comparison of measurements and listening tests

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ABSTRACT

Speech is the most disturbing source of noise in open space offices. The interference can be reduced by room acoustic measures such as sound absorption, sound insulation and sound masking. A variety of products advertise with their ability to reduce annoying speech. However, there is still no standardized method to quantify the reduction of speech sound by such products. A procedure was proposed in 2016 and applied here. In addition to the establishment of such a method, the question arises as to how much speech sound has to be reduced so that the user can profit from it or at least notice a perceptible difference. The proposed method has been used to evaluate office furniture. In addition, recordings of speech sounds were made with different furnishing and listening tests were conducted. It was examined whether the extent of the reduction of speech sound by the furniture is sufficient to demonstrate improvements with regard to cognitive performance. As it was shown that the reduction of speech sound by the furniture in the tested design at a near distance is insufficient, scenarios were investigated in which the background noise was varied. Customary office furnishing did not achieve a sufficient reduction of speech sound.

INTRODUCTION

Speech is the most disturbing source of noise in open space offices [1]. The interference can be reduced by room acoustic measures such as sound absorption, sound insulation and sound masking [1]. A wide range of products advertises its ability to reduce annoying speech. However, there is still no standardized method for declaring the reduction of speech by such products.

An appropriate method was proposed in 2016 [2] and applied here. It is a method to determine the sound reduction by office furnishing products, which is carried out in the diffuse sound field (reverberation room). The sound power level is determined without and with the office furnishing product according to ISO 3741 and a difference value is calculated, which is adapted to the speech spectrum. As a result, a single number value D_S (Speech Reduction Index) is obtained.

In addition to the establishment of such a procedure, the question arises as to the extent to which speech sound must be reduced so that the user can profit from it or at least notice a perceptible difference. The research questions of the reported listening test are therefore:

To what extent do usual acoustic measures (screens) in the office reduce disturbing speech?

Is the extent to which usual acoustic measures (screens) in the office reduce disturbing speech sufficient to obtain an effect on the users?

EXPERIMENT

The proposed method [2] has been used to evaluate various workplace constructions. The screens were a simple self-construction (wooden frame and absorptive material) with a rated sound absorption coefficient (α_w) of 0.7. The comparison to a workplace with a table and chair without a screen served as a reference. The examined workplace constructions and associated results from the reverberation room are shown in Table 1. In addition to the measurements in the reverberation room, the applicability of the method in an ordinary room (seminar room) was examined. This resulted in a maximum difference of 1.2 dB (A). Surprisingly the D_S determined in the seminar room was smaller in the majority of cases.

Table 1: Investigated workplace configurations

Construction		D_S [dB(A)]
I		0
II		1,7
III		3,7
IV		5,5

In addition to the measurements, artificial head recordings of speech sounds were produced in the seminar room with different furnishing and listening tests were carried out. The speech sound source was calibrated to a level of 60 dB (A) at a distance of one meter. The receiver position was 5 meters away from the sender position. The measurement and recording setup in the seminar room is shown in Figure 1.

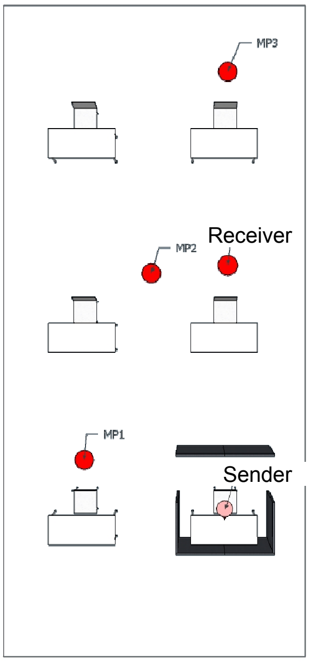

Figure 1: Setup in the seminar room

With the aid of the artificial head recordings (presentation by headphones) a laboratory experiment was conducted in the High-Performance Indoor Environment Laboratory of the Fraunhofer Institute for Building Physics in Stuttgart. In total 33 participants (Ø 23.73 years, 44.1% female, 52.9% male) were engaged. It was examined whether the extent of the reduction of speech noise by the different workplace configurations is sufficient to demonstrate effects on the participants. Therefor the performance and sensation of the participants when working during silence were compared to working during the speech recordings of the various workplace configurations.

As it became apparent that the D_S achieved by the screens would not be sufficient to achieve an effect, additional scenarios were investigated in which the speech level was additionally lowered by 10 dB (A) and/or the background noise level (Noise Criterion Curves) was additionally increased to 42 dB (A). The resulting equivalent sound levels (L_{eq}) of the test conditions are shown in Table 2.

