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If speech is the source of noise, how can the source be eliminated or reduced?

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ABSTRACT

The exposure to noise can be reduced by eliminating the source of noise (if possible), substituting the source with a quieter one, applying engineering modifications, using administrative controls, and by using protective equipment. It is generally agreed that the solutions controlling the source are more cost effective than those controlling noise along the propagation path. Administrative controls and the use of personal protective equipment are measures that control the noise at the receiver and are supposed to be applied only if measures at the source are not possible. However, in this line of argumentation human beings are usually only treated as receivers of noise but not as noise sources. Results are reported in which an inverse Lombard effect or rather the Fletcher effect is used to reduce the speech effort and thus the speech level of persons. A feasibility study shows that the speech level can be lowered by up to 3 dB without the necessary manipulation being perceived to be distracting.

Keywords: room acoustics, open plan offices, sidetone, speech effort

1. INTRODUCTION

It has been shown numerous times, that lack of acoustic privacy and disturbance caused by background speech rank among the least satisfying parameters of the indoor environmental quality in office buildings (1, 2). Acoustic privacy refers to not being able to prevent others from overhearing your own conversations or to prevent overhearing the conversations of others. It follows from this that the presence of background speech is closely related to acoustic privacy.

Occupational safety and health (OSH) aims to promote and maintain the highest degree of safety and health at work, therefore creating conditions to avoid the occurrence of work accidents and ill health. To achieve such goal employers have to implement safety and health measures based on risk assessments and legislation. Since OSH applies a holistic approach to promote the social, mental and physical well-being of employees, it also addresses non-auditory effects of noise like increased stress, cardiovascular function, annoyance, performance, sleeping problems, and mental health. These effects can be triggered by rather low noise levels which cause no direct harm to the hearing system (auditory effects). The presence of background speech is well known to impair subjective well-being and work performance (3, 4).

OSH usually applies a hierarchy of prevention and control measures, which starts by avoiding risks and eliminating hazards. If this is not possible, hazards have to be reduced and minimized or separated from the employees. However, if a colleague is the source of speech noise, separating him from the other employees is not easy or not wanted. Because this would be mean, providing single offices or sufficient acoustically separated spaces for communication or concentrated work but also disconnecting people.

Preventive measures which aim to reduce the likelihood of occurrence of a hazard can be applied. Those incorporate engineering or technical measures (designed to act directly on the risk source, in order to remove, reduce or replace it) and organizational or administrative measures (meant to force changing of behaviors and attitudes and promote a safety culture). Thus reducing the vocal effort of a speaker and therefor the level of disturbing background speech for his colleagues is a desirable goal.

Preventive measures can be followed by protection measures which include collective measures (designed to enclose or isolate the risk, for instance through the use of physical barriers, organizational or administrative measures to diminish the exposure duration) and individual measures (any adequate Personnel Protective Equipment designed to protect the worker from the residual risk).

The OSH approach has been very successful for example in reducing the background noise level in offices caused by technical noise sources. However, doing so the impairment caused by background speech may even have increased since the disturbing background speech is no longer masked by background sound from technical sources. The consideration of work colleagues as potential noise sources has so far found no adequate consideration. Many guidelines and recommendations specifically ignore this kind of noise which is caused by the presence of other people in the room.

For this reason, a feasibility study is presented here, which investigates whether electro-acoustic measures on the technical equipment of the source of background speech, namely the speaker, can reduce the vocal effort of the speaker and thus also reduce background speech. For this purpose, the so-called sidetone settings of five different headphone systems were systematically manipulated and the effects on the speech sound level of the speakers was examined. The sidetone settings are intended to intervene directly at the source of the disturbing noise, namely the speech sound caused by the speaker. A system was developed which reproduces the speaker´s own speech sound on the headphones as a sidetone during a simulated conversation with a headset. By means of this technique it is attempted to reduce the speech level by psychoacoustic measures. The effectiveness of the development was validated in an experiment by measuring the speech levels and also the acceptance of the development was tested by questionnaires. Only the effects on speech levels will be reported here.

