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Research Article

Musicians' Hearing Handicap Index: A New Questionnaire to Assess the Impact of Hearing Impairment in Musicians and Other Music Professionals

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Purpose: We aimed to develop and validate the Musicians' Hearing Handicap Index (MHHI), a new self-evaluation tool for quantifying occupation-related auditory difficulties in music professionals. Although pure-tone audiometry is often considered the "gold standard" and is usually employed as the main instrument for hearing assessment, it cannot fully describe the impact of hearing dysfunction. The MHHI is an attempt to complement the hearing impairment assessment toolbox and is based on a unique approach to quantify the effects of hearing-related symptoms or hearing loss on the performance of musicians and other music industry professionals.
Method: An initial set of 143 questionnaire items was successively refined through a series of critical appraisals, modifications, and suggestions. This yielded an intermediate questionnaire consisting of 43 items, which was administered to 204 musicians and sound engineers. After exploratory factor analysis, the final form of the MHHI questionnaire was obtained, consisting of 29 items. The questionnaire's test–retest reliability, internal consistency, discriminating power, content validity, criterion validity, and aspects of construct validity and inherent conceptual structure were assessed.
Results: Exploratory factor analysis revealed a combination of four common factors for the 29 validated questionnaire items. They were named "impact on social and working lives," "difficulties in performance and sound perception," "communication difficulties," and "emotional distress." The MHHI was shown to be a valid and reliable instrument to assess musicians' and sound engineers' occupational difficulties due to hearing impairment and related symptoms.
Conclusion: The ability of the MHHI to discriminate between groups of music professionals with different auditory symptoms or pure-tone audiometry thresholds suggests that auditory symptoms might influence a professional's performance to an extent that cannot be assessed by a pure-tone audiogram.

Musicians and other professionals involved in the music industry, including music producers and sound engineers, constitute a special occupational group in which music-induced hearing loss has been identified as a major clinical entity (Schink et al., 2014; F. Zhao et al., 2010). Music-induced hearing loss can be defined as gradually developing high-frequency sensorineural hearing loss in response to chronic exposure to loud music. It manifests on pure-tone audiograms (PTAs) either as notches at 3000, 4000, or 6000 Hz or as a high-frequency down-sloping audiometric configuration (Jansen et al., 2009; Phillips et al., 2010). There is also evidence of a high prevalence of tinnitus and hyperacusis with or without hearing loss in this group (Kähäri et al., 2003; Schink et al., 2014).

The World Health Organization (WHO) defines a handicap as "a disadvantage for a given individual, resulting

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from an impairment or a disability, that limits or prevents the fulfillment of a role that is normal (depending on age, sex, and social and cultural factors) for that individual" (WHO, 1980). It is commonly reported that even small changes in hearing ability, along with symptoms such as tinnitus and hyperacusis, can have a detrimental effect on the working ability of musicians and sound engineers, potentially even ending their careers (Žuškin et al., 2005).

However, PTAs cannot adequately describe the impact of hearing loss (Newman et al., 1990). Although the literature reports several validated questionnaires for evaluating the effects of voice disorders, anxiety, and musculoskeletal pain in singers and musicians, no such tools are readily available to quantify the effects of hearing-related symptoms or hearing loss on the performance of musicians and other music professionals (Brugués, 2009; Cirakoğlu & Sentürk, 2013; Cohen et al., 2007). Questionnaires on the perception of a handicap, originally designed for other populations, might not be suitable for identifying issues associated with hearing loss in them. In this specific population, hearing loss might have a significant impact not only on social, situational, and emotional responses and well-being (Ventry & Weinstein, 1982) but also on work productivity and financial health (Archbold et al., 2014; Checkley, 2015; Knutt, 2018; Pouryaghoub et al., 2017; Schink et al., 2014; Webber, 2019; F. Zhao et al., 2010). Additionally, most existing questionnaires on hearing loss lack both a multifaceted design (accounting for different aspects, manifestations, or etiologies of hearing loss and its consequences) and a common language and approach, such as those proposed in the WHO International Classification of Functioning, Disability and Health (ICF). The lack of a common language often obscures the ability to identify factors affecting hearing loss and their relationship with the clinical diagnosis (Granberg, Pronk, et al., 2014). The ICF is a framework for classifying activity limitations and/or participation restriction. As described by the WHO, ICF assists in scientific research by providing a framework or structure for interdisciplinary research on disability and for allowing research results to be comparable.

In the contemporary framework of self-production and distribution of music, the same person frequently undertakes various roles (e.g., musician, recording or stage sound engineer, producer) involving listening, perceiving, performing, and coordinating, among others. (Bennett, 2013; Pras & Guastavino, 2011; Strasser, 2009; Zager, 2011). Therefore, here, a music professional is defined as an individual with a multitude of roles in the music industry who might be exposed to a variety of factors affecting hearing function such as high sound levels or increased duration of exposure. Consequently, a questionnaire (such as the one proposed in the current study) that can quantify the perceived impact of hearing loss on music professionals would be an important development. Of course, deeper engagement with a specific role in the music industry could justify a specific job title (e.g., sound engineer, performer, music producer). The separate investigation of specific cases is an important task that will be considered in further research.

Here, we describe the development of the Musicians' Hearing Handicap Index (MHHI), a concise instrument that measures the perceived impact of hearing-related issues on the ability of musicians and other music professionals to work and perform.

Method

Our study included three major steps: selection of items and development of the initial version of the MHHI, administration of the questionnaire to a sample of the population of interest, and analysis of the results and evaluation of their validity and reliability, resulting in the development of the final form and structure of the MHHI. The study design and planning are shown in Table 1. The next sections follow the flow of activities listed in Table 1.

Item Development

Item Selection and Development of the Initial Version of the MMHI

The process was completed in three stages. The selection of the questions was based on the methodology described by Haynes et al. (1995). We searched previously developed questionnaires on PubMed and Google using the following keywords: "questionnaire AND music AND hearing," "questionnaire AND music," "questionnaire AND musician," "questionnaire AND performers," "questionnaire AND singers," and "questionnaire AND hearing." The collected questionnaires were categorized into three groups:

Group A: Questionnaires used in the general population to assess hearing or other hearing-related conditions. These were the Hearing Handicap Inventory for Adults (HHIA; Newman et al., 1990), the Hearing Handicap Inventory for the Elderly (Ventry & Weinstein, 1982), the Tinnitus Functional Index (Meikle et al., 2012), the Tinnitus Handicap Inventory (Newman et al., 1996), the Tinnitus Handicap Questionnaire (Kuk et al., 1990), the Hyperacusis Questionnaire (Khalfa et al., 2002), and the Social Hearing Handicap Index (Ewertsen & Birk-Nielsen, 1973).

Group B: Questionnaires used in musicians/nonmusicians to assess their perception of music after cochlear implantation. These were the Musical Cohort Health Questionnaire West (Hagberg, 1980), The University of Canterbury Music Listening Questionnaire (Looi & She, 2010), the Munich Music Questionnaire (Brockmeier, 2000), and a patient questionnaire on the appreciation of music in adult patients with cochlear implants (Mirza et al., 2003).

Group C: Questionnaires used in performers (musicians, singers). These questionnaires were not necessarily related to hearing issues; rather, they assessed the extent to which a dysfunction could affect professional life. This group also included questionnaires about musical background, social life, and occupational hazards. The questionnaires were the Singing Voice Handicap Index (Cohen et al., 2007); the Voice Handicap Index for Singers (Rosen & Murry, 2000)' the Musculoskeletal Pain Intensity and

Table 1. Study design and planning.

	Task	Time	Actors/participants	Results	Remarks
Item development	Literature review	t_A – 1 year	Authors	184 items	
	Determination of domain				
	Item generation				
	Validation of items' content	t_A – 6 months	4 authors/experts	37 items	
	Face validation of items	t_A – 3 months	14 music professionals	43 items	
MHHI development	Subjects' Recruitment	t_A	204 music professionals		As the completion of the main administration of the 43-item questionnaire with 204 participants took more than 3 months, the EFA and dimensionality reduction were completed more than 6 months after t_A (the time of administration to the first participant). Consequently, all validity and reliability administrations were conducted upon the 43-item questionnaire, and the results were reduced to the final 29-item MHHI.
	Questionnaire Administration (43-item qnr.)				
	EFA	(See the Remarks)		29 items	
	Dimensionality Reduction			4 factors	
	Construct Validation				
	Scoring				
MHHI evaluation	Internal Consistency	(See the Remarks)	204 music professionals	Split-half reliability	
	Test-retest Reliability (upon 43-item qnr.)	t_A + 15 days	57 music professionals	ICC(3, 1) for the 29-item MHHI	
	Criterion Validation (upon 43-item qnr. vs. HHIA)	t_A + 1 month	130 music professionals	Pearson/Spearman correlation coefficients	
	Known-groups Validation			Group differences	

Note. t_A (the time of administration of the 43-item questionnaire to the first participant) was taken as time reference. MHHI = Musicians' Hearing Handicap Index; qnr. = questionnaire; EFA = exploratory factor analysis; ICC = intraclass correlation coefficient; HHIA = Hearing Handicap Inventory for Adults.

