Listening Effort and Speech Intelligibility

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Introduction

Hearing impaired people often report that it is difficult to understand speech in situations with high background noise levels. Difficulty often means that hearing impaired people are able to understand everything but they need to concentrate to the speaker very much or in other words, they need a lot of listening effort (LE). In this study we evaluated whether listening effort can be measured by a simple scaling procedure. Another question was whether LE and speech intelligibility (SI) are different factors that both describe the perception of speech in noise or if they influence each other so that the measure of one would be sufficient.

Materials and Methods

In a first study 10 normal hearing subjects (group 1) and 10 subjects with moderate hearing loss (group 2) participated. SI measure was performed using the adaptive Oldenburg sentence test to get the SRT and the slope of the psychometric curve [1]. An effort scaling using a 60 point scale from “extreme effortful” to “effortless” was used to evaluate the subjectively perceived LE at 11 different signal to noise ratios (SNRs). So, SI and LE could be compared over a wide range of SNRs. Both measurements were performed with two different background noises: the “olnoise” and a “cafeteria noise”. The “olnoise” is a continuous noise with a speech shaped spectrum. The “cafeteria noise” is a recording of a crowded cafeteria.

In a second study 8 normal hearing subjects participated. Additionally to the “olnoise” and the “cafeteria noise”, the ICRA noise #7 (ICRA7) was used as a background to evaluate whether modulation has an effect on LE and/or SI. Therefore, the power spectra of all noises were adapted to match each other (see figure 4). So, it can be excluded that the different spectra of the background noises do influence LE and/or SI.

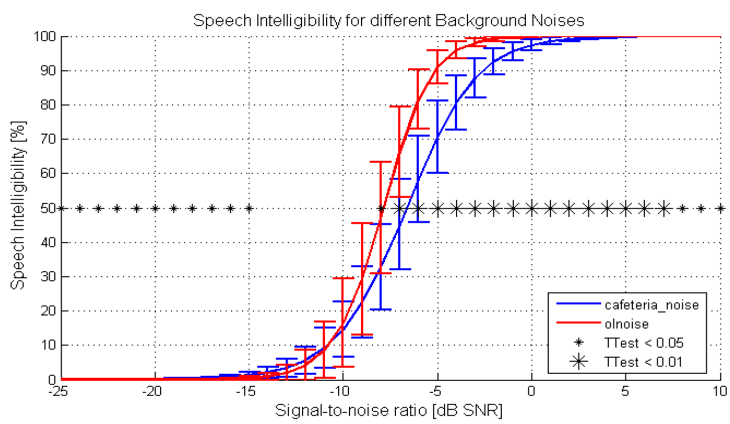


Figure 1: Mean results of the speech intelligibility tests for the group of normal hearing subjects (upper part). Error bars denote the standard deviation and the stars denote the signal to noise ratios at which the differences between the two background noises are statistically different (TTest, small stars: p<0.05, bigger stars p<0.01).

Results

In the first study subjects from both groups showed better speech reception thresholds with the “olnoise” compared to the “cafeteria noise” over a wide range of SNRs (figure 1). However, the effort was rated to be less with the “cafeteria noise” (figure 2).