2. METHOD

2.1 Procedure

Participants were instructed to read aloud sentences of the HSM-sentence test (5) while wearing different types (SH HD 600, SH HD 600 mono, SH HD 280, SH CHAT, SH MB 660 UC) of headphones (Sennheiser) and being exposed to three different conditions of background sound (SILENCE, ONE SPEAKER, SOME SPEAKERS) and to eight different sidetone settings as well as a baseline condition with no sidetone (0, 49, 55, 61, 67, 73, 79, 85, 91 dB). Thus a factorial design with the independent variables type of headphone (5 levels), sidetone setting (8 levels) and condition of background sound (3 levels) was applied. The headphones differ with regard to their characteristics as described in Table 1.

Table 1 – Headphone Characteristics

Type	Design Type	Sidetone
SH HD 600	over-ear open-back headphones	both ears
SH HD 600 mono	over-ear open-back headphones	one ear
SH HD 280	over-ear closed-back headphones	both ears
SH CHAT	earpad headphones	both ears
SH MB 660 UC	over-ear closed-back headphones with active noise cancelling	both ears

The background sounds were presented via the headphones and differed with regard to level (levels in brackets correspond to the level with active noise cancelling switched on) and the number of voices as described in Table 2.

Table 2 – Background Sounds

Condition	Level dB (A)
SILENCE	~
One Speaker	53.6 (40.63)
Some Speakers	53.9 (41.49)

The sidetone settings were varied in steps of 6 dB in gain (0, 49, 55, 61, 67, 73, 79, 85, 91 dB) which means that every participant received different sidetone levels depending on her/his own speech level. The reduction of the speech level during each sidetone setting was compared to the speech level with no sidetone.

2.2 Participants

Data were collected from N = 20 participants. Most of the subjects were students of various disciplines. The subjects were between 21 and 69 years old (M = 28.65 years, MD = 25 years). Ten female and 10 male subjects participated in the listening test.

3. RESULTS

The results of this feasibility study have to be interpreted with caution since plenty of individual data points were lost due to technical problems during recording of individual speech levels. In order to be able to conduct the statistical analysis in a factorial manner, the missing data was substituted by the mean of the experimental condition. The ANOVA was calculated with de-logarithmed levels. Additionally the factors HEADPHONE and SIDETONE were treated as between-subject factors because of problems with the data protocol even so each participant wore each headphone and was exposed to each sidetone setting.

3.1 Statistical Analysis

A three-way (HEADPHONE, SIDETONE, BACKGROUND SOUND) repeated measures ANOVA with two between-subject factors (HEADPHONE, SIDETONE) and one within-subject factors (BACKGROUND SOUND) was conducted and is reported in Table 3 (Between Subjects Effects) and Table 4 (Within Subjects Effects).

Table 3 – Between Subjects Effects

	Sum of Squares	df	Mean Square	F	p
HEADPHONE	11.88	4	2.971	12.632	< .001
SIDETONE	5.75	7	0.821	3.492	0.001
HEADPHONE ✻ SIDETONE	6.29	28	0.225	0.956	0.532
Residual	165.57	704	0.235		

The analysis reveals significant main effects of the factors HEADPHONE ($F(4,704)=12.63$, $p<.001$, $\eta^2=.014$) and SIDETONE ($F(7,704)=3.49$, $p<.01$, $\eta^2=.007$) but no significant interaction of both factors.

Table 4 – Within Subjects Effects

	Sum of Squares	df	Mean Square	F	p
BACKGROUND SOUND	8.80	2	4.398	20.779	< .001
BACKGROUND SOUND ✻ HEADPHONE	6.47	8	0.809	3.820	< .001
BACKGROUND SOUND ✻ SIDETONE	2.47	14	0.176	0.833	0.634
BACKGROUND SOUND ✻ HEADPHONE ✻ SIDETONE	8.29	56	0.148	0.699	0.955
Residual	298.02	1408	0.212		

The analysis reveals significant main effects of the factors BACKGROUND SOUND ($F(2,1408)=20.78$, $p<.001$, $\eta^2=.010$). The interaction between BACKGROUND SOUND and HEADPHONE is also significant ($F(8,1408)=3.82$, $p<.001$, $\eta^2=.008$).