Interference Questionnaire for Professional Orchestra Musicians (Berque et al., 2014); the Jazz Musicians Questionnaire (Jeffri, 2015); a questionnaire on musicians' use of hearing protectors, self-reported hearing disorders, and the experience of their working environment (Laitinen & Poulsen, 2008); and a questionnaire on the musician–instrument relationship as a candidate index for professional well-being in musicians (Simoens & Tervaniemi, 2012).

Nine of these questionnaires were assessed as the most relevant (Ewertsen & Birk-Nielsen, 1973; Brockmeier, 2000; Cohen et al., 2007; Khalfa et al., 2002; Kuk et al., 1990; Newman et al., 1996; Newman et al., 1990; Simoens & Tervaniemi, 2012; Ventry & Weinstein, 1982). A pool of items was generated after reviewing the literature, with some of the items being inspired, modified, or adapted from other health-related questionnaires mentioned above.

Several items were categorized under the components of both parts of the ICF Core Set for Hearing Loss (Granberg, Pronk et al., 2014; ICF Research Branch, 2017): Part 1, Functioning and Disability (Body Functions [b] and Activities & Participation [d]) and Part 2, Contextual Factors (Environmental Factors [e]). Although the ICF Core Set for Hearing Loss does not determine specific categories for Personal Factors in Part 2, several notions in our items (such as "stress" or "being left out") were directly assigned to this subpart of the ICF Core Set for Hearing Loss, as in previous studies (Granberg, Swanepoel, et al., 2014).

Four of the authors (an otolaryngologist, a speech and language therapist, a musicologist, and an orchestra conductor), with a large amount of working experience with musicians and performers, conducted a thorough assessment of the relevance and appropriate adaptation of the 184 items that were initially selected. They aimed to achieve a significant reduction in the length of the questionnaire and to ensure the validity of its content. We filtered out items with an item content validity index of < .8 (Polit & Beck, 2006; Zamanzadeh et al., 2015). This procedure yielded 37 items, which were used in the subsequent steps of the current study.

In the next step, we administered the 37-item questionnaire to 33 professional musicians and sound engineers. They were asked to comment on the relevance and appropriateness of the items for quantifying hearing functionality. Several concepts concerning hearing functionality were illustrated and discussed with the participants before the submission of their comments. They were also encouraged to make their own suggestions, verbally or in writing, on the questionnaire format. At this stage, 14 subjects completed the questionnaire (19 of the 33 professionals dropped out), and six new items were added based on their suggestions, yielding a 43-item questionnaire. To keep the evaluation procedure simple, we adopted a binary rating of the relevance/appropriateness instead of more elaborate methodologies (Nair et al., 2011; Thorn et al., 2018; Zamanzadeh et al., 2015), requiring a consensus of > 75% among the 14 respondents (Melo et al., 2017). Therefore, an item was accepted if more than 11 respondents marked it as appropriate. Items regarded as irrelevant or inappropriate by a respondent (or when a new item was suggested) were discussed in person with the respondent and subsequently rephrased/adapted. After subjecting also the rephrased/adapted and the newly suggested items to a final consensus review round (among the 14 respondents), the number of items of the questionnaire increased to 43, with the adoption of six newly suggested items. This process ensured adequate face validity of the questionnaire.

The resulting 43-item questionnaire was developed, administered, and validated in Greek. A certified professional translator and a clinician who is a proficient English speaker independently translated all of the items into English, thus following a double/parallel translation approach (Behr, 2018). Any discrepancies between the two translations were resolved by a third proficient but nonnative English speaker (also a clinician and one of the authors of the current study). However, the final English version of the questionnaire needs to be validated using the back-translation methodology (Hall et al., 2018; Son, 2018).

Classifications of the major effects of hearing loss are available in the literature (Foxton et al., 2004; Heffernan et al., 2016; Husain et al., 2014; O'Reilly et al., 2015; Portnuff, 2016; Reed, 2018; Sellman, 2009; WHO, 2019). Following these classifications, the items were initially divided into four domains, as follows: (a) social difficulties, (b) physical difficulties during performance related to hearing impairment (e.g., Appendix B, B4), (c) music perception difficulties related to hearing impairment (e.g., Appendix A, C4), and (d) emotional difficulties.

MHHI Development

The questionnaire used a 5-point Likert scale, in which the minimum and maximum scale values of 0 and 4 represent *never* and *always*, respectively. Higher scores indicate more severe problems. The default scale value is anchored at 0 (*never*). The total questionnaire score was computed as the sum of the response values on the Likert scale for all items. The participants were instructed to answer all questions. They were also instructed to respond with a 0 when they felt that an item did not apply to them.

Administration to a Sample Population: Subjects and Scoring

A total of 204 professional musicians and music professionals participated in the main study. The subject demographics are presented in Table 2. The mean age (± standard deviation [*SD*]) was 35.7 ± 9.1 years; 155 subjects (76%) were men, and 49 (24%) were women. Only six worked exclusively as sound engineers, while 72 worked as musicians and sound engineers or as musicians and music producers. Seventy-four (36.3%) of the subjects were classical music performers, and 62 of them were also employed in nonclassical orchestras. The rest of them were nonclassical music professionals. The instruments played included strings (23%), piano/keyboards (17.2%), percussions (11.8%), and woodwinds (6.4%). Fifty-nine (28.9%) of the subjects were also singers. The mean duration of occupation-related exposure to music was 13.0 ± 7.8 years.

Table 2. Subjects' group demographics and Musicians' Hearing Handicap Index (MHHI) total scores.

Variable	Group 1	Group 2	Group 3	Group 3.1	Group 3.2	Total
n	38	54	112	38	74	204
Age (*SD*)	29.2 (6.3)	34.2 (8.3)	38.7 (8.9)	38.0 (9.2)	39.0 (8.8)	35.7 (9.1)
Male (sex)	30	33	92	28	64	155
Years of exposure (*SD*)	6.2 (6.1)	10.6 (8.3)	14.5 (8.9)	14.0 (10.0)	14.8 (8.5)	13 (7.8)
Tinnitus, *n* (%)	—	37 (69.8)	64 (57.1)	—	64 (86.5)	101 (49.5)
Hyperacusis, *n* (%)	—	37(69.8)	35 (31.2)	—	35 (47.3)	72 (35.2)
Distortion, *n* (%)	—	6 (11.3)	9 (8.0)	—	9 (12.2)	15 (7.3)
Diplacusis, *n* (%)	—	2 (3.8)	4 (3.6)	—	4 (5.4)	6 (2.9)
MHHI total score (*SD*)	5.5 (5.7)	21.1 (14.8)	13.9 (13.5)	8.3 (4.9)	17.1 (8.8)	15.1 (16.1)

Note. The em dashes signify that the variable is not-applicable or meaningless for the specific group (e.g. tinnitus in Group 1).