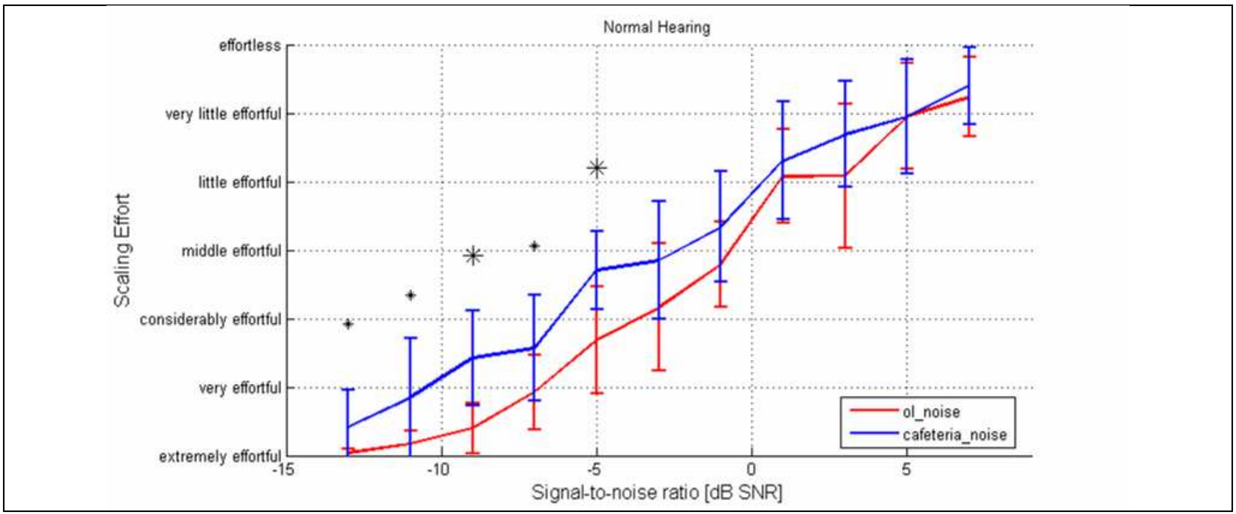
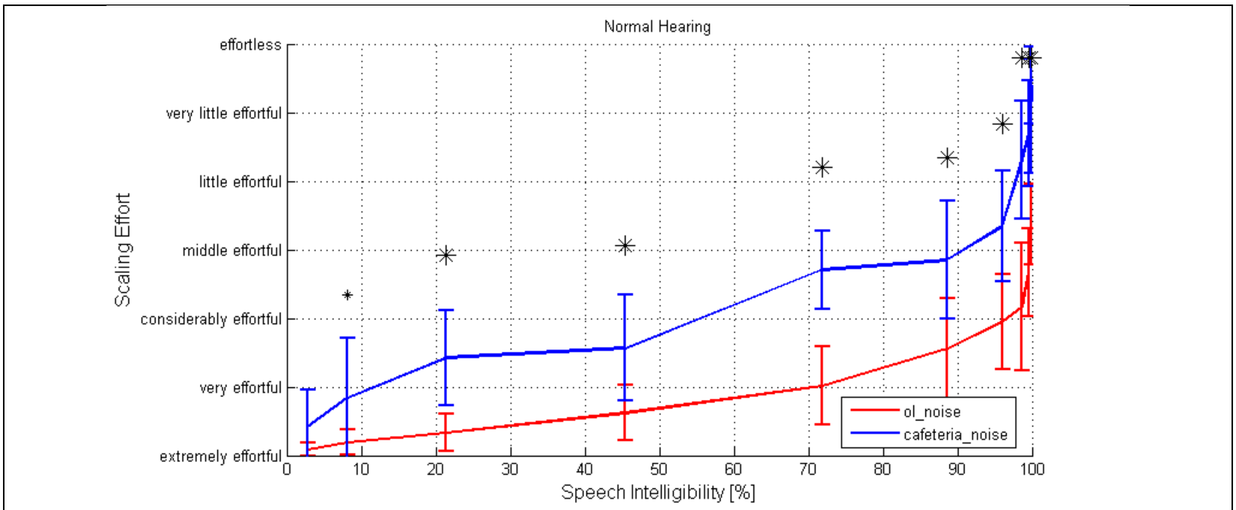


Figure 2: Mean results of the effort scaling with normal hearing subjects. Error bars denote the standard deviation and the stars denote the signal to noise ratios at which the differences between the two background noises are statistically different (TTest, small stars: $p<0.05$, bigger stars $p<0.01$).

In figure 3 the results of the LE is plotted as a function of SI. This gives the opportunity to see whether LE and SI are different for the two background noises. When the background noise influences both, SI and LE in the same way, the results would overlap in figure 3. This is not the case for the whole range of SI, from nearly 0% to 100% speech intelligibility. The figure shows that subjects rated to have less effort with the cafeteria noise to reach the same intelligibility.

The two background noises are different in their spectra and their modulation. Both might influence the SI and/or LE. Therefore, an additional noise was introduced for the next study: the ICRA #7 noise, which is an artificial noise with a speech shaped modulation. Also, all noises were adapted according their power spectra (compare for figure 4).

As can bee seen in figure 5, subjects still rate the “cafeteria noise” to be less effortful compared to the “olnoise” for the same speech intelligibility (stars in figure 5 denote statistically significant difference between these background noises). The ICRA7 noise was rated to be less effortful compared to the “olnoise” but more effortfull compared to the “cafeteria noise”, however, this differences were not statistically different. This indicates that modulation is not the reason for the difference in LE (as a function of SI) because the ICRA7 is the background noise with the strongest modulation.



