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# LOUDNESS OF SPEECH PRONOUNCED BY A VISIBLE OR HIDDEN SPEAKER LOCATED AT SEVERAL DISTANCES

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## ABSTRACT

The at-ear pressure level of a sound decreases as the distance between the source and the listener increases. However, a form of loudness constancy with sound source distance has been revealed under certain experimental conditions by several studies in the literature. In the present study, listeners were instructed to evaluate both the loudness “at the ears” (the extent to which the sound has been heard loud) and the loudness “at the source” (the extent to which the sound has been emitted loud) of speech as a function of the source distance. The speech signals under test consisted in disyllabic french words pronounced with different vocal efforts by a speaker located at several distances from the listening point. The speaker could be either visible or hidden, providing or not the listeners with visual information about his relative distance and his vocal effort. The experiment took place in both anechoic and reverberant virtual environments, providing or not the listeners with absolute auditory cues to the speaker’s distance and acoustic power. The results show a robust constancy with distance for the estimates focusing on the loudness “at the source”, whereas the loudness “at the ears” was clearly following the at-ear sound pressure variations induced by distance. These results differ to some extent from those previously observed for white noises, which do not provide intrinsic information about their source power. Moreover, the loudness functions obtained when the listeners estimated the loudness “at the ears” for speech were similar to those obtained for noises in a previous experiment. This result somehow differs from those obtained in the literature where the overall loudness of noises or speech was evaluated without specifically focusing the listener’s attention on the loudness “at the ears”.

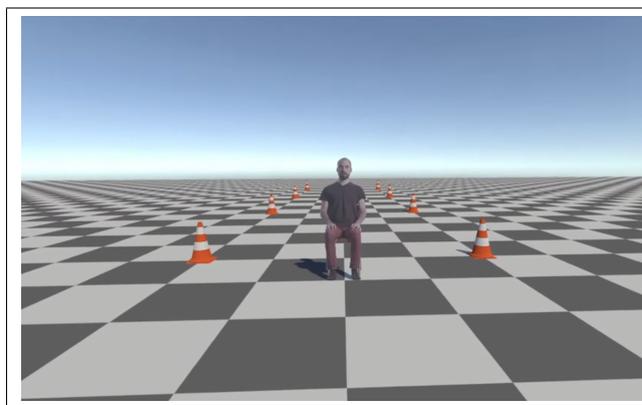
## 1. INTRODUCTION

Contrarily to “directional loudness” that represents loudness variations with the source azimuth [1, 2], “loudness constancy” describes a phenomenon by which the loudness remains constant when varying the distance of the sound source [3]. It has been observed on noise signals when specifically focusing the subject’s attention on the loudness “at the source” (the extent to which the sound has been emitted loud). However, when the subject is asked to assess the loudness “at the ears” (the extent to which the sound has been received loud) of similar signals, loudness appears to decrease with distance [2, 4].

For speech signals, loudness constancy seems to occur even without specifically instructing the subject to focus on the loudness “at the source” [5, 6]. The aim of the present study is to verify whether loudness constancy can still be achieved for speech signals when specifically directing the subject’s attention towards loudness or “at the ears”.

## 2. EXPERIMENTAL SETUP

17 subjects (6 women and 11 men aged 20 to 26 years) with normal hearing took part in an experiment where they were asked to assess the loudness of speech stimuli on a free-modulus scale [4]. French words were pronounced by a speaker located at several distances (1, 2, 4, 8 and 16 m) in a virtual environment. This environment was provided to the subject by using a head-mounted display (HTC Vive) and headphones (Sennheiser HD 650). The speaker could be either visible (see Fig. 1) or hidden behind a large panel.