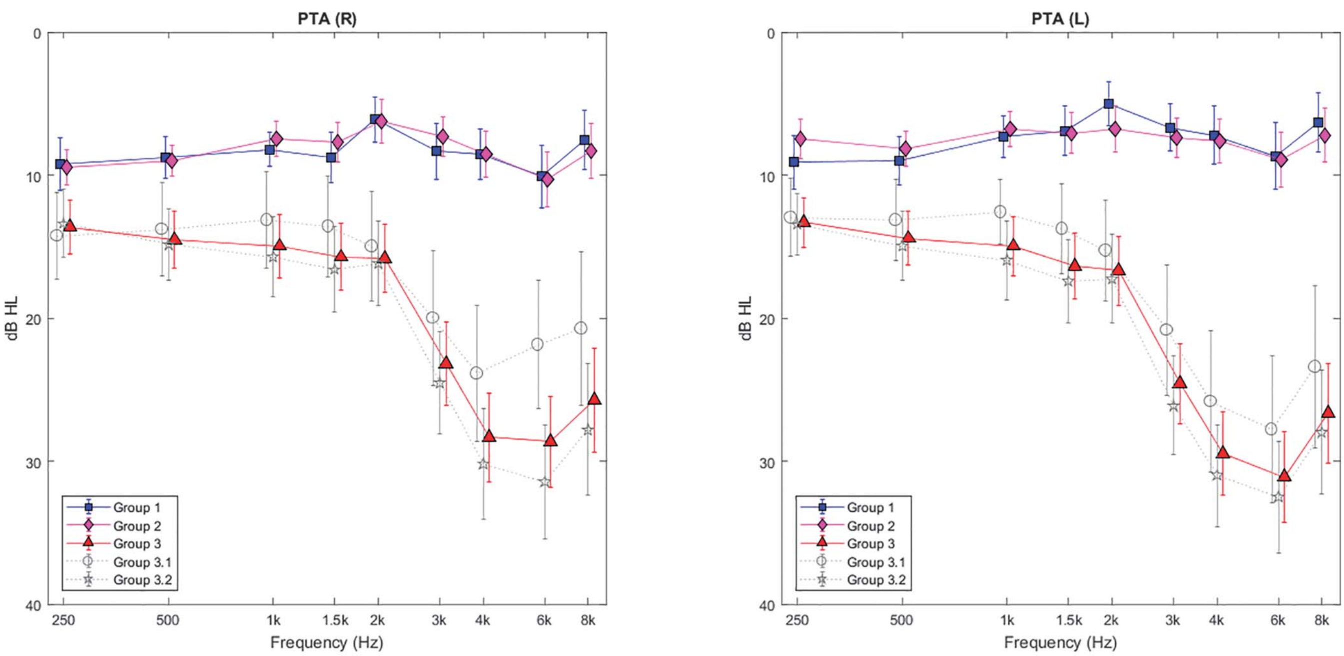
The participants were volunteers who signed a consent form approved by the Ethics Committee of the Hippocrateion Hospital in Athens (Reg. No. 9531, 27/5/2014) prior to participating in the study; all procedures were performed following the Declaration of Helsinki. All participants were recruited from the Musician's Clinic of the 1st Department of Otolaryngology at the National and Kapodistrian University of Athens. To limit the potential impact of presbycusis, the age of the participants was limited to the range of 18–59 years. All participants were asked to avoid noise or music exposure for at least 48 hr before audiological testing to minimize any temporary threshold shift effects. Amateur musicians and subjects with conductive hearing loss, as well as patients diagnosed with retrocochlear pathology or Ménière's disease, were excluded. All participants underwent a detailed otorhinolaryngology examination, including classical audiometry with an Amplaid A321 audiometer (EN 60645-1, ANSI S3.6-1996) using TDH49 headphones (tested at 250, 500, 1000, 1500, 2000, 3000, 4000, 6000, and 8000 Hz) and tympanometry using a GSI TympStar Version 2 tympanometer.

Ideally, the value of any measurement instrument depends on its discriminatory power, that is, the optimal balance between sensitivity and specificity, according to its intended use. For a screening tool or a confirmatory tool between subgroups with specific characteristics, high sensitivity is especially desirable (Lan et al., 2017; Schwartz & Martin, 2012). In our study, we addressed a particular population (music professionals) with a specific prevalence of symptoms and audiometric characteristics (Di Stadio et al., 2018; Schink et al., 2014). Thus, a series of dichotomies related to symptoms and audiometric characteristics is necessary to assess the discriminatory power of the tool for a specific population. Additionally, such dichotomies may facilitate the investigation of its value in isolation (e.g., preclinical assessment/screening) or alongside clinical evaluations with or without audiometric measurements. A natural dichotomy arises between normal or pathological PTA (thresholds ≥ 25 dB HL). Another difference becomes evident, noting that several participants, having pure-tone thresholds within normal limits, complained of severe auditory symptoms, which cannot be attributed to threshold shifts. Other participants, also with normal pure-tone thresholds, did not report any symptoms. Several previous studies investigated symptoms, such as tinnitus or reduced speech perception, in listeners with a normal audiogram. They suggested the existence of a new clinical entity, cochlear synaptopathy, also known as "hidden hearing loss." Thus, we decided to assign our subjects to three major groups based on a normal or abnormal PTA (audiometric thresholds > 20 dB HL in at least one frequency in both ears) and the presence or absence of self-reported auditory symptoms (tinnitus, hyperacusis, distortion), irrespective of any further quantification or evaluation by the researcher. Group 1 included subjects with normal PTA thresholds and no reported symptoms and was considered the reference group; Group 2 included subjects with auditory symptoms and a normal PTA; and Group 3 included subjects with an abnormal PTA, regardless of the presence or absence of symptoms. We further divided Group 3 into two subgroups: those without symptoms (Subgroup 3.1) and those with symptoms (Subgroup 3.2). These types of dichotomies between subjects, besides their substantive meaning in terms of PTA thresholds and auditory symptoms, also facilitate a convenient way of conducting and interpreting a subsequent "known-groups" validity assessment. Figure 1 shows the PTA thresholds for both ears in the three groups of subjects.

There was no important asymmetry between the thresholds of the two ears in any of the groups. The sample size and the number of items were chosen to make them suitable for the subsequent exploratory factor analysis (EFA): (a) an item-to-factor ratio of > 5:1 (the number of items [*p*] was 43, and the expected number of retained factors [*r*] did not exceed 5; MacCallum et al., 1999; Matsunaga, 2010) and (b) a participant (*N*)-to-item (*p*) ratio (*N:p*) of approximately 5:1 (Costello & Osborne, 2005). The final number of subjects (*N*) enrolled was 204.

Regarding the item-to-factor ratio (*p:r*), McCallum et al. (1999) showed that the possibility of poor convergence of factor solutions or Heywood cases is practically eliminated when this ratio exceeds 6.6 (20:3), provided that the sample size is at least 100, even when communalities are low. The item-to-factor ratio, also known as overdetermination, is critical since "…weakly overdetermined factors tend to exhibit poor simple structure without a substantial number of high loadings…it is desirable that the number of variables be at least several times the number of factors…recommended at least five times as many variables as factors…" (MacCallum et al., 1999). In our case, *p:r* was 43:4, which clearly

Figure 1. Mean thresholds and ±2 *SE* for each group for the right ear, PTA (R), and for the left ear, PTA (L), are shown. PTA = pure-tone audiogram.



satisfied the above recommendations. Regarding the participant-to-item ratio (*N:p*; in our case 204:43 ≅ 4.75:1), the literature presents significantly diverse suggestions, from as low as 3:1 up to 10:1 or higher (Cattell, 1973; Everitt, 1984). As *N* increases, factor solutions are expected to become more stable. Some studies also demonstrate the interaction between *N*, *p:r,* and factor communalities (MacCallum et al., 1999), with very accurate solutions even with *N:p* as low as 1.2. In other words, "…there is not a minimum level of *N* or *N:p* ratio to achieve good factor recovery…" (Hogarty et al., 2005). It seems that the optimal cutoff value for *N:p* depends on several problem-specific characteristics. In the literature, most studies use an *N:p* of < 5:1 (Anthoine et al., 2014; Costello & Osborne, 2005). Many other factors may need to be considered, including sample size, study period, recording of lengthy questionnaires, and dropout rate, among others. An excellent summary of these issues and literature suggestions regarding sample sizes can be found in the study by N. Zhao (2009). In this study, the *N:p* ratio of 4.75:1, in conjunction with an adequate *p:r* and the moderate-to-high factor communalities obtained, supports a stable factor solution. Nevertheless, the EFA results shall be complemented by a separate future study with different participants and the use of structural equation modeling techniques such as confirmatory factor analysis.

Statistical Analysis

The statistical analyses were performed using SPSS Version 22 (IBM Corp.). The data were checked for normality using the Shapiro–Wilk test. After assessing the questionnaire with the 204 participants, the following types of items were excluded from the final questionnaire: (a) items with limited intersubject variability and hence limited discrimination ability between subjects (these were defined as the items to which the same answer was given by > 90% of the participants) and (b) items with a low absolute value of loading (< .35) in a subsequent EFA. The EFA was performed, after testing for sampling adequacy using the Kaiser–Meyer–Olkin test and checking the between-items correlation matrix (interitem Pearson r: $.002 \leq r \leq .78$) using Bartlett's test of sphericity. After extraction, the factors were checked for reliability using Cronbach's alpha. The MHHI factor scores were computed by the *regression score* estimation method, which essentially weighs each item's z score by the specific item loading on each factor while relieving the effect of interitem correlations. This approach has the advantage of higher stability between different samples while retaining each item's effect upon the common factors (Distefano et al., 2009; Rummel, 1970). The MHHI total score was computed by summing the scores of all factors. The scoring method can be mathematically formulated as follows (Gorsuch, 2014):

$$\mathrm{MHHI}_r = \sum_{i=1}^{N_F} \mathrm{FS}_i, \tag{1}$$

where

$$\mathrm{FS}_i = Z_{1\times V} \cdot (R_{V\times V})^{-1} \cdot P_{iV\times 1}. \tag{2}$$

N_F is the number of retained factors from the EFA (namely dimensionality).

FS_i is the score for each individual on factor *i.*

$Z_{1 \times V}$ is the row vector of *z* scores of questionnaire items (*V*).

$R_{V \times V}$ is the questionnaire's interitem correlation matrix.

$P_{iV \times 1}$ is the column vector of factor *i* in the pattern matrix.

Finally, the $MHHI_r$ is converted to the MHHI total score by rescaling it into a range of 0–100, as MHHI total score $= \frac{MHHI_{r-min}}{max-min} 100$, where min and max are the minimum and maximum values of the $MHHI_r$ obtained from an adequate sample size (204 subjects in the current study).