3.2 Descriptive Analysis

Figure 1 depicts the reduction of the speech level depending on the sidetone settings compared to the condition with no sidetone collapsed over all headphones. It appears that for the higher sidetone gains the speech level decreases but only during the ONE SPEAKER and SOME SPEAKERS condition.

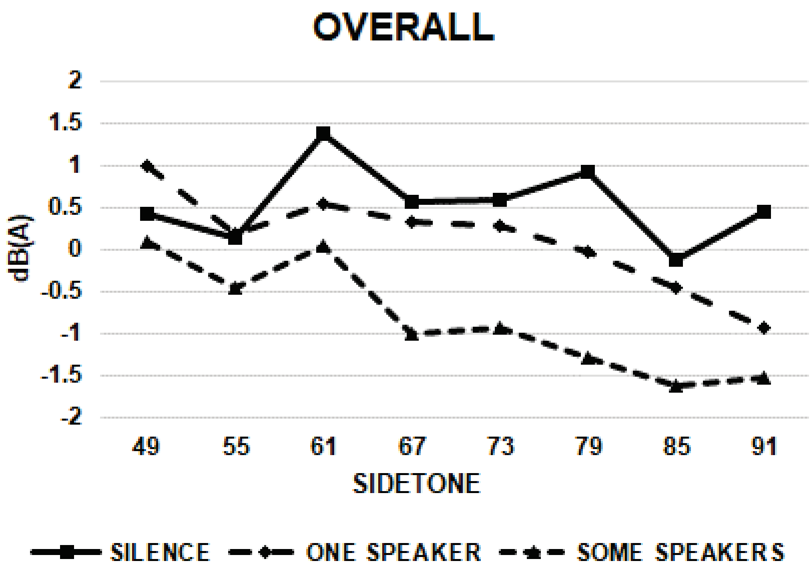

Figure 1 – Reduction of speech level during different sidetone settings and background sound conditions collapsed over all headphones.

Figure 2 depicts the reduction of the speech level depending on the sidetone settings compared to the condition with no sidetone for the SH HD 600 headphone. It appears that for the higher sidetone gains the speech level decreases but only during the SOME SPEAKERS condition.

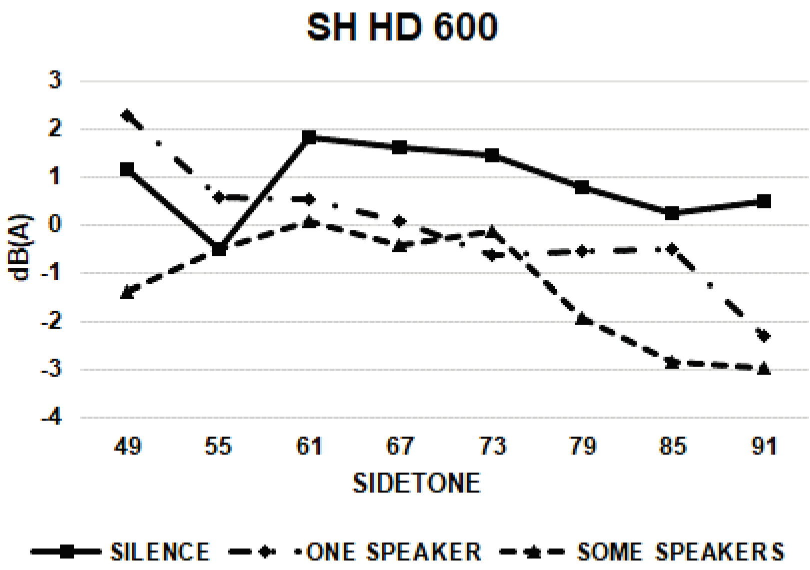

Figure 2 – Reduction of speech level during different sidetone settings and background sound conditions for the SH HD 600 headphone.

Figure 3 depicts the reduction of the speech level depending on the sidetone settings compared to the condition with no sidetone for the SH HD 600 headphone but with monaural sidetone presentation. There seems to be no pattern of results.

