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A TUTORIAL TO BUILD A VOICE DOSIMETER

Pasquale Bottalico[1*] **Charles J. Nudelman**[1]
[1] Department of Speech and Hearing Science, University of Illinois Urbana-Champaign, United States

ABSTRACT

Voice dosimeters gather voice production data in the daily lives of individuals with voice disorders. Previously, several voice dosimeters were commercially available. However, these devices have been discontinued and are not available to clinicians and researchers alike. In this tutorial, instructions for a low-cost, easy-to-assemble voice dosimeter are provided. This do-it-yourself (DIY) voice dosimeter is further validated based on performance results. Ten vocally healthy participants wore the DIY voice dosimeter. They produced several tasks recorded by the DIY voice dosimeter and a reference microphone simultaneously. The expanded uncertainty (u) of the mean error in the estimation of four voice acoustic parameters as measured by the DIY dosimeter was performed by comparing the signals acquired through the reference microphone and the dosimeter. For measures of sound pressure level, the DIY voice dosimeter had a mean error of -0.68 dB (u 0.56 dB). For fundamental frequency, the mean error was 1.56 Hz for female participants (u 0.62 Hz) and 1.11 Hz for male participants (u 0.34 Hz). The mean error and uncertainties for the DIY voice dosimeter are comparable to the most accurate voice dosimeters that were previously on the market.

Keywords: vocal dosimeter, voice device, uncertainty of measurements, speech acoustics

1. INTRODUCTION

Voice disorders are prevalent, especially among occupational voice users. [1–10] Compensatory voicing behaviors, which are maladaptive vocal productions, contribute to the pathophysiology of voice disorders. [4, 7, 11, 12] Ecologically valid approaches, such as voice dosimetry, can gather objective measurements of voice signals in daily life, aiding clinicians in assessing their patients' daily voice use outside the clinic. [4,13–17] Voice dosimetry measures vocal doses, sound pressure level, and fundamental frequency, providing insight into recovery patterns of occupational voice users with and without voice disorders.

Four voice dosimeters, including APM, VoxLog, VocaLog2, and Voice Care, were available commercially to measure various voice-related acoustic measures such as intensity, fundamental frequency, time dose, cycle dose and distance dose. [16, 18]

The present study aims to address this problem by providing a tutorial for a low-cost (less than $250), easy-to-assemble voice dosimeter that is validated based on performance results.

2. DO-IT-YOURSELF (DIY) VOICE DOSIMETER

The DIY (do-it-yourself) voice dosimeter and placement is displayed in Fig. 1. The dosimeter consists of a Roland R-07 Portable Audio Recorder (Roland Corporation) attached to a contact microphone (Lsgoodcare) via a 3.5mm headphone splitter (to separate the microphone and headphone inputs). At the time of writing, the R-07 retailed for less than $200 (USD), the contact microphone for less than $20 (USD), and the splitter for less than $10 (USD). In this tutorial, we used a Roland R-07. The Roland R-07 uses a microSD memory card with SDHC format compatibility and can record up to approximately 15 hours depending on the specifications, capacity and conditions of the battery used. However, any other portable recorder with an external microphone input would work, but duration of recording should be considered with other devices.

The placement of the DIY voice dosimeter's contact mi-

***Corresponding author**: *pb81@illinois.edu.*

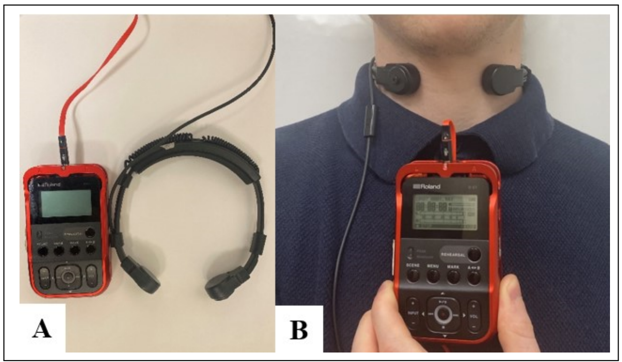

Figure 1. The Do-It-Yourself (DIY) dosimeter device (A) and placement (B).

crophones is based on previous evidence which indicates that a voice signal is measured most accurately via contact microphones when they are placed laterally on the neck, inferior to the major horns of the hyoid bone, especially, at the level of the thyrohyoid space. [19]

In comparison to previous voice dosimeters, the DIY voice dosimeter is most aligned with the Voice Care device (PR.O. VOICE SRL, Torino, Italy), which utilized a similar external contact microphone. The microphone selection of the DIY voice dosimeter was modeled after the Voice Care device because it was found to be most accurate in its SPL and fo in a previous study that compared it (the Voice Care device) to the VocaLog2, VoxLog, and the APM3200. [14]