Differences in sex and age were checked using the Mann–Whitney *U* test. The test–retest reliability was determined with the intraclass correlation coefficient (ICC; 3, 1) and Pearson correlation (Heinrich et al., 2019; Koo & Li, 2016; Vaz et al., 2013). To do so, the questionnaire was administered to 57 participants, who were randomly selected from our 204 subjects. This was performed 7–15 days after the participants completed it for the first time. This duration is considered an adequate retest time interval in the literature, as it offers a balance between possible carryover effects and short-term response shifts (Marx et al., 2003; Polit, 2014), with the proviso of no reported or measured changes in the subject's auditory function.

MHHI Evaluation

The evaluation of the MHHI included an investigation of several types of reliability and validity. The internal consistency of the MHHI was assessed using the split-half approach. We investigated the known-groups validity of the MHHI total score and subscales (factors) using a nonparametric equivalent of the parametric analysis of covariance (Jones, 2017; Petraitis et al., 2001) since assumptions regarding normality and homoscedasticity were not satisfied in most cases. Age was used as a covariate to control for its possible effect. This test belongs to a general group of nonparametric tests (Karpati et al., 2017; Nichols & Holmes, 2001; Petraitis et al., 2001). Randomization is used in the form of data permutations for estimation of the distribution of mean differences between groups. Thus, it checks the null hypothesis, H0, according to which all MHHI scores originate from the same distribution. The use of randomization tests is also mandated over conventional nonparametric testing, as the former can also facilitate control of covariates (such as age in our case). To do so, the randomization tests were conducted in MATLAB (Mathworks, Inc., Release 2017a.), employing 4,000 permutations. This number was considered adequate in terms of the convergence rate of the estimated statistical significance of the main effects on the means' difference between compared conditions over the number of permutations. When progressively increasing the number of permutations, the rate of change of the main effect's significance was smaller than .01 per 100 of the 4,000 permutations.

Results

MHHI Development

Administration to a Sample Population—Subjects and Scoring

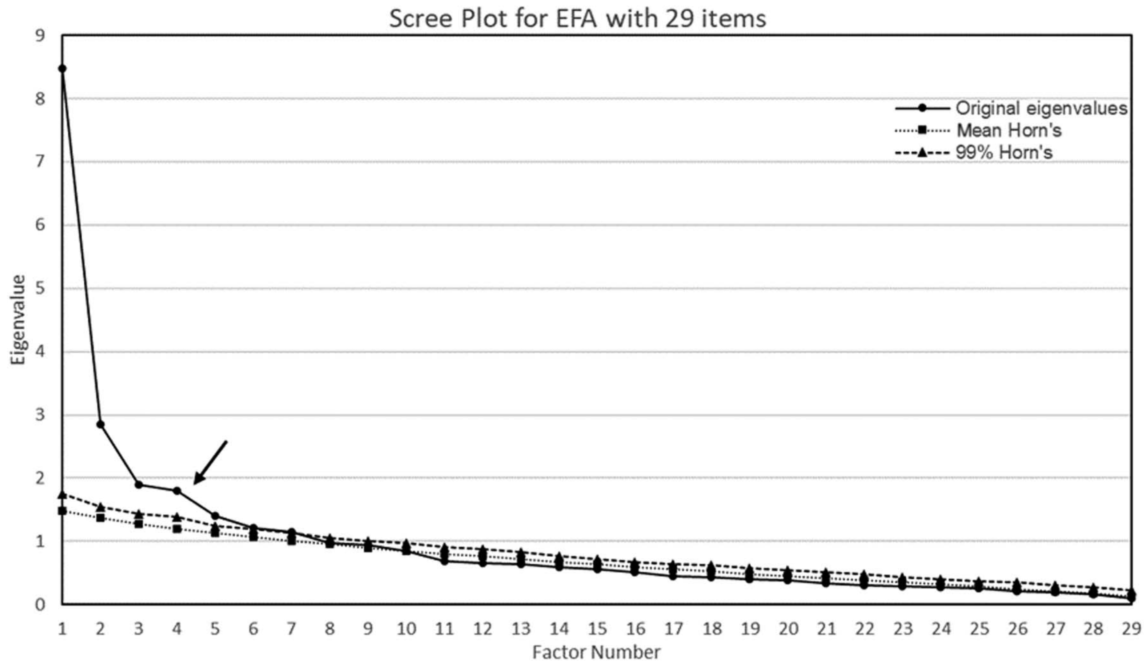
Table 2 shows the subject demographics and the mean values and *SD*s (intersubject) of the MHHI total score for the three groups of subjects. The MHHI total score distribution was positively skewed, mostly unimodal, and often with long right tails.

Exploratory Factor Analysis

From the initial 43-item questionnaire, nine items with high intersubject similarity were removed, yielding a 34-item questionnaire. The EFA was conducted on the responses to the 34-item questionnaire using principal-axis factoring with oblique rotation (Promax, kappa = 4). The Kaiser–Meyer–Olkin measure for sampling adequacy was 0.837, and Bartlett's test of sphericity was significant at $p < .001$. Therefore, EFA for the 34-item questionnaire was considered viable. Figure 2 shows the scree plot of the EFA and the results of the Horn's parallel analysis (Hayton et al., 2004) for estimating the number of meaningful factors. Using the 99th percentile criterion, seven factors yielded a meaningful solution (Appendix C). Using the no-randomness criterion (instead of the 99th percentile), 11 meaningful factors could be retained. However, for reasons of parsimony, we finally retained fewer than seven factors. Observing the scree plots and the decline of explained variance per factor, we reached a solution that included four factors. The characteristic pattern of diminishing eigenvalues around the arrow shown in Figure 2 is also reported in the literature as a criterion for selecting dimensionality (Rummel, 1988). The first and second factors explained 38.4% of the total variance. After the exclusion of five items with absolute loadings of < .35, a 29-item version of the questionnaire was obtained, and the EFA was performed again. This EFA on the 29 items did not produce any changes in the composition of common factors, and the differences in variance accounted for (VAF) were negligible. The final version of the 29-item MHHI is shown in Appendix A, and the 14 items that were omitted from the initial 43-item version are presented in Appendix B. Thus, the final version of the MHHI, consisting of 29 items and four factors, explained 51.8% of the total variance (from 29.2% down to 6.2% for each factor). Table 3 presents the final 29-item solution of the EFA, with four common factors. All items (except for item D5) loaded significantly on a single factor, yielding a compact solution. Although the total explained variance was relatively low, it is consistent with the results of similar studies (including the "HHIA," the "Hearing Handicap Inventory for the Elderly," and the "Tinnitus Handicap Questionnaire"), in which the explained variance ranged between 45% and 57.6% (Kuk et al., 1990; Newman et al., 1990; Ventry & Weinstein, 1982).

Three experts among the authors (an otolaryngologist, a speech and language therapist, and an orchestra conductor)

Figure 2. Scree plot of the exploratory factor analysis (EFA) solution.



were asked to independently assign unique qualitative names to the common factors, based on the WHO's recommendations for the ICF (Fox et al., 2015). After the overall consideration and review of the experts' suggestions, a consensus was reached, contributing to the questionnaire's content validity (de Vet et al., 2011).

The factors were named as follows:

- Factor 1: Impact on social and working life
- Factor 2: Difficulties in performance and sound perception
- Factor 3: Communication difficulties
- Factor 4: Emotional distress

The Cronbach's alpha values for the factors (.864 [eight items], .837 [eight items], .727 [seven items], and .751 [six items], respectively) were used as measures of their internal consistency, also known as "internal reliability" or "structural reliability" (de Vet et al., 2011). Such values are considered good to acceptable (Streiner & Norman, 2008). The MHHI's total score item reliability (Cronbach's alpha when any one item was deleted) ranged between .880 and .900.

During the EFA analysis phase, we also investigated EFA solutions with an increased number of retained factors (up to eight). As the number of factors was increased, the explained variance also increased, but the number of items per factor decreased. When we retained more factors, the distribution of items to factors allowed for a clearer interpretation of their underlying concept/nature. In Appendix C, we present an EFA solution with seven retained factors and 29 items, which we favor as the solution with the most straightforward factor interpretation. However, we also noticed that increasing the number of factors beyond four was also followed by a drop in their internal consistency metrics and a slight decrease in Cronbach's alpha for the first four factors and the overall MHHI. The Cronbach's alphas of the additional factors were lower than .7, ranging between .615 and .68. These values are generally regarded as "poor/questionable," especially for results of basic research or clinical questionnaires (Streiner & Norman, 2015). Additionally, as the number of factors increased, the item-to-factor ratio decreased (see the discussion in the Method section). Therefore, we chose the four-factor solution as it was most appropriate in terms of the commonly accepted suitability criteria. Some further comments are made in the "Discussion" section of the article.