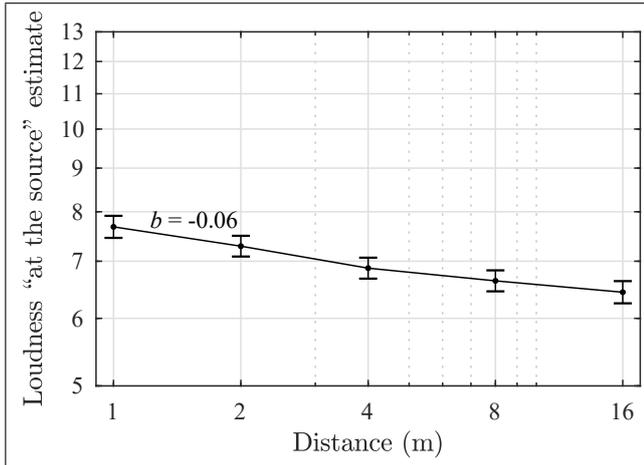
**Figure 1.** Speaker (visible) located at a given distance within a visual environment.

The experiment was split in two different sessions in which the subject was explicitly told to focus on how the sound was produced or perceived loud, in order to respectively gather loudness “at the source” or “at the ears”. Instructions were given in written form within the virtual environment and were also read by the experimenter at the beginning of each session (loudness “at the source” or “at the ears”). Participants carried out the two sessions in random order on two different weeks and performed around ten training estimates at the beginning of each sub-session which answers were not kept. Each session lasted approximately one hour.

### 3. RESULTS

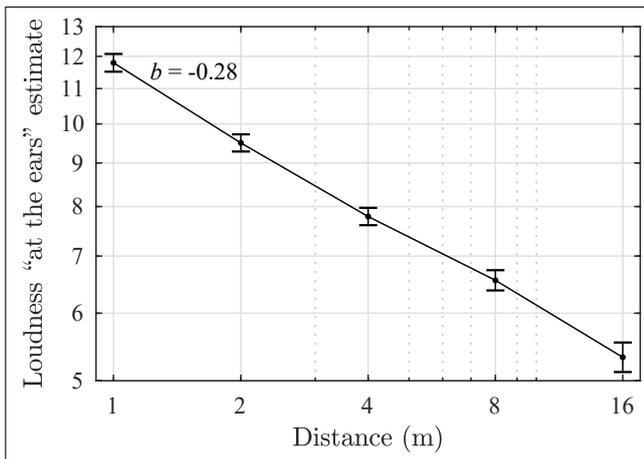
Since loudness estimates were gathered using a free-modulus scale, they were first normalized using the same method as described by Altmann *et al.* [7]. During this process, estimates were converted to their logarithm.

Two repeated-measures analyses of variance (ANOVA) were performed on the normalized logarithm of loudness estimates, respectively for “at the source” and “at the ears” assessments. In both cases, the residuals of the linear model followed a normal distribution. Distance proved to have a significant effect on loudness “at the source” ( $F(1.689, 27.024) = 29.126, p < 0.001$ ), see Fig. 2.



**Figure 2.** Mean loudness “at the source” estimate as a function of distance, with 95% confidence intervals.

Distance also proved to have a significant effect on loudness “at the ears” ( $F(1.096, 17.541) = 69.480, p < 0.001$ ), see Fig. 3.



**Figure 3.** Mean loudness “at the ears” estimate as a function of distance, with 95% confidence intervals.

The loudness functions depicted on Fig. 2 and Fig. 3 were subsequently fitted to a power function:

$$L = k \cdot r^b \quad (1)$$

where  $L$  is the loudness,  $r$  the distance and  $k$  a constant. The exponent  $b$  indicated in Eqn. (1) represents the slope of

the loudness function and is indicated next to its respective function. According to Zahorik and Wightman [3] and despite the significant distance effect (see Fig. 2), loudness constancy can be assumed regarding “at the source” estimates ( $b = -0.06$ ) which agrees with past studies [5, 6] about speech signals. One should note that under several experimental conditions the speaker was hidden and/or located in an anechoic environment, which emphasizes the robustness of this constancy. Nevertheless, such a constancy did not occur for “at the ears” estimates ( $b = -0.28$ , see Fig. 3).

### 4. CONCLUSION

From the results of this study and the literature, it can be concluded that loudness constancy can be achieved for speech stimuli when the subject’s attention is explicitly or implicitly directed towards loudness “at the source”. However, the present results indicates that the loudness of speech decreases with distance when the subject’s attention is explicitly directed towards loudness “at the ears”.

### 5. REFERENCES

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