Table 2: Equivalent sound levels (L_{eq}) of the test conditions

Construction	**L_{eq} [dB(A)]**
Silence	< 30
I	52,4
II	49,8
III	47,1
IV	45,7
I - 10dB	42,4
IV - 10dB	35,7
I + NC	52,7
IV + NC	47,2
I - 10dB + NC	45,1
IV - 10dB + NC	42,8

Participants worked on 12 trials of a verbal working memory test (serial recall task) during each sound scenario. Digits 1 to 9 were displayed in random sequence (700 ms presentation time and 300 ms interstimulus interval). After a retention interval of 8 s, the digits were displayed on the screen in a 3x3 matrix and had to be recalled and selected in the exact order of presentation. In addition, participants worked on several questionnaires covering perceived workload, annoyance, speech intelligibility and distance to the speaker.

RESULTS

Performance

The mean error rate of the participants during processing of the working memory task is shown in Figure 2.

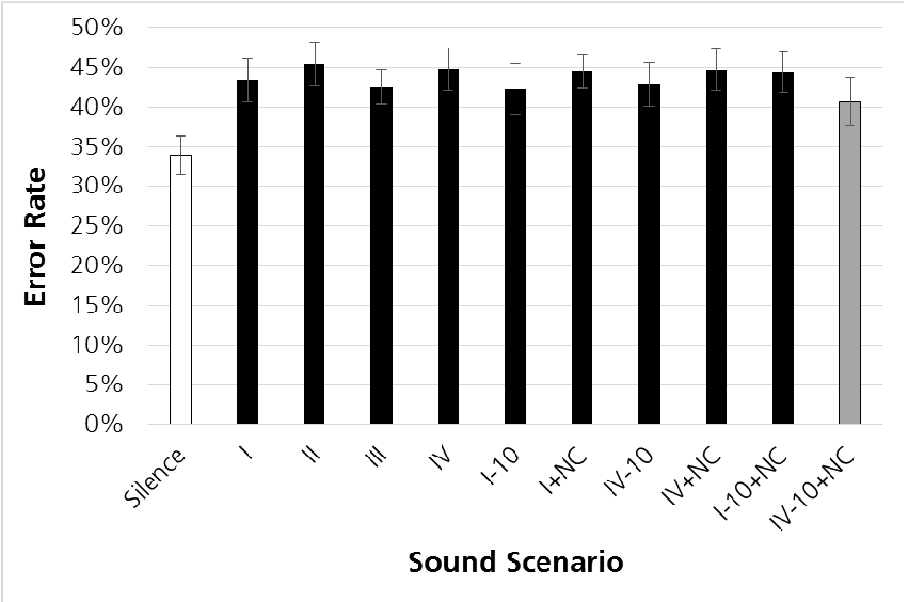

Figure 2: Mean error rate during processing of the working memory task

The statistical analysis comprises two single-factor ANOVAs with either 11 or 10 levels (with and without silence). A clear effect of the sound scenarios ($F(7.1, 227.3) = 4.19$; $p < .01$; $\eta^2 = .116$) is shown in the analysis with 11 levels (including silence). This effect is not found ($F(6.4, 205.5) < 1$; $p = .49$; $\eta^2 = .028$) in the analysis with 10 levels (without silence). When working during silence, less mistakes are made. The different workplace configurations have no significant effect. Paired comparison (significant differences marked by levels of gray), only reveal an advantage of the combination of construction IV with additional level reduction and background noise enhancement as compared to construction I (table and chair).

Workload

The average perceived workload (NASA-TLX) of the participants during processing of the working memory task is shown in Figure 3.

