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Subjective evaluation of music hall acoustics: Response of expert and non-expert users

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ABSTRACT

Many studies have attempted to measure human response in music halls in order to determine acoustic quality. However, all these works have used parameters defined by experts. This approach may be an important drawback since users who have to evaluate such concepts may not understand or misunderstand parameters which do not correspond to their own conceptual structure.

This paper attempts to establish a methodology to define valid evaluation scales for different collectives and determine evaluation criteria related to the overall assessment of music hall acoustics. It analyses music hall acoustics from the user's perspective and investigates the differences of perception between experts and non-experts through Semantic Differential within the frame of Kansei Engineering.

The research was carried out through a field study in 17 auditoria of the Valencia Region (Spain). Perceptions regarding the acoustic quality of these venues were studied in a group of non-experts (236) and other of experts (74). Differences of perception between both collectives were identified and analysed. The main factors characterising the subjective preference of each group were determined (5 factors for non-experts and 6 for experts) and their influence on the global acoustic assessment was quantified. Furthermore, predicting perceptual models were built and the utility of the methodology was tested through the semantic profiles of two venues not included in the above analysis.

This methodology was useful for studying music hall acoustics from the viewpoints of experts and non-experts and it may also enable optimization of design features of music halls.

1. Introduction

Study of perception in the field of music hall acoustics (opera houses, theatres and venues for classical music and orchestra performances) has been of great interest over the past and present century [1–9]. Many studies have attempted to find the physical parameters which determine whether the acoustics of a venue are good or not. In the early 1920s, Sabine's study [10] led to the general view that reverberation time was the only parameter that represented the acoustic quality of a music hall. This idea remained for several years and researchers focused their efforts on studying the absorbing properties of new materials in order to control reverberation time and maximize acoustic quality. However, researchers came to realize that other parameters also influenced acoustic perception in addition to the universal criterion of reverberation time. This fact led to many other studies related to *new* physical parameters influencing the perception of acoustic comfort, including Early Decay Time (EDT) [11], Initial Time Delay Gap (ITDG) [5], Spatial Impression [12], Clarity Factors C_{50} and C_{80} [13], Gain Factor (G) [14], Interaural Cross-Correlation (IACC) [1] and Speech Transmission Index (STI) [4,15].

Some studies also began to relate all these physical parameters to human response and the subjective evaluation that they evoke on the listener (intimacy, enveloping sound, clarity, loudness, balance, warmth, etc.) [4,5,7,9,14,16]. This led to a new branch of acoustics known as psychoacoustics. Many authors have conducted research in this field and in particular, Leo Beranek [3]. He was the first author to establish a new parameter different from reverberation time which, according to his research, had a great influence on the listener. He stated that the feeling of intimacy in a music hall (directly related to ITDG) contributed up to 40% of the global assessment of the venue. After him, many other authors studied and quantified the influence of other acoustic parameters on the listener's perception, including the influence of Lateral Energy

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Fraction (LF) on the perception of enveloping sound [2]; influence of Clarity Factor C_{80} on perceived subjective clarity [5]; influence of Gain Factor G(A) on perceived loudness [14]; influence of IACC on the diffusion of sound [7]; influence of STI on the perceived intelligibility of sound [4].

All these studies have something in common: they evaluated listeners' impressions through questionnaires and tests. The sample of listeners was composed of experts in some cases (musicians, acousticians, conductors, etc.) [2–4,7]; and non-experts in others (students or habitual listeners) [6,8,17]. However, in these experiments all the concepts and attributes for evaluation were always set by experts (professional musicians, conductors, acousticians). That is, the mental scheme of non-experts was not taken into account when designing the questionnaires. This approach could lead to erroneous results since non-experts may misunderstand concepts set by experts. Studies have shown that professional musicians have a different conceptual structure from that of the non-musicians [18–22]. For instance, the interviewee and the interviewer may interpret the attribute *reverberant* differently, and this would make the results difficult to interpret. Furthermore, as experts filter the information to assess, some of the parameters appreciated by non-experts may never be evaluated. These particular disadvantages have been tackled by techniques such as the Semantic Differential method (SD).