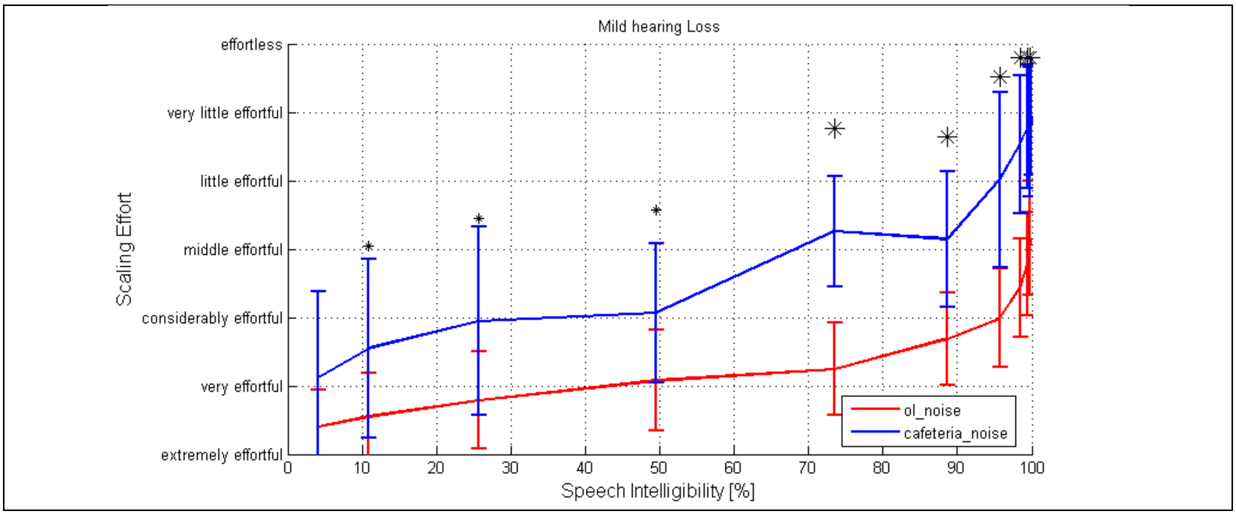


Figure 3: Mean result of the effort scaling as a function of speech intelligibility. Upper part of the figure shows the mean results of the normal hearing group and the lower part shows the mean result for the hearing impaired subjects (group 2). Error bars denote the standard deviation and the stars denote statistically significant differences (TTest, small stars: $p<0.05$, bigger stars $p<0.01$).

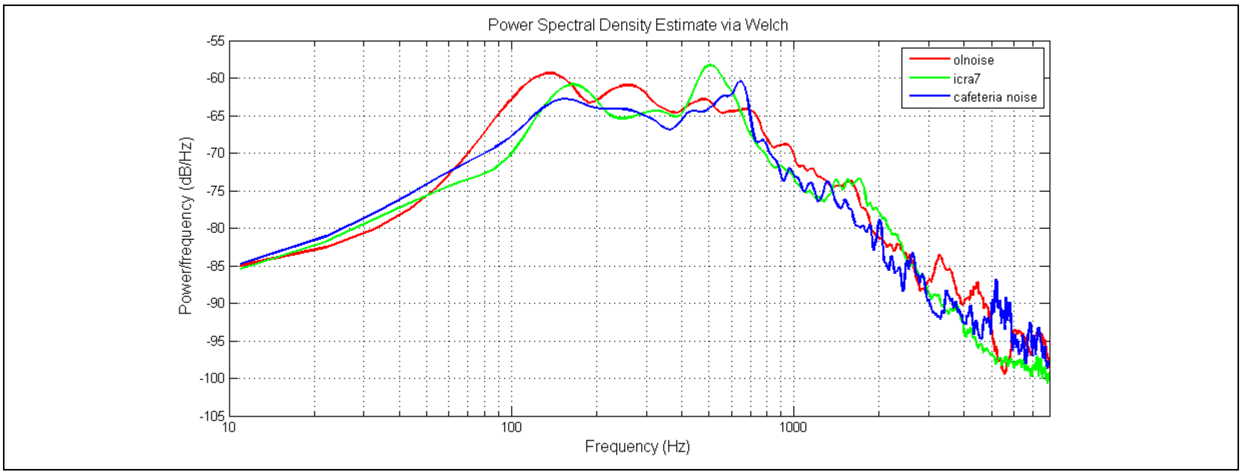


Figure 4: This figure shows the adapted long term power spectra of the background noises in study 2.