Pearson correlations between MHHI factors and between each factor and the total score are shown in Table 4. All of them were statistically significant. The highest correlation values, between Factors 2 and 3 (.563) and between Factors 2 and 4 (.568), indicated a possible, albeit moderate, relationship between their respective concepts. Such relationships suggest the need for further analyses of the underlying social, psychological, or physiological processes; however, this is beyond the scope of this article. All factors correlated well with the MHHI total score ($.73 < r < .84$).

Table 5 (see the section on known-groups validity below) shows the results of the statistical tests for mean differences among all groups. No differences between the sexes were noted in the total score ($F = 0.396$, $p = .427$). Furthermore, the MHHI total score and age were uncorrelated

Table 3. Factor loadings for the 29 items of Musicians' Hearing Handicap Index (MHHI).

Item	MHHI subscales (factors): Impact on social and working life (Factor 1)	Difficulties in performance and sound perception (Factor 2)	Communication difficulties (Factor 3)	Emotional distress (Factor 4)
A4	**0.907**	0.104	−0.129	−0.115
D6	**0.884**	−0.029	0.047	−0.170
A5	**0.868**	−0.113	0.057	−0.125
A7	**0.578**	0.128	0.136	−0.082
D1	**0.564**	−0.045	0.357	−0.043
D7	**0.395**	0.070	−0.052	0.309
D4	**0.391**	0.137	0.131	0.195
A9	**0.335**	0.074	−0.225	0.193
B3	0.077	**0.645**	−0.030	−0.217
B10	0.072	**0.627**	−0.024	−0.128
B11	0.108	**0.565**	−0.047	−0.028
B1	−0.090	**0.552**	0.043	0.019
D12	0.208	**0.493**	−0.008	0.155
B6	−0.091	**0.472**	0.151	−0.018
B8	0.239	**0.449**	0.053	0.023
D5	0.315	**0.384**	0.109	0.131
D8	0.069	−0.086	**0.609**	0.120
A6	−0.018	0.007	**0.588**	0.065
D2	0.222	−0.072	**0.572**	0.036
C1	−0.167	0.368	**0.529**	−0.007
A8	0.337	−0.207	**0.522**	0.029
C4	−0.241	0.341	**0.487**	0.088
C5	−0.135	0.328	**0.435**	−0.069
D10	0.180	−0.212	0.053	**0.726**
D9	−0.119	−0.121	0.145	**0.611**
A1	−0.249	−−0.001	0.040	**0.605**
C6	−0.082	−0.097	0.127	**0.493**
C9	0.015	0.107	−0.074	**0.474**
D11	0.270	0.323	−0.190	**0.355**

Note. Oblique rotation (Promax, $K = 4$). Values in bold indicate the component that the item best loads on.

when evaluated for the entire sample (Spearman $r = .027$, $p = .699$), and no differences were found between professionals (mostly music performers) engaged in different musical genres ($F = 0.382$, $p = .206$).

MHHI Evaluation

Evaluation of Reliability

Internal consistency reliability. The internal consistency of the MHHI was evaluated using the split-half approach. As the number of items was odd but larger than 11 (Warrens, 2015), the mean of all Guttman (quasi) split-half reliabilities of items can be given by the Cronbach's alpha, which was .90 (considered excellent). The MHHI's total reliability score, represented by Cronbach's alpha when any one item was removed from analysis, ranged between .890 and .901.

Table 4. Correlation between Musicians' Hearing Handicap Index factors and total score.

Factor	2	3	4	Total score
1	.464*	.461*	.327*	.737*
2		.563*	.568*	.837*
3			.402*	.783*
Total score			.736*	

*$p < .05$.

Test–retest reliability. For the estimation of test–retest reliability, we computed the ICC and Pearson r for each factor and for the total score, after the second administration of the questionnaire to 57 participants. The implementation of ICC requires an estimation of the significance of means' differences between the two applications of the MHHI questionnaire. We therefore first conducted a paired-samples t test for each of the four factors and for the total score. No difference was identified ($p > .52$ for all). The ICC (3, 1) values for test–retest reliability (Koo & Li, 2016) were .801 (moderate to excellent), .934 (excellent), .689 (good), and .883 (moderate to excellent), respectively, for the four factors, and .894 (excellent) for the total MHHI questionnaire score that was based on the 29-item questionnaire. Using bivariate correlation, the MHHI total score's correlation was Pearson $r = .934$, $p < .001$. Table 6 shows the mean

Table 5. Statistical tests for mean differences of Musicians' Hearing Handicap Index (MHHI) factors and total score between the groups.

		MHHI Factor 1		MHHI Factor 2		MHHI Factor 3		MHHI Factor 4		MHHI total score	
Group (I)	Group (J)	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*	*F*	*p*
1	2	22.419	**< .01**	21.408	**< .01**	9.670	**< .01**	3.905	**.050**	24.191	**< .01**
1	3	5.606	**.019**	10.882	**< .01**	7.120	**< .01**	0.468	.495	4.688	**.035**
2	3	16.172	**< .01**	1.739	.200	4.198	**.044**	1.604	.264	10.465	**< .01**
1	3.1	2.927	.095	2.099	.153	4.502	**.039**	1.570	.215	4.490	**.039**
1	3.2	6.076	**.015**	16.365	**< .01**	3.477	.071	0.386	.536	5.672	**.016**
2	3.1	8.981	**< .01**	15.907	**< .01**	6.411	**.010**	2.354	.108	20.825	**< .01**
2	3.2	12.044	**< .01**	0.009	.940	1.362	.240	0.938	.312	3.504	.060
3.1	3.2	0.395	.564	13.102	**< .01**	4.840	**.031**	1.555	.228	13.650	**< .01**

Note. Bold typeface highlights indicate $p < .05$.

values and *SD*s for the MHHI total score in the test–retest evaluation.

Evaluation of Validity

Concurrent and predictive criterion validity. Given that the literature does not report other relevant instruments for measuring hearing health among musicians, we investigated the MHHI's criterion validity against one of the most widely accepted instruments, the HHIA (Newman et al., 1990). The motivation for the development of the HHIA was analogous to that for the MHHI, namely, the lack of correspondence between performance in specific audiometric tests and the impact of hearing loss on communication ability and psychosocial life.

One month after the administration of the MHHI retest to 57 participants, we administered both the 29-item MHHI questionnaire and the HHIA to another group of 130 participants, randomly chosen from the pool of 204 subjects who had previously completed the MHHI, for a comparative assessment of their psychometric properties. The 1-month time interval since the retest administration of the MHHI ensured minimal carryover effects and a low possibility of alteration of the audiological status of the subjects. The impact of any of these was also reduced by the large sample size. The Pearson and Spearman correlation coefficients between the MHHI total score and the HHIA total score were $r = .815$ and $p = .781$, respectively, showing a good concurrent criterion validity of the MHHI.

The other major aspect of criterion-related validity, namely predictive validity, usually involves testing for a certain construct and then comparing the results with those of a different measure obtained at some point in the future. Therefore, it will be possible to assess it at a later point in time when additional data from the subjects will have been gathered.

Known-groups validity. Known-groups validity reflects a questionnaire's ability to discriminate between groups of subjects known to differ on some characteristics of interest (Davidson, 2014).

MHHI. The relationships between the MHHI factors and total score and the presence of auditory symptoms or PTA pathology was assessed using the point-biserial correlation coefficient (r_{pb}), as shown in Table 7. The MHHI factors and total score were significantly correlated with auditory symptoms, although the correlations were weak to moderate ($r_{pb} < .45$). All correlations with PTA pathology were negligible.

Table 5 shows the results of the tests for mean differences between the groups of subjects. The MHHI total score discriminated among all groups. Its discriminating sensitivity was highly significant both between the normal PTA groups (Group 1 vs. Group 2) and between the subgroups of the pathological PTA group (Subgroup 3.1 vs. Subgroup 3.2). The pathological PTA group (Group 3) also differed from both normal PTA groups. An exception to this was the difference between Group 2 and Subgroup 3.2, for which the *p* value (.060) was just marginally higher than the .05 significance cutoff. All MHHI factors contributed significantly to the discrimination between the groups, except for factor 4. This factor contributed only to the discrimination between Groups 1 and 2.

MHHI versus HHIA. Following the investigation for concurrent criterion validity against the HHIA, we also compared the validity of known groups between the MHHI and HHIA. The results of the nonparametric analysis of covariance are shown in Table 8.

The MHHI was also sensitive to mean differences between all groups' pairs, again with the exception of Group 2 versus Subgroup 3.2. On the other hand, the HHIA total

Table 6. Test–retest reliability of sample characteristics and Musicians' Hearing Handicap Index (MHHI) total score.

Variable	Group 1	Group 2	Group 3	Group 3.1	Group 3.2
No. of subjects for retest	12	16	29	8	21
MHHI total score (*SD*), retest	5.6 (5.3)	20.8 (19.3)	15.4 (17.3)	6.9 (5.3)	18.6 (11.9)
MHHI total score (*SD*), obtained in 1st administration	5.5 (5.7)	21.1 (14.8)	13.9 (13.5)	8.3 (4.9)	17.1 (8.8)

Table 7. Point-biserial correlation of Musicians' Hearing Handicap Index factors and total score with auditory symptoms and pure-tone audiogram (PTA) pathology.

