OBJECTIVE STRESS ASSESSMENT OF INDOOR NOISES BASED ON MULTIPLE LINEAR REGRESSION ANALYSIS

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Abstract- This paper proposes an objective assessment of stress under indoor noise conditions. In the proposed assessment method, both a qualitative stress score and quantitative feature parameters are collected according to a sequence of various indoor noises. Thequalitative stress score is obtained by continuously evaluatingthe perceptual intensity of stress for a certain period with a score ranging from 1 to 10 under indoor noise conditions. In addition, the quantitative stressscoreis represented by a combination of various audio feature parameters consisting of psychoacoustic, spectral, and temporal features. Finally, amultiple linear regression analysis is conducted on the pairs of the qualitative and quantitative stress scores to design an objective stress score estimator. It is shown from the evaluation that the proposed stress assessment method could estimate stress score with mean error of 1.06 and standard deviation of 0.92.

Keywords- objective stress assessment; indoor noise; qualitative stress score; audio feature parameter; multiple linear regression analysis.

I. INTRODUCTION

Indoor noises are one of the main causes of mental stress to a listener because they unintentionally stimulate the hearing sense [1]. To examine accurately the relationship between physical characteristics of the indoor noises and the severity of their effect on the listener's mental stress, an assessment method of indoor noises is required.

As a conventional method, equal loudness (Leq) has been widely used to measure the severity of indoor noises [2]. Since Leq measures the loudness perceived by the listener in a straightforward manner, it is the preferred mode of measurement for legal regulation and control involving various types of indoor noises [2]. However, the Leq alone is insufficient for measuring perceived the mental stress level from indoor noises, because it is limited to representing the physical loudness of the indoor noises, rather than the complex relationship with perceived mental stress. To overcome such a limitation, other objective stress assessments should be devised to represent the more complex relationship between stress intensity by indoor noises and numerous physical characteristics of indoor noise.

Thus, this paper proposes an objective stress assessment of indoor noises.In the proposed method, subjective stress assessment based on a listening test is first conducted. This is realized by asking participants to quantify the perceptual intensity of stress using a stress score ranging from 1 to 10 for a certain period of indoor noises. Since the indoor noises have different loudness levels, as well as different spectral and temporal characteristics, it is important to compensate for dynamic changes of the perceived stress level according to various types of indoor noises. Therefore, the stress score is iteratively evaluated throughout short sequences of indoor noises using a user interface designed for qualitative stress evaluation. Next, the quantitative feature parameters are extracted from the indoor noise sequence used in the subjective stress assessment part. Specifically, eleven different audio feature parameters, which are known as highly correlated with the stress score [3], are carefully chosen. Finally, the objective stress score estimator is designed by conducting a multiple linear regression analysis on the pairs of stress scores and the qualitative stress parameters.

Following this introduction, Section 2 describes a procedure of the subjective stress assessment for indoor noises. Section 3 proposes the objective stress assessment. Subsequently, Section 4 evaluates the proposed method and Section 5 concludes this paper.

II. SUBJECTIVE STRESS ASSESSMENT

Fig. 1 shows the procedure of the subjective stress assessment. As shown in the figure, the subjective stress assessment consists of two steps: participant screening and a listening test. A detailed description of each step is given in the following subsections.

2.1. Participant Screening

Since the subjective stress assessment depends on the subjective response to the stimulus of the indoor noise, determining the normal statuses of participants' mental and physical conditions is essential for reliable and consistent results. Therefore, all participants are first screened in terms of mental and hearing conditions. Specifically, all the participants first undergo a psychological test using the Minnesota multiphasic personality inventory-2 restructured form (MMPI2-RF) [4], where the MMPI2-RF consists of 338 yes/no questions and the time for taking the test is about 30 to 50 minutes. The result of the MMPI2-RF of each participant is then analyzed by a psychologist to screen

out those whose results indicate abnormal mental status.

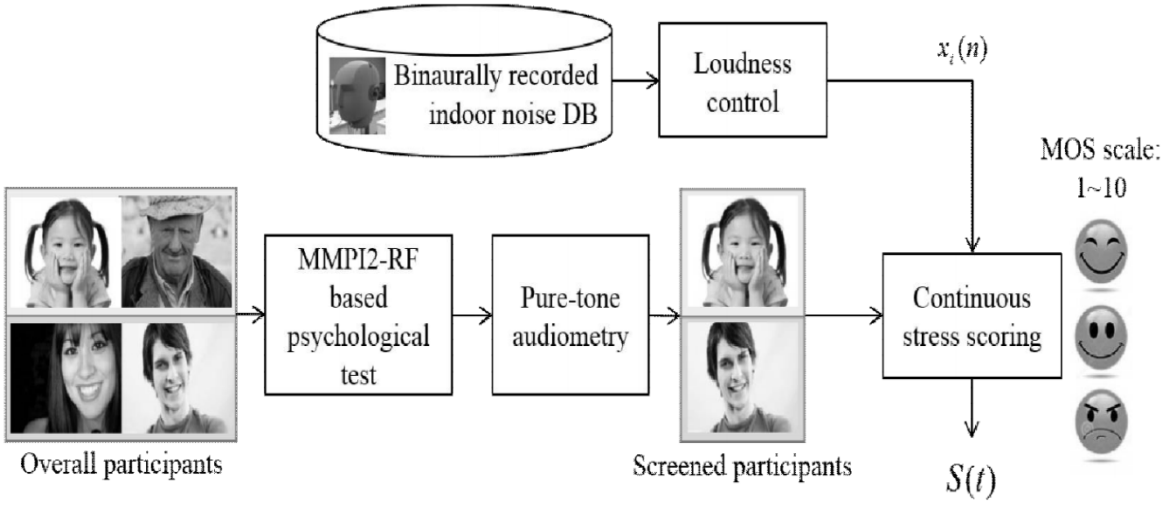


Fig.1. Procedure of the qualitative stress assessment.