As in previous studies, [13] individual calibration should occur at the start of the recording, and running speech should be used as calibration for everyone who uses the DIY voice dosimeter. The calibration should be performed in a quiet room. The future results of this study confirm this. Users of the DIY voice dosimeter should be instructed to perform a calibration procedure at the start of each recording session either independently, or under the guidance of a clinician. The user should be instructed to avoid touching the contact microphones and, medical-grade tape can be used to affix the contact microphones to the neck if the user foresees a high degree of physical activity while wearing the device. The procedure used for the calibration was based on Švec and Granqvist. [20]

3. VALIDATION

Ten participants were enrolled in the study and were recruited through sequential convenience sampling. Five of the participants were male and five were female. With protocol approval from the University of Illinois at Urbana Champaign Institutional Review Board (IRB #18179), speech samples of the participants were recorded at three vocal effort levels: relaxed, normal, and raised. The vocal efforts were defined following the standard ISO 9921. [21] The recordings were performed in a soundproof double-walled Whisper Room (interior dimensions: 177 × 181 cm and h = 228 cm). The T30 was measured for mid-frequencies to be 0.05 s in the soundproof room and background noise equal to 25 dB(A). The DIY voice dosimeter was placed on the participants' anterior neck at the level of the thyrohyoid space and their voice signal was recorded both by the DIY voice dosimeter and by a reference microphone. The reference microphone was an M2211 microphone (NTI Audio, Tigards, OR), which was selected due to its status as a Class 1 microphone. [22] In the present validation, the M2211 was placed at 45 degrees azimuth to the right of the participant at a fixed distance of 15 cm from the mouth. The direct digital recording sampled at 44100 Hz was recorded using an external soundboard (UH-7000 TASCAM, Teac Corporation, Montebello, CA, United States) connected to a personal computer (PC) running Audacity 3.1.3 (SourceForge, La Jolla, CA). Similarly to the procedure proposed by Švec and Granqvist, [20, 23] the calibration of the DIY consisted of comparing the SPL of a sustained /a/ vowel produced with a normal vocal effort measured with the DIY dosimeter and with the Lingwaves II SPL-meter. For the validation, the participants were instructed to produce three sustained /a/ vowels and then to read aloud the first six sentences of "The Rainbow Passage," a standardized text in English using three vocal effort levels (relaxed, normal, and raised). These tasks were recorded simultaneously via the DIY voice dosimeter and the M2211. The two recordings were analyzed and compared to determine the performance results of the DIY voice dosimeter.

3.1 Analysis

The evaluation of the accuracy of the DIY voice dosimeter was completed following ISO/IEC Guide 98-3. [24] This evaluation involved the comparison of the speech signals, which were recorded simultaneously on the DIY voice dosimeter and the reference microphone, resulting in estimated mean error of SPLmean and fo mean for both devices. The recordings were processed with MAT-

LAB R2022a (Mathworks, Natick, MA, USA) and Praat 5.4/5.4.17 (Netherlands). The SPL values were calculated with a Matlab custom-made script (available under request to the authors). The fo was estimated with Praat using the autocorrelation method and the following settings: Time step = 0.05 s; Pitch floor = 50 Hz, very accurate = yes, pitch ceiling = 500 Hz, and the standard values for the other settings (silence threshold, voicing threshold, octave cost, octave-jump cost, and voiced/unvoiced cost). Summary statistics were calculated to evaluate the uncertainty of the mean error of the parameters estimated by the devices. Prior to calculating the summary statistics, the interquartile technique was employed to remove outliers.

The evaluation of measurement uncertainty was based on previous uncertainty protocols for voice dosimeters. [14] In this study, the measurand was the Mean Error (ME) for SPLmean and fo mean considered separately. The uncertainty contributions due to reproducibility were considered for the different (a) participants, (b) tasks, and (c) styles. The Type A and Type B uncertainties of the ME were evaluated and then combined. The Type A uncertainties were obtained from the evaluation of the propagation of the uncertainty among participants over the 6 combinations of speech tasks and styles. The tasks and styles were chosen in order to create different amplitude (style) and fluctuation (task) of the signals, with the ultimate goal of minimizing the correlations among repeated within-subject measurements. The Type B standard uncertainty (evaluated using available knowledge from preliminary analysis of the data) was obtained by considering the uncertainties of the inputs of the ME (i.e., the uncertainties pertaining to the mean values of the time histories from both signal [DIY voice dosimeter] and signal [mic]).