Factor	Symptoms	PTA pathology
1	.377**	−.040
2	.444**	.026
3	.373**	.010
4	.224**	−.017
Total score	.444**	−.021

**$p < .01$.

score showed mean differences only for Group 1 versus Group 2, Group 1 versus Subgroup 3.2, and Group 2 versus Subgroup 3.1. The HHIA almost attained statistical significance ($p = .06$) for the differences between Groups 1 and 3. However, it failed to differentiate between subjects with a pathological PTA with or without symptoms (Subgroups 3.1 and 3.2). Additionally, the MHHI differentiated well between Group 1 and Subgroup 3.1 (subjects without auditory symptoms, but with or without PTA pathology), whereas the HHIA failed to do so.

Consequently, at least for this specific population (musicians) and this type of subject grouping (e.g., by the presence of auditory symptoms or PTA pathology), it seems that the MHHI has a better known-groups validity profile than the HHIA.

Discussion

In line with the previous literature, our work showed that the impact of hearing impairment on the performance of musicians could not be predicted by PTA, especially when noting that the presence or severity of hearing symptoms is not necessarily related to the PTA thresholds. These thresholds are, however, still accepted as the gold standard for hearing assessment. In this context, it is worth mentioning that some of the audiology questionnaires that are most commonly used in clinical practice have shown, at best, a moderate correlation with classical audiometry (Kuk et al., 1990; Newman et al., 1990; Ventry & Weinstein, 1982). It is interesting to note that, in the HHIA, both the mean speech frequency pure-tone average (500, 1000, and 2000 Hz) and the mean high-frequency pure-tone average (1000, 2000, and 4000 Hz) showed only a weak correlation with the questionnaire score (Newman et al., 1990).

Table 8. Test of significance of differences between group means using nonparametric analysis of covariance for Musicians' Hearing Handicap Index (MHHI) and Hearing Handicap Inventory for Adults (HHIA) total scores.

Group (I)	Group (J)		MHHI total score	HHIA total score
1	2	*p*	**< .01**	**.018**
		F	22.946	5.752
1	3	*p*	**< .01**	.066
		F	10.221	3.480
2	3	*p*	**.012**	.104
		F	6.313	2.543
1	3.1	*p*	**.010**	.764
		F	6.649	0.139
1	3.2	*p*	**< .01**	**.032**
		F	11.737	4.874
2	3.1	*p*	**< .01**	**.016**
		F	10.896	5.753
2	3.2	*p*	.108	.412
		F	2.636	0.652
3.1	3.2	*p*	**.013**	.112
		F	6.232	2.979

Note. Bold typeface highlights indicate $p < .05$.

In this study, we propose a new tool in the form of a self-report questionnaire that is intended to quantify the degree and types of difficulties that music professionals face during their occupational and everyday activities. In the MHHI questionnaire, the items are organized into categories/factors that encompass elements of the proposed ICF Core Set for Hearing Loss (Granberg, Pronk, et al., 2014). Clinicians might benefit from (a) limited proliferation of multiple self-report questionnaires on hearing disability/impact and (b) improved concision and usability of these instruments. This can be attained by reducing overlap and redundancy through the necessary readaptations to enhance their conformance to a unified/common ground of concepts or scientific parlance such as linking items to chapters or categories provided in the ICF Core Set for Hearing Loss (Granberg, Dahlström, et al., 2014; Granberg, Möller, et al., 2014).

The MHHI questionnaire is also capable of discriminating between groups of music professionals with different auditory symptoms and PTA thresholds. These may be regarded as objective data against which the differentiating properties of the MHHI are validated (known-groups validity). This discriminating power is especially important in the case of musicians with auditory symptoms but normal PTA thresholds and in musicians without symptoms and unknown PTA thresholds. The ability of the MHHI to differentiate between groups of subjects may initially seem unexpected, considering the weak correlation between MHHI total score and the presence of symptoms and its negligible correlation with the presence of PTA pathology. However, this can be misleading if one does not take into account the fact that the (point-biserial) correlation is not based on differences between groups but reflects a variation of the average MHHI score among group pairs. For example, the relationship between the MHHI and the presence of symptoms relies on the relationship between a combination of Group 1 and Subgroup 3.1 versus a combination of Group 2 and Subgroup 3.2 and not on the differences between isolated groups (e.g., Group 1 vs. Subgroup 3.1).

Moreover, this lack of correlation between the MHHI total score and PTA underline the significance of investigating the musicians' reactions to hearing deficits beyond the typical PTA or auditory symptoms. Weak correlations between the self-reported degree of hearing difficulties and audiometric measures have also been reported in other studies

(Newman et al., 1990). However, in our study, the negligible relationship with PTA pathology stresses the value of the MHHI beyond a typical PTA-based characterization of a musician's auditory function.

An interesting finding arising from the analysis of the discriminating potential of the MHHI was that Group 3 scored lower than Group 2. Specifically, the MHHI total score did not seem to map onto the expected order of disability across groups, especially between Groups 2 and 3. In other words, those with hearing loss showed less disability than those without hearing loss, as assessed by PTA. A possible explanation is that, once the hearing loss has been established over a period of years, it may not impact performance anymore. Such possible response shifts have already been described in the literature (Heinrich et al., 2019), especially after Treadwell and Lenert's (1999) prospect theory. Interestingly, in this study, the mean age of Group 3 was 40.1 years, while that of Group 2 was 34.7 years. Although such a difference is not large, it could attest to Treadwell and Lenert's theory. If we consider the possibility of a common age of exposure auditory symptoms appearance in Groups 2 and 3, then Group 3 had a longer time to compensate. This notion is further enhanced by our data that seem to show a strong relationship between age and self-reported exposure. Professional experience may also play an important role in compensating for the adverse impact of hearing deficits on occupational performance. Similar observations have been reported in several studies on relevant fields such as voice/singing production (Swirsky-Sacchetti et al., 2017) and other intellectual or professional accomplishment targets (Reis & Ruban, 2004).

Additionally, music-related tasks (creation, production, or even focused listening) usually demand cognitive effort, including working memory, judgment, decision making, and affective awareness. The integrity of such functionality cannot be captured or even indirectly inferred by PTA thresholds. Given such possibilities, and since the point-biserial correlation of the MHHI with the presence of PTA pathology is negligible and that with the presence of auditory symptoms is weak, it is not possible to preclude the appearance of such a reversal of ordering of the MHHI total score partitions assigned to Groups 2 and 3. All things considered, the subjective nature of a self-report instrument, where the assessed severity of symptoms may be influenced by several cognitive and/or behavioral factors and phenomena, could also account for the apparent MHHI total score "reversal" between groups of subjects with a different PTA classification (e.g., Group 2 vs. Group 3). In fact, this was also observed in the HHIA total score as obtained in the criterion validity analysis of the MHHI (data not shown). These observations justify the use of the term "index" in the name of the MHHI, as a sum of subscales. As an index, it can be consistently applied to taxonomical and classification problems. A "scale," on the other hand, is appropriate for ordinal classifications or ranking-type decision problems (Crossman, 2019; Dembczyński et al., 2010). Although the ultimate goal of the MHHI may not necessarily be the successful classification of groups of subjects according to PTA pathology or symptoms, its discriminating validity offers evidence of its sensitivity as a measurement instrument.

The theoretical and empirical origins for the initial selection of the MHHI items (143 items) are well documented in the relevant literature. An examination of the construct validity of the MHHI from another perspective, namely, that of convergent validity with the conceptual origins of the questionnaire items (the initial four concepts; see the Method section), suggests that the qualitative interpretation of the item groupings into the common factors of the EFA (see Table 3) explicitly highlights various specific aspects of deficits and difficulties in performance and social and emotional distress that may underlie hearing impairments. Consequently, the factorial structure of the MHHI provides a more refined exposition of the concepts from which the items were selected. This is shown in Appendix A, where both the common factors and the conceptual origin of each item are presented.

It must be noted that the computation of the MHHI total score as an unweighted sum of factor scores is just one of various possible ways of scoring. More elaborate questionnaire scoring approaches, which employ weighted regression techniques, connectionist structures, fuzzy sets, and so on, are reported in the literature (Koufteros et al., 2009; Pike et al., 1998; Symeonaki et al., 2015; Wandishin & Mullen, 2009; Yu & Lin, 2007). These approaches aim to optimize the instrument properties and performance in terms of reliability, validity, receiver operating characteristics, and adequacy to describe other audiological conditions/populations or measurements. However, this is beyond the scope of the current article. Related progress will be reported in future works by our team.