Next, pure tone audiometry [5] is conducted on the participants who pass the first screening described above. In this part, tonal signals with frequencies of 250–8,000 Hz are used in testing, and the pure-tone average (PTA) [5] is measured for the further screening out inappropriate participants. Consequently, the participants who pass both screening steps are invited to the listening test for the qualitative scoring of stress.

2.2. Listening Test for Qualitative Stress Scoring

The listening test for subjective stress assessment is performed as follows. First, an indoor noise database (DB) compiled by the binaural recording technique is prepared in advance. The noise DB is composed of 28 different indoor noises recorded using a dummy head, where the noises are excerpted from the sound DB for stress assessment [6]. Next, each participant uses a qualitative stress scoring system to conduct the listening test. This scoring system consists of a listening test software, an input interface with jog-dial, Hi-Fi headphones, and a personal computer orchestrating all the software and the devices. Using this system, the participants are asked to give a stress score immediately using jog-dial for what they have perceived from the temporal moment of the indoor noise sequence that they have listened to through the headphones.

Using both the noise DB and the stress scoring system, a listening test is carried out for each participant. First, in order to get reference scores, noise data from the noise DB are divided into a sequence of consecutive segments whose length is T_b seconds long. Then, each screened participant listens to all the segments and gives perceptual stress scores to them. For a given segment, the scores obtained from all the participants are then averaged, and this average score is used as a reference score to this segment. In addition, the reference scores are used for a multiple regression analysis, which will be described in detail in the next subsection.

III. PROPOSED OBJECTIVE STRESS ASSESSMENT

In order to estimate a stress assessment score in an objective way, the quantitative feature parameters for the objective stress assessment are first calculated from the indoor noise sequence that is used in the qualitative stress assessment. In particular, eleven feature parameters, including three psychoacoustic parameters [7], six spectral and three temporal parameters [8], are calculated for each frame of the indoor noise sequence. Note that it has been determined that the set of eleven parameters is highly correlated with the stress score [3].

After the feature parameters are prepared, an objective stress score estimator is derived by a multiple linear regression analysis technique [8]. To this end, averaged stress score over all participants, $S(t)$, at the t-th frame is modeled as a linear combination of multiple feature parameters as

$$S(t) = b_0 + \sum_{i=1}^{11} b_i F_i(t)$$

where $F_i(t)$ indicates the i-th feature parameter at the t-th frame and b_i is the i-th regression coefficient. The multiple linear regression analysis described in Eq. (1) gives numerically optimal values of b_i. Finally, an objective stress score for a given indoor noise can be estimated by a weighted sum of $F_i(t)$ ofthe indoor noise with b_i .

IV. PERFORMANCE EVALUATION

The performance of the proposed stress assessment method was evaluated in terms of the mean andstandard deviation of errors between the reference stress score and the estimated one. Here, the reference stress score was obtained through averaging multiple subjective stress scores from 30 screened participants. In

addition, the length of indoor noise sequence, $x_t(n)$, and its unit frame length, T_b, were 300s and 3s, respectively. Thus, 100 estimated stress scores were considered in this evaluation.The mean and standard deviation of errors were measured as 1.06 and 0.92, respectively.

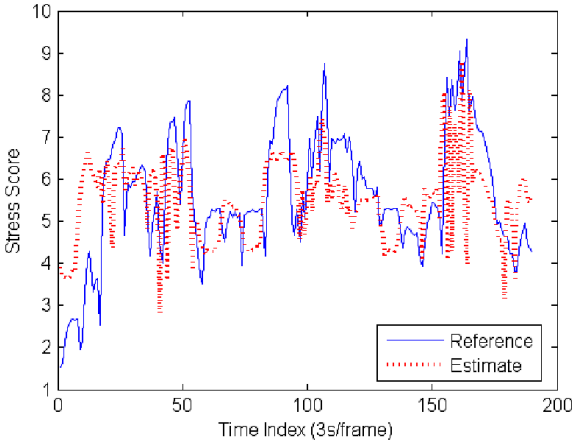


Fig.2. Example of trajectories of reference (blue line) and estimated stress score (red dotted line) obtained by using the proposed stress assessment.

Fig. 2 illustrates an example of trajectories of the reference and the estimated stress scores. As shown in the figure, the trajectory of the estimated stress score was very similar to that of the reference score. This reveals that the proposed stress assessment could represent the subjective stress of indoor noise.

CONCLUSION

In this paper, an objective assessment of stress under indoor noise conditions was proposed. To this end, the qualitative stress score was first obtained by continuously evaluatingthe perceptual intensity of stress for a certain period with a score ranging from 1 to 10 when an indoor noise sequence was played out through Hi-Fi headphones. Next, eleven different feature parameters, which were related topsychoacoustic, spectral, and temporal information, were extracted from the indoor noise sequences. Finally, the stress score estimator was derived from a multiple linear regression analysis between average stress score and the quantitative feature parameters. It was shown from the evaluation that the proposed method canestimate stress scoresaccurately in an objective way.

ACKNOWLEDGMENTS

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