4. RESULTS

4.1 Sound Pressure Level

The DIY voice dosimeter underestimated the SPLmean for the raised vowel, and all speech conditions, while it overestimated the SPLmean by 3 dB for the relaxed vowel. The DIY voice dosimeter had a mean error of –0.68 dB in the evaluation of SPLmean. Figure 2 displays the mean differences of the SPL between the signal [DIY voice dosimeter] and [mic] for each task and voice style.

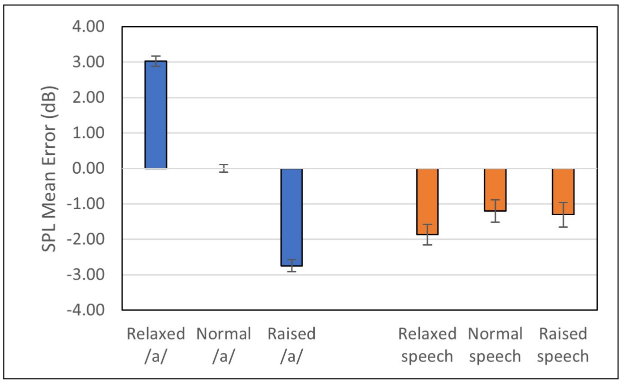

Figure 2. Mean differences in mean error of SPLmean between the DIY voice dosimeter and microphone for each task and voice style.

4.2 Fundamental Frequency

The DIY voice dosimeter slightly underestimated the relaxed vowel, and all speech conditions in both male and female participants. This underestimation of fo mean ranges from a magnitude of negative 0.3-1.6 Hz in males 0.1-1.6 Hz in females. For the fo mean, the mean values were calculated for each task, style and participant. The DIY voice dosimeter had a mean error of 0.65 Hz in the evaluation of fo mean for the male participants and a mean error of 0.72 Hz in the evaluation of fo mean for the female participants. The mean differences of the fo mean between the signal [DIY voice dosimeter] and [mic] for each task and voice style are shown in Fig. 3 for male participants and in Fig. 4 for female participants.

5. CONCLUSIONS

Following the present tutorial's calculation of the SPL and fo uncertainties, the DIY voice dosimeter can be considered a valid tool to be gather these objective acoustic measures in clinical and research settings as needed until more suitable dosimeter devices become commercially available. These findings imply that the DIY voice dosimeter device can be relied upon to gather valid measures of SPL and fo from users' voice signals. As previously mentioned, the present validation was performed on 10 healthy speakers, however, given the reliability in comparison to the M2211 microphone (a Class 1 microphone), we are operating under the assumption that the DIY voice dosimeter will perform reliably with a variety of voice signals (i.e., in individuals with voice disorders).

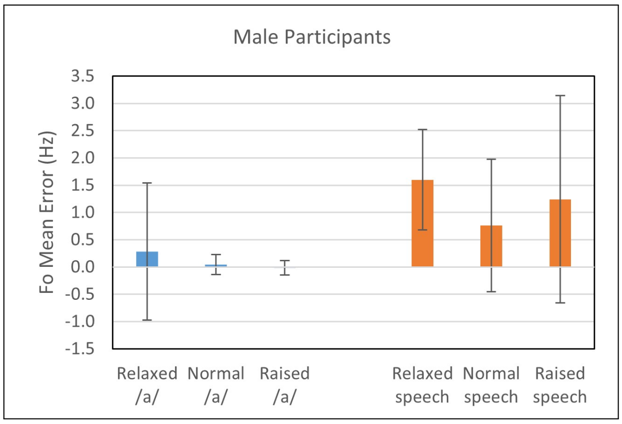

Figure 3. Mean differences in mean error of fo mean between the DIY voice dosimeter and microphone for male participants in each task and voice style.

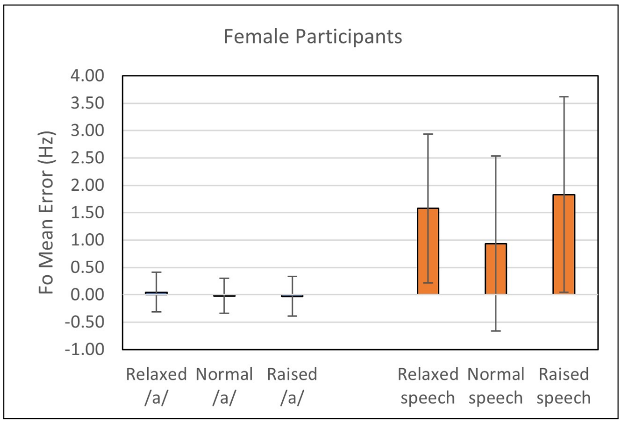

Figure 4. Mean differences in mean error of fo mean between the DIY voice dosimeter and microphone for female participants in each task and voice style.

6. ACKNOWLEDGMENTS

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