Some important comments and remarks regarding the comparison between MHHI and HHIA on known-groups discrimination are necessary at this point. This comparison was based on the data from subjects who participated in the administration of the HHIA for the investigation of the MHHI's criterion validity. Although the differences between the performance of the MHHI and HHIA were evaluated at the same point in time, it is important to examine the MHHI's test–retest stability/reliability metrics between this administration and the initial administration (with 204 participants), which took place more than 1 month earlier. The ICC (3, 1) and the Cronbach's alpha for the MHHI total scores between the data at these two time points were .800 and .796, respectively, which are considered moderate to excellent (Koo & Li, 2016). These values were close to the results of the MHHI's test–retest reliability, which had been tested earlier (7–15 days after the first MHHI administration). The differences between the two may have resulted from the subjects' response variation due to the time since the initial MHHI administration or the minuscule discrepancies in group composition between the samples. However, as was already discussed in the section on concurrent validity, within this time interval and for such a sample size (N = 130), we do not expect a significant impact from possible alterations to the audiological profile of the participants.

To validate the MHHI in an English-speaking population, a back-translation process (from English into Greek) is necessary to supplement the already available forward translation from Greek into English. This would help achieve conceptual equivalence between the two languages.

An important step toward the completeness of the validation of any instrument like the MHHI is the process of standardization to different parts of the target population. For example, administration of the MHHI to music professionals of different ages, years of exposure, musical instruments, musical genres, or even geographical areas. Such parameters, as well as other occupational activity parameters and environmental factors, would support the instrument's characteristics for global application.

Conclusions

The properties of the MHHI justify its use as a valuable tool to quantify and assess hearing in music professionals. It may become part of the standard clinical evaluation and facilitate the choice and assessment of integrated treatment or rehabilitation strategies, including hearing aids and counseling, among others. The aim is not only to relieve auditory sensitivity loss (Beck & Danhauer, 2019; Sereda et al., 2015) but also to improve situational or emotional problems (Ventry & Weinstein, 1982). It may be used for grading the severity of auditory dysfunction in terms of patient-perceived impact, either alone or in conjunction with other audiological indices. Furthermore, it offers information on factors influencing musical performance to a greater extent than typical audiological tests (such as the PTA) would indicate. Last but not least, the MHHI, as a self-report/evaluation instrument, might be employed as part of hearing screening or preservative actions for music professionals.

Finally, although we presented a version of the MHHI based on a four-factor EFA, we recognize that, under some circumstances, the selection of a solution based on a specific number of factors may be debatable. A rigorous evaluation of the suitability, interpretative value, and validity/reliability of EFA solutions with more than four factors and an overall assessment of their appropriateness against the solution selected in the current article could potentially lead to a slight reorganization of the MHHI subscales. Such reorganization could enhance its psychometric and statistical properties, an effect that could be tested in further studies.

Author Contributions

Aikaterini Vardonikolaki: Conceptualization (Lead), Data curation (Lead), Formal analysis (Supporting), Investigation (Lead), Methodology (Lead), Project administration (Lead), Validation (Lead), Visualization (Lead), Writing – original draft (Lead), Writing – review & editing (Equal). **Vassilis Pavlopoulos:** Methodology (Supporting), Writing – review & editing (Supporting). **Konstantinos Pastiadis:** Formal analysis (Lead), Methodology (Supporting), Writing – review & editing (Supporting). **Nikolaos Markatos:** Investigation (Supporting), Project administration (Supporting), Validation (Supporting). **Ilias Papathanasiou:** Methodology (Supporting), Writing – review & editing (Supporting). **Georgios Papadelis:** Methodology (Supporting), Writing – review & editing (Supporting). **Miltos Logiadis:** Methodology (Supporting), Writing – review & editing (Supporting). **Athanasios Bibas:** Conceptualization (Supporting), Methodology (Supporting), Supervision (Lead), Writing – review & editing (Lead).

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Appendix A (p. 1 of 2)

MHHI Questionnaire (English/Greek Version)

Final version of MMHI in the Greek (*italics*) and English languages. The leading number indicates the common factor with which the item is grouped, and the following two-digit code (letters accompanied by numbers) indicate the concept and ordering from which the item originated during the initial phase of collection of the questionnaire's items.

Please fill one of the following numbers in the Score column next to each question.

Παρακαλώ τοποθετήστε έναν από τους παρακάτω αριθμούς κάτω από τη στήλη με την ένδειξη βαθμός ώστε να αντιστοιχεί σε κάθε ερώτηση.

ΠΟΤΕ (NEVER)	**ΣΠΑΝΙΑ (RARELY)**	**ΜΕΡΙΚΕΣ ΦΟΡΕΣ (SOMETIMES)**	**ΣΥΧΝΑ (OFTEN)**	**ΠΑΝΤΑ (ALWAYS)**
0	**1**	**2**	**3**	**4**

Question		**Score**
1-A7	Do you feel that your hearing difficulties limit your social life? *(Αισθάνεστε ότι η ακοή σας περιορίζει την κοινωνική σας ζωή;)*	
1-D1	Do you feel more stressed–anxious than before when meeting with other people, because of your hearing difficulties? *(Νοιώθετε μεγαλύτερη ένταση-νευρικότητα σε σχέση με παλαιοτέρα όταν συναναστρέφεστε με άλλους εξ αιτίας της ακοής σας;)*	
1-A4	Do you avoid socializing because of your hearing difficulties? *(Αποφεύγετε τις κοινωνικές συναναστροφές εξ αιτίας του προβλήματος στην ακοή;)*	
3-A8	Do you feel left out of conversations because of your hearing difficulties? *(Νοιώθετε αποκομμένος/η από συζητήσεις εξ αιτίας της ακοής σας;)*	
2-B1	Does your hearing gradually deteriorate during rehearsal? *(Η ακοή σας προοδευτικά χειροτερεύει κατά τη διάρκεια της πρόβας μέσα στη μέρα;)*	
1-A9	Has your hearing dysfunction caused you to lose your livelihood? *(Η δυσλειτουργία στην ακοή σας συντέλεσε στο να χάσετε την εργασία σας;)*	
2-B3	Do you experience tinnitus at the end of the day? *(Έχετε εμβοές στο τέλος της ημέρας;)*	
2-B10	Do you experience any discomfort when hearing sounds that you didn't find irritating before? *(Νοιώθετε ότι σας ενοχλούν ήχοι που πριν δεν τους αντιλαμβανόσασταν σαν ενοχλητικούς;)*	
3-D2	Do other people get annoyed because of your hearing problems? *(Οι υπόλοιποι εκνευρίζονται εξ αιτίας της δυσλειτουργίας στην ακοή σας;)*	
2-B6	Is your hearing worse at the end of the day, regardless of whether or not you were in rehearsal or in concert? *(Είναι η ακοή σας χειρότερη στο τέλος της ημέρας ανεξάρτητα αν έχετε πρόβα/ παράσταση ή όχι;)*	
1-A5	Do you avoid seeing your close friends and relatives because of your hearing difficulties? *(Έχετε μειώσει τις συναναστροφές με στενούς φίλους και συγγενείς λόγω προβλήματος στην ακοή σας;)*	
4-A1	Do your colleagues complain that you are no longer in tune? *(Οι υπόλοιποι συνεργάτες σας παραπονούνται ότι δεν 'πατάτε 'ακριβώς πάνω στη μουσική σε σχέση με το παρελθόν όπου δεν είχε διαπιστωθεί τέτοιο πρόβλημα;)*	
4-C9	Do you feel that your hearing fails you while performing? *(Νοιώθετε ότι σας εγκαταλείπει η ακοή σας ενώ βρίσκεστε στη μέση ενός κονσέρτου/συναυλίας;)*	
3-A6	Do you ask other people to repeat what they have just said, even if you are talking face-to-face? *(Ζητάτε από τους άλλους να επαναλάβουν αυτό που είπαν έστω και αν μιλάτε μαζί τους κατά πρόσωπο;)*	
2-B11	Have you noticed whether certain settings or musical instruments cause you more discomfort than before? *(Έχετε διαπιστώσει ότι κάποια όργανα/χώροι σας ενοχλούν παραπάνω από άλλα/άλλους σε σχέση με το παρελθόν;)*	
2-D5	Do you feel that your hearing difficulties are indeed a hindrance to you? *(Αισθάνεστε ότι η δυσλειτουργία στην ακοή σας είναι όντως πρόβλημα για εσάς;)*	
3-C1	Do you have to try harder than before in order to follow a musical piece? *(Αισθάνεστε ότι καταβάλλετε μεγαλύτερη προσπάθεια από ό,τι παλαιοτέρα για να παρακολουθήσετε ένα μουσικό κομμάτι;)*	
3-C4	Is identifying timbre more difficult for you than it used to be? *(Έχετε δυσκολίες να αντιληφθείτε το ηχόχρωμα σε σχέση με το παρελθόν;)*	
1-D6	Have you become withdrawn because of your hearing problems? *(Έχει μειωθεί η κοινωνικότητα σας εξ αιτίας του προβλήματος της ακοής σας;)*	
1-D7	Do you regard your hearing problems as a form of disability? *(Αισθάνεστε ότι το πρόβλημα στην ακοή σας αποτελεί κάποια μορφή αναπηρίας;)*	
1-D4	Do you feel that your colleagues do not sympathize with your hearing problems? *(Αισθάνεστε ότι οι συνεργάτες δεν κατανοούν το πρόβλημα με την ακοής σας;)*	