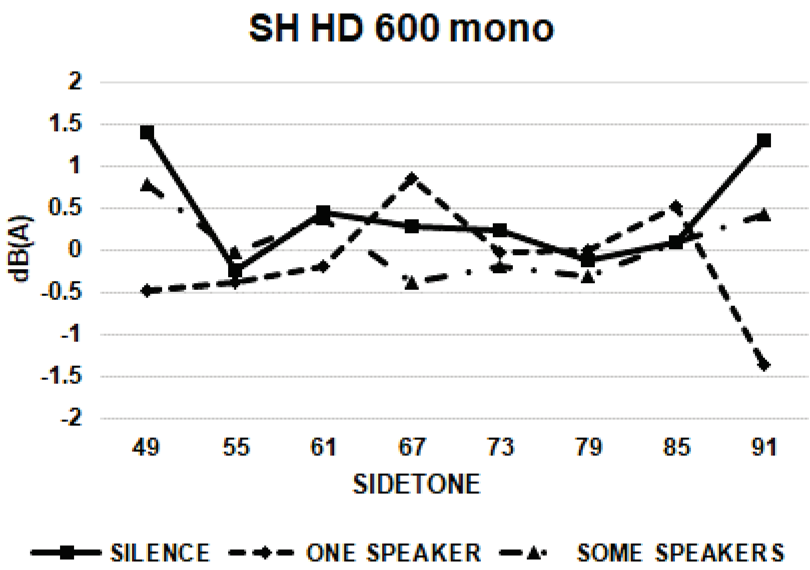

Figure 3 – Reduction of speech level during different sidetone settings and background sound conditions for the SH HD 600 headphone but with monaural sidetone presentation.

Figure 4 depicts the reduction of the speech level depending on the sidetone settings compared to the condition with no sidetone for the SH HD 280 headphone. It appears that for the higher sidetone gains the speech level decreases for all background sound conditions.

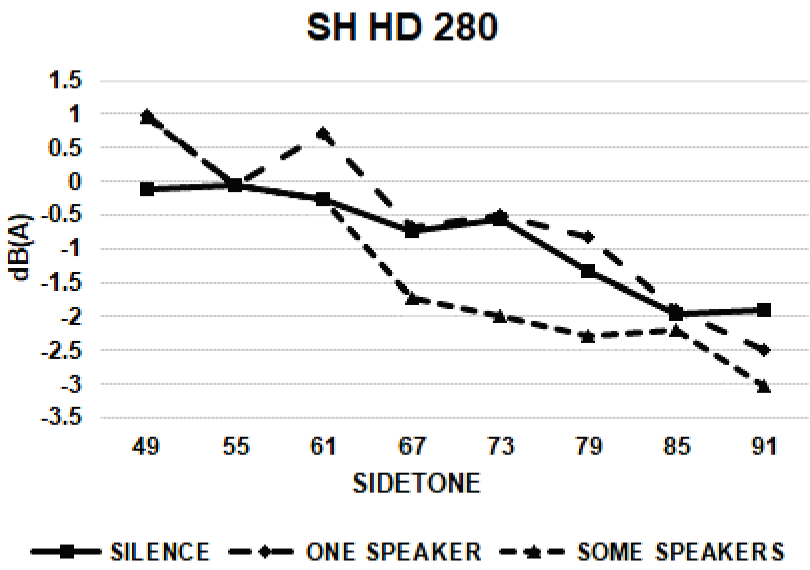

Figure 4 – Reduction of speech level during different sidetone settings and background sound conditions for the SH HD 280 headphone.

Figure 5 depicts the reduction of the speech level depending on the sidetone settings compared to the condition with no sidetone for the SH CHAT headphone. There seems to be no pattern of results.