SD, also known as Differential Semantics, is a useful tool designed by Osgood et al. [23] to quantify the affective meaning of concepts. It is very often used to investigate users' perceptions of product form. This method studies product semantics by means of adjectives and expressions which reflect users' emotional impressions and measures users' perceptions on a Likert scale. Many researchers have used this technique to study particular aspects of product form: colours, shapes, styles, comfort and many other attributes in product design. Furthermore it has been applied in different market sectors, including the automotive industry [24], housing design [25], building sector [26,27], mobile phone industry [28], and environmental acoustics [29].

SD is the main tool for applying Kansei Engineering. KE is an ergonomic consumer-oriented technology for new product development [30]. It was developed in the 1970s at the Kure Institute of Technology (Hiroshima, Japan). This technique is based on the principle that an individual's judgement is not only influenced by the stimuli (combination of objective and subjective parameters) but also by the scheme of concepts of a concrete group of users (*semantic space*). Thus, this method allows quantifying users' perceptions of a product in their own language and relates these subjective responses to particular design features.

KE consists of several phases. In the first stage, users' perceptions of a particular product must be captured in their own words by collecting as many expressions and words *(kansei words)* as possible to define the semantic space of the product. In this stage, SD is an essential and useful instrument for achieving this objective. Then, the semantic space must be reduced to a limited number of words, and the Affinity Diagram is an appropriate technique for this purpose [31]. These words are then transformed into several uncorrelated factors that define users' perceptions of the product. Principal components factor analysis is a very useful tool in this step [32]. Finally, these factors must be translated into design elements in the real product to satisfy individual preferences. Therefore, KE is a very useful instrument for studying users' emotional impressions which may differ from those of experts [33–35].

Many studies have used SD, within the frame of KE to analyse users' perceptions of a multitude of products: automotive industry [24,36]; mobile phones [37]; office furniture [38]; footwear design [39,40], beer cans [41] and even acoustics and sound perception [42–44]. Nevertheless, to our knowledge, this technique has been not applied to date in the field of music hall acoustics with the aim of measuring the human response of users.

This paper therefore aims to establish a methodology to define valid evaluation scales for different collectives and determine evaluation criteria related to the overall assessment of the acoustics of music halls (opera houses, theatres and venues for classical music and orchestra performances). The objective was to determine the evaluation concepts used by experts and non-experts collectives to express their value judgements in this field of study. The SD method within the frame of Kansei Engineering was used to achieve this purpose. In this way, it was possible to identify which attributes determined the overall opinion of users to evaluate music hall acoustics from criteria defined by the users themselves; and the same in the case of experts. The evaluation concepts were then used to analyse differences between the emotional responses of both collectives. Since perception depends on two main aspects: physical–objective parameters and subjective evaluation; the ultimate and future aim of this research is to detect and try to improve emotional response, link it to physical parameters and finally translate it into design elements that improve the overall quality of music halls. This issue has been never tackled before in the sphere of music halls and this research may help to shed some light on this empty field of study.

2. Materials and methods

The methodology consisted of two main activities: firstly, select a representative sample of expert and non-expert users of music halls. Secondly, select a sample of music halls across the region of Valencia (Spain) to be assessed by the sample of users according to a set of acoustic qualities. The region of Valencia was chosen for its long and rich musical tradition. In this region there are more than 350 musical societies, and an annual international music contest has taken place in the city of Valencia since 1886 with the participation of leading orchestras from Europe and around the world.

2.1. Subjects

A sample of 310 participants (74 experts and 236 non-experts) was collected. This sample comprised users of concert halls in different towns and cities in the region of Valencia. The selection technique was simple random sampling for non-expert users, who were contacted before the performance at the music hall. Expert users (professional musicians, acousticians, and conductors) were contacted through the chiefs of the auditoria who provided a list of experts willing to participate in the study. Then, simple random sampling was used to select them. Table 1 shows statistical data on the participants.

Table 1
Data on the sample of subjects participating in the study.

Gender			Age			Professional relation with music hall		
Male	171	59%	<20	15	4.84%	Experts	74	23.87%
Female	139	41%	20–30	58	18.71%	Non-experts	236	76.13%
			31–40	78	25.16%			
			41–50	87	28.07%			
			51–60	43	13.87%			
			61–70	18	5.80%			
			>70	11	3.55%			