Appendix A (p. 2 of 2)

MHHI Questionnaire (English/Greek Version)

Question		Score
4-D10	Does your hearing problem make you feel embarrassed? *(Ντρέπεστε για το πρόβλημα στην ακοή σας;)*	
4-D11	Has your musical productivity declined—are you not as effective on stage? *(Αισθάνεστε μη παραγωγικοί πλέον για τη μουσική—έχει μειωθεί η απόδοση σας στην παράσταση;)*	
3-C5	Is pitch discrimination more difficult for you than it used to be? *(Σας είναι πιο δυσδιάκριτες οι κατευθύνσεις μιας μελωδικής γραμμής σε σχέση με το παρελθόν;)*	
3-D8	Do you feel embarrassed when asking people to repeat what they have just said? *(Σας κάνει να αισθάνεστε άσχημα το γεγονός ότι αναγκάζεστε να ζητήσετε από τους άλλους να επαναλάβουν;)*	
2-B8	Do you feel that your hearing is worse than your colleagues' in certain settings? *(Αισθάνεστε ότι σε κάποιους χώρους η ακοή σας είναι πιο ευάλωτη σε σχέση με αυτή των συναδέλφων σας;)*	
4-D9	Do you feel embarrassed when having to repeat a musical piece because of your hearing difficulties? *(Ντρέπεστε όταν χρειάζεται να ξαναπαίξετε ένα κομμάτι εξαιτίας του προβλήματος με την ακοή σας;)*	
2-D12	Do you not enjoy music as much as you did, because of your hearing difficulties? *(Αισθάνεστε ότι δεν απολαμβάνετε την μουσική σε σχέση με παλιότερα εξαιτίας του προβλήματος με την ακοής σας;)*	
4-C6	Do you find it difficult to tune your musical instrument/are you unaware that your musical instrument is out of tune? *(Δυσκολεύεστε να κουρδίσετε το όργανο σας / αδυνατείτε να καταλάβετε ότι το όργανο σας είναι ξεκούρδιστο;)*	

Appendix B

Items That Were Omitted From the Final Version of the MHHI Questionnaire

Question	
B2	Does the sound reaching your ears seem to you distorted in any way with regard to what you consider normal? *(Ο ήχος που φτάνει στα αυτιά σας ακούγεται διαστρεβλωμένος/παραμορφωμένος σε σχέση με αυτόν που θεωρείτε φυσιολογικό;)*
C11	Is identifying a familiar musical piece more difficult for you than it used to be? *('Εχετε δυσκολίες να αναγνωρίσετε ένα γνωστό σας μουσικό κομμάτι που ακούτε σε σχέση με το παρελθόν;)*
C3	Do you have to try harder in order to play louder? *(Καταβάλλετε μεγαλύτερη προσπάθεια για να αυξήσετε την ένταση στο μουσικό όργανο που παίζετε σε σχέση με το παρελθόν;)*
C7	Have you limited your repertoire to musical pieces that you think you can hear better, in order to keep pace with the rest of the team? *(Έχετε περιοριστεί σε συγκεκριμένο ρεπερτόριο που νομίζετε ότι το ακούτε καλύτερα ώστε να συμβαδίζετε πιο εύκολα με την υπόλοιπη ομάδα;)*
B4	Do you suffer from joint and/or muscle pain along with you hearing dysfunction? (*Πάσχετε από πόνο στις αρθρώσεις- ή και μύες τελευταίως παράλληλα με την πτώση \στην ακοή σας;)*
D3	Do you feel that your friends and family do not sympathize with your hearing problems? *(Αισθάνεστε ότι οι γνωστοί, φίλοι, συγγενείς δεν κατανοούν το πρόβλημα με την ακοή σας;)*
B9	Have you ever had to cancel a performance or rehearsal because of your bad hearing? *(Έχετε αναγκαστεί να ακυρώσετε παραστάσεις/πρόβες εξ αιτίας της κακής ακοής σας;)*
B5	Does the sound make you dizzy while performing or rehearsing, and occasionally cause you to stop? *(Ζαλίζεστε στην διάρκεια της παράστασης/πρόβας εξ αιτίας του ήχου και ενίοτε αναγκάζεστε να σταματήσετε;)*
C10	Do you feel that music is more "flat" than it used to be? *(Αντιλαμβάνεστε τη μουσική πιο "επίπεδη" σε σχέση με το παρελθόν;)*
C2	Do your colleagues ask you if you have a diagnosed hearing problem? *(Οι συνάδελφοί σας σάς ρωτούν αν έχετε διαγνωσμένο ή μη πρόβλημα ακοής;)*
B7	Do you feel that some days are better than others with regard to your hearing? *(Αισθάνεστε οτι υπάρχουν μέρες που η ακοή σας είναι καλύτερη σε σχέση με άλλες;)*
A2	Does your family complain that they do not sufficiently communicate with you by phone because of your hearing? *(Η οικογένεια σας παραπονείται ότι δεν συνεννοείστε επαρκώς μέσω τηλέφωνου εξ αιτίας της ακοής σας;)*
A3	Does a hearing problem make you to use the phone less often than you would like? *(Έχετε σταματήσει/μειώσει τη χρήση του τηλεφώνου εξ αιτίας της δυσκολίας στην ακοή σας;)*
C8	Do you have to try harder in order to play a musical piece with your main instrument? *(Καταβάλετε μεγάλη προσπάθεια για να αναπαράγετε κομμάτια με το κύριο μουσικό σας όργανο;)*

Appendix C

EFA Solution Based on 29 Items and Seven Common Factors

Item	Impact on social life (Factor 1)	Impact on working life (Factor 2)	Communication difficulties (Factor 3)	Music Perception difficulties (Factor 4)	Music Performance difficulties (Factor 5)	Hearing fatigue after listening/ performance effort (Factor 6)	(Nonspecific) sound perception difficulties (Factor 7)
	MHHI subscales (factors)						
A5	**1.030**	−0.130	−0.068	0.074	−0.055	−0.004	−0.068
D6	**0.827**	−0.060	0.040	−0.018	−0.035	−0.041	0.109
A4	**0.815**	0.065	−0.102	−0.127	−0.050	0.116	0.104
D1	**0.653**	0.050	0.162	0.156	0.029	0.094	−0.186
A7	**0.462**	0.042	0.201	−0.107	−0.029	0.034	0.213
A9	**0.422**	0.227	−0.243	−0.014	0.249	−0.324	−0.023
C2	**0.405**	0.015	0.073	−0.109	0.205	0.254	−0.040
D10	−0.163	**0.795**	0.115	−0.121	0.183	−0.003	−0.170
D7	0.136	**0.771**	0.097	−0.195	−0.087	−0.032	−0.076
D11	0.044	**0.749**	−0.216	0.186	−0.008	0.016	0.003
D4	0.124	**0.504**	0.078	0.071	−0.102	0.211	0.016
D5	0.070	**0.474**	0.141	0.070	−0.038	−0.038	0.226
C9	−0.098	**0.442**	−0.172	0.047	0.278	0.110	0.082
A6	−0.115	−0.058	**0.785**	−0.089	0.104	0.166	−0.011
D8	0.004	−0.037	**0.750**	0.036	0.188	−0.220	0.089
A8	0.180	0.195	**0.538**	0.001	−0.084	−0.107	−0.141
D2	0.224	−0.021	**0.360**	0.291	−0.045	−0.038	0.067
C5	0.089	−0.103	−0.073	**0.866**	0.047	−0.098	−0.091
C4	−0.222	0.162	−0.007	**0.675**	−0.073	0.090	0.096
C1	−0.009	−0.094	0.118	**0.663**	0.070	0.158	0.017
D9	0.027	0.075	0.136	0.051	**0.657**	0.027	−0.092
A1	−0.082	0.057	0.110	0.051	**0.602**	−0.059	0.098
C8	0.010	−0.069	0.059	−0.039	**0.474**	0.136	0.099
B1	0.063	0.026	−0.128	−0.116	0.097	**0.811**	0.091
B7	0.012	0.080	0.078	0.044	−0.072	**0.539**	−0.084
B6	0.099	−0.053	−0.116	0.231	0.105	**0.504**	−0.050
B11	0.098	−0.069	−0.093	0.003	0.127	−0.100	**0.768**
B10	−0.022	−0.125	0.051	−0.048	−0.006	0.082	**0.696**
B8	0.010	0.286	0.072	0.060	−0.082	−0.025	**0.417**

Note. Oblique rotation (Promax, $K = 4$);. Values in bold indicate the component that the item best loads on.