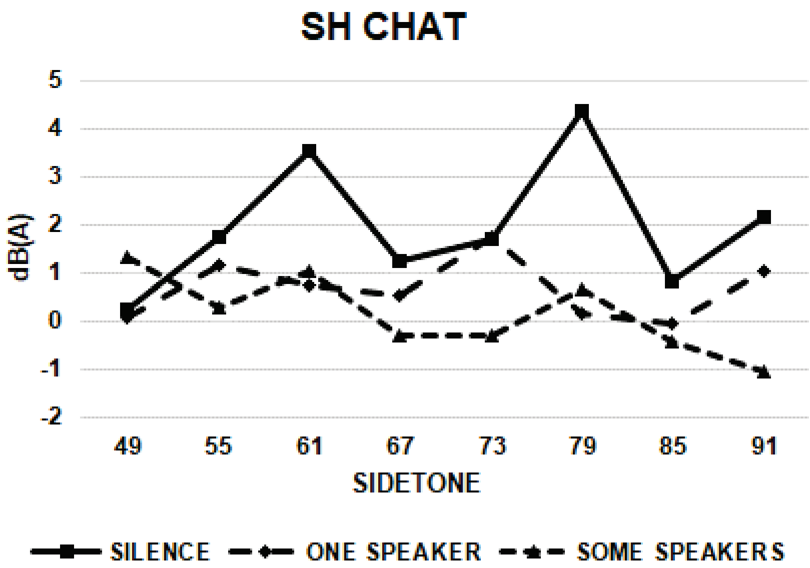

Figure 5 – Reduction of speech level during different sidetone settings and background sound conditions for the SH CHAT headphone.

Figure 6 depicts the reduction of the speech level depending on the sidetone settings compared to the condition with no sidetone for the SH MB 660 UC headphone. There seems to be a reduction of speech level for all levels of sidetone gain but only for the SOME SPEAKER condition.

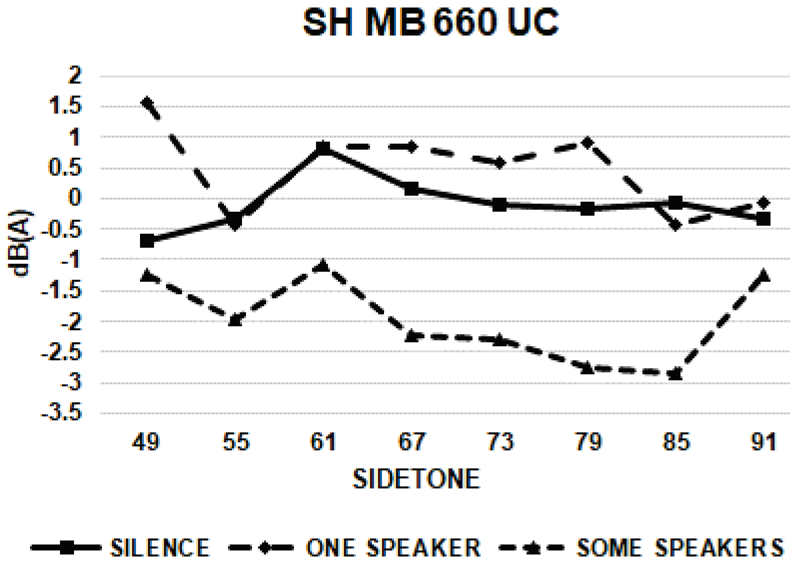

Figure 6 – Reduction of speech level during different sidetone settings and background sound conditions for the SH MB 660 UC headphone.

4. DISCUSSION

Since the results of the analysis have to be treated with caution the discussion of the results has to be preliminary. As there were problems with the recording of the speech levels during the different experimental conditions the technical setup of this feasibility study needs to be improved. However, the results seem to be promising with regard to the possibility to impact upon the speech level of a speaker during a headset conversation by means of manipulating the sidetone settings of the headphone. However, the results seem to vary depending on the background sound situation and depending on the headphone being used.

5. CONCLUSIONS

Since background speech usually ranks among the least satisfying parameters of the indoor environmental quality in office buildings even so common room acoustical measures are applied, new solutions have to be found. This feasibility study yields that the speech level of a speaker can be influenced by applying certain sidetone settings to the headsets being used. However, the effect is limited in quantity and the results of this feasibility study have to be treated with caution due to limits to the statistical protocol.

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