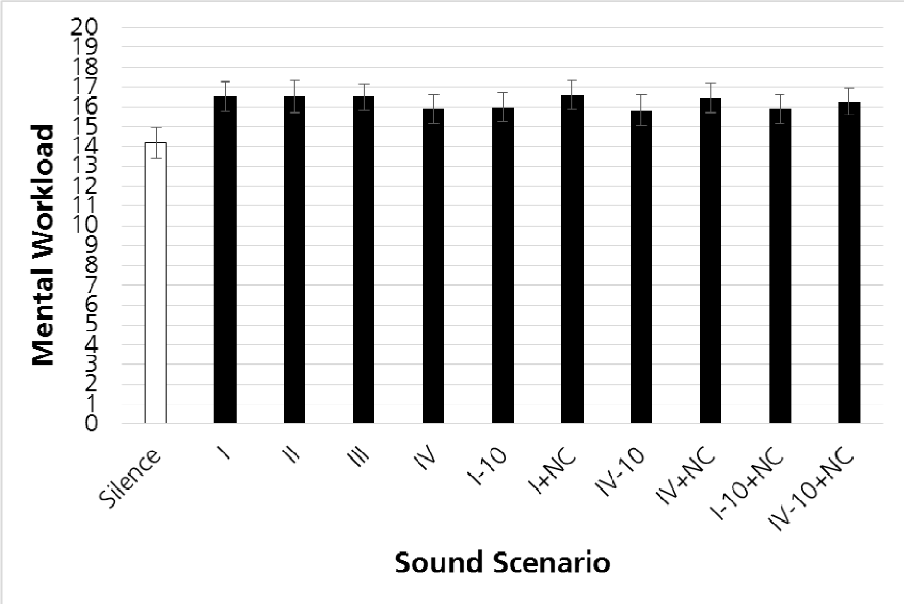

Figure 3: Perceived workload during processing of the working memory task

A clear effect of the sound scenarios ($F(10, 310) = 7.69$; $p < .01$; $\eta^2 = .199$) is shown in the analysis with 11 levels (including silence). As in the case of the error rates, no significant result can be found ($F(9, 279) = 1.82$; $p = .64$; $\eta^2 = .056$) if silence is no longer included in the evaluation with 10 levels. Working during background speech is therefore perceived to be more difficult than during silence. The various workplace constructions intended to reduce the perceived interference do not appear to be effective.

Annoyance

The average perceived annoyance (ISO/TS 15666) of the participants during processing of the working memory task is shown in Figure 4.

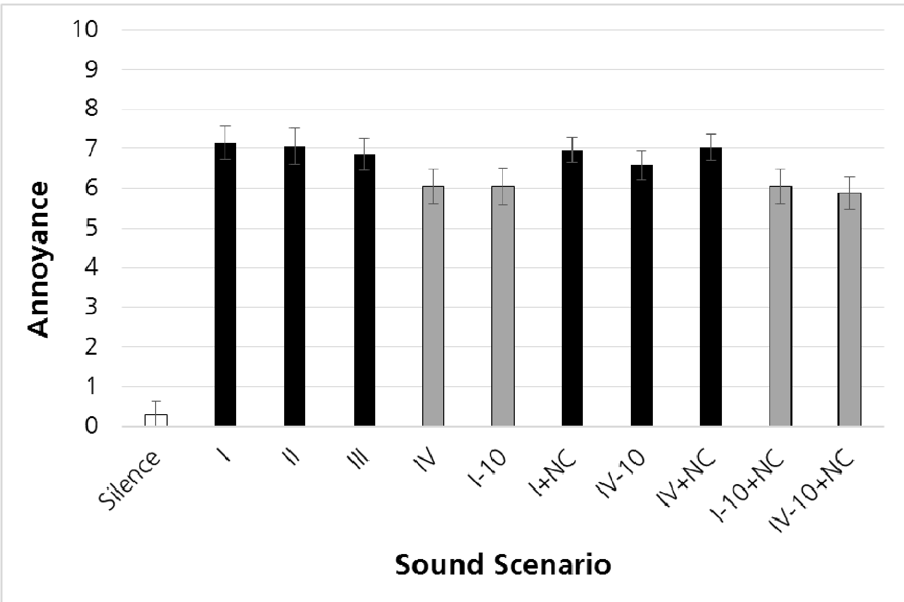

Figure 4: Perceived annoyance during processing of the working memory task

In the statistical evaluation the analysis with 11 levels ($F(10, 310) = 45.06$; $p < .01$; $\eta^2 = .592$) including silence as well as the analysis with 10 levels ($F(9, 279) = 3.42$; $p < .01$; $\eta^2 = .099$) without silence both yield significant results. Pairwise comparisons reveal that four workplace constructions yield significant differences compared to construction I (table and chair). Significant differences arise for construction IV, construction I with an additional level reduction by 10 dB (A), construction I with an additional level reduction by 10 dB (A) and an enhancement of background noise to 42 dB(A) as well as construction IV with an additional level reduction by 10 dB (A) and an enhancement of background noise to 42 dB(A).

Speech Intelligibility

The average reported speech intelligibility of the participants during processing of the working memory task is shown in Figure 5.