Discussion

In these studies we were able to show that LE and SI are two different factors that both describe the perception of speech in noisy conditions. Interestingly, the "cafeteria noise" was the background noise which was rated to be the one with the least effort to reach the same intelligibility.

In a study which investigated the effects of different noise reduction algorithms Marzinzik and Kollmeier [2] showed that it is not possible to demonstrate the positive effects of the noise reduction by means of speech intelligibility test (adaptive Göttinger speech test). However, by rating the listening effort the positive effect of noise reduction algorithms were significantly shown. Our current studies might explain this finding because they show that sometimes SI and LE are different factors that both describe perception of speech in noisy conditions.

It seems that the long term power spectra and the modulation are not responsible for the differences in listening effort for the same intelligibility. A possible explanation might result from the fact that the "cafeteria noise" was the only "natural" noise used in these studies. It might be that the subjects are used to this kind of noise and therefore it is not as effortful for them to extract the speech signal. However, more studies are required to test this explanation.

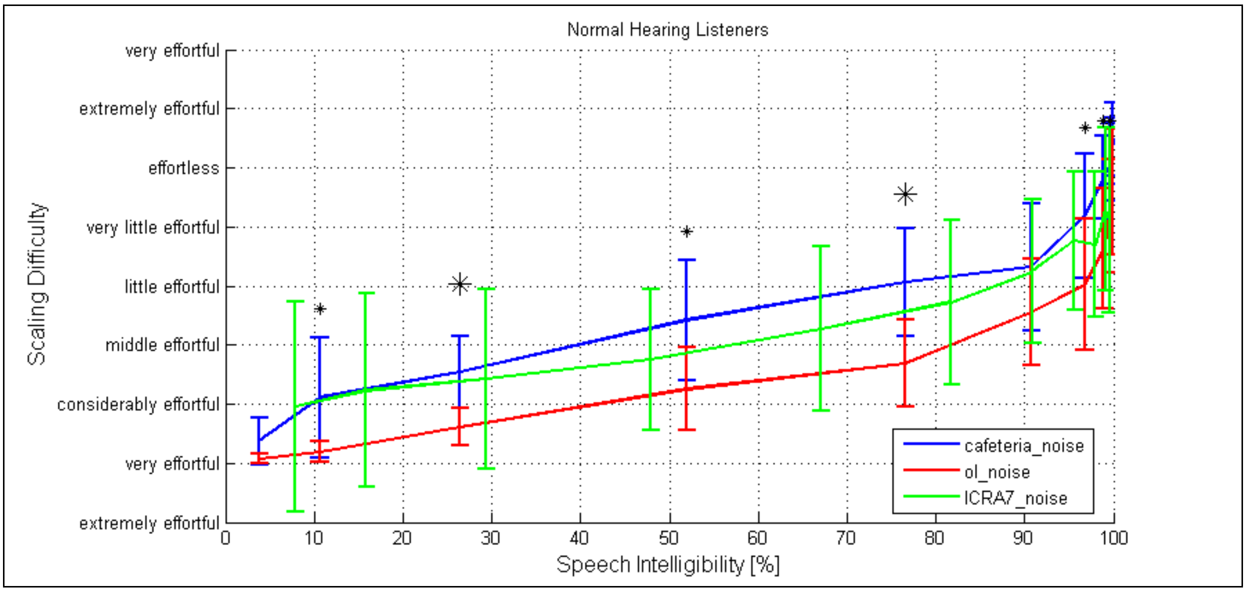


Figure 5: *Mean result of the effort scaling as a function of speech intelligibility. Error bars denote the standard deviation and the stars denote the speech intelligibility at which the differences between the "olnoise" and the "cafeteria noise" are statistically different (TTest, small stars: p<0.05, bigger stars p<0.01).*

Acknowledgement

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References

Brand, T. and B. Kollmeier, Efficient adaptive procedures for threshold and concurrent slope estimates for psychophysics and speech intelligibility tests. J Acoust Soc Am, 2002. 111(6): p. 2801-10.

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