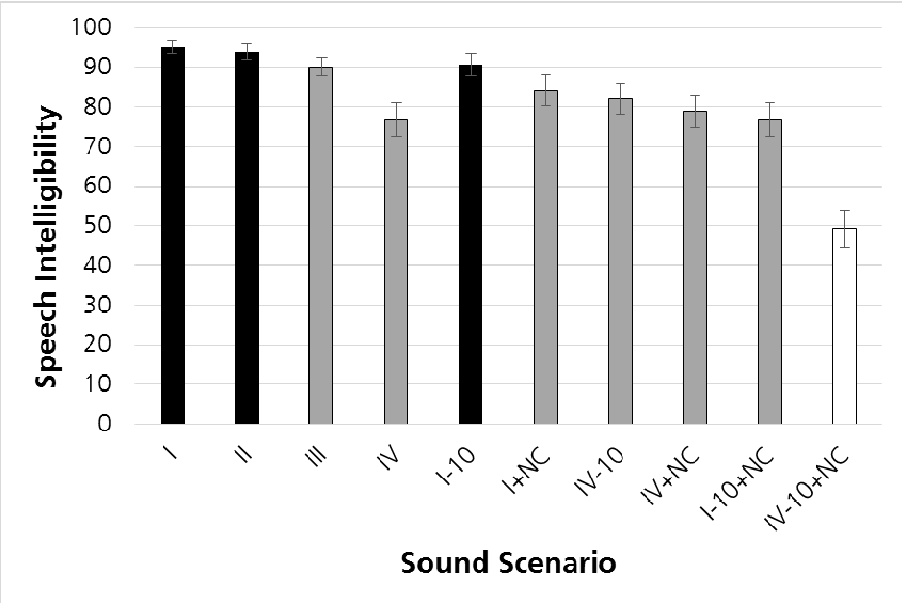

Figure 5: Reported speech intelligibility during processing of the working memory task

With regard to the statistical analysis of reported speech intelligibility, only an analysis with 10 levels is indicated. This analysis reveals significant differences between the sound scenarios $F(9, 279) = 28.67$; $p < .01$; $\eta^2 = .480$. Pairwise comparisons with construction I (table and chair) yield several significant differences. It is particularly noteworthy that the reported speech intelligibility drops drastically for construction IV with an additional level reduction by 10 dB (A) and an enhancement of background noise to 42 dB(A).

Distance

The average perceived distance to the speaker reported by the participants during processing of the working memory task is shown in Figure 6.

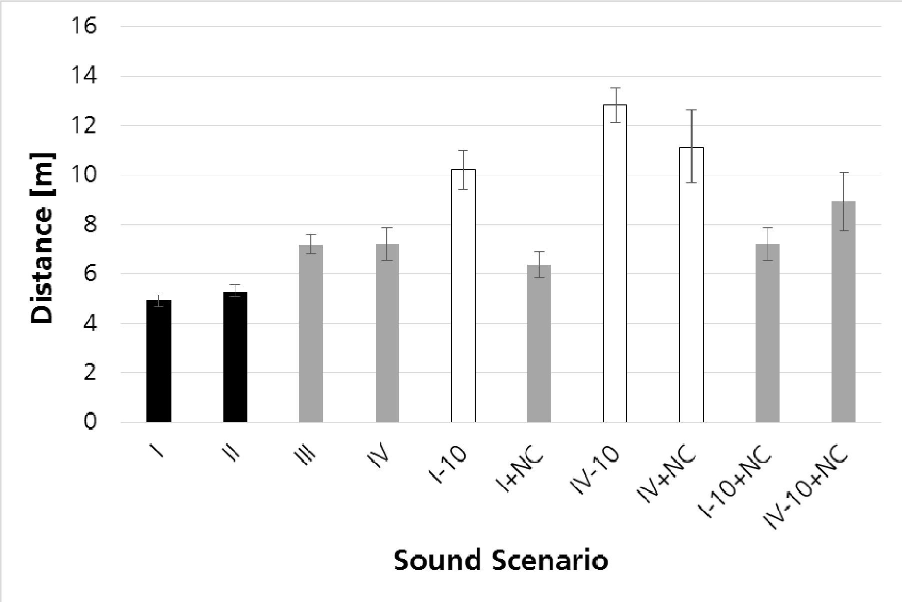

Figure 6: Perceived distance to the speaker during processing of the working memory task

The statistical analysis of the perceived distance to the speaker with 10 levels shows significant differences between the sound scenarios ($F(9, 279) = 15.03$; $p < .01$; $\eta^2 = .327$). Pairwise comparisons with construction I (table and chair) reveal several significant differences. The result pattern is inconsistent as the level reduction by 10 dB (A) and the enhancement of background noise level to 42 dB (A) have different effects for the constructions I and IV.

CONCLUSION

The reported investigation shows that usual acoustic measures in the office reduce interfering background speech only marginally (restriction to investigated experimental setup). In this case, the extent to which the acoustical measures impacted on interfering speech is hardly sufficient to obtain an effect on the users. However, the pattern of results is partly inconsistent and interactions must be further investigated. The D_S method is evaluated positively, especially since it is related to the cause of reported acoustic problems (background speech) in offices. However, the connection between D_S and spatial properties in real offices as well as the entire workplace layout still needs to be established.

REFERENCES

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