Development and application of questionnaires to assess acoustic environment in open plan offices

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Summary
Aiming to improve communication and facilitate the team work, the open plan offices have become the most common type of workspace organization nowadays.
However, several studies demonstrated that the acoustic environment is considerably less satisfactory in these offices than in private offices, leading to issues such as productivity decrease. Furthermore, the noise levels measured in these places rarely exceed the comfort standard limits. Therefore, surveys have been made with questionnaires as a tool to assess the acoustic environment of these offices, aiming to correlate the subjective perception with the objective measurements, and consequently, characterize the ISE (Irrelevant Speech Effect). This paper intends to develop and clarify the questionnaires used in the research, taking into consideration cultural aspects, to bring results to the Brazilian reality.

PACS no. 43.55.Hy

1.   Introduction

The spatial configuration of so-called open plan offices is increasingly being embedded in the architecture design of the corporate universe. The spaces traditionally divided by walls and partition are being transformed into large open spaces, reducing the use of private offices. This office typology facilitates communication and collaboration between employees, as well as providing more fluid interaction and significant space savings.

However this types of spaces help improving some aspects in offices, such as ease of communication with co-workers due to proximity, they cause a decreasing in privacy and the increase of annoyance of office co-workers [1].

The auditory system of the human being permanently keeps monitoring the surroundings, with the ability to listen and hear at the same time. Taking this into account, it could be concluded that each individual have a different perception of the environment as a result of its personal subjective selection process, during the act of perceiving[1].

In general, some sounds are judged more unpleasant when people feel they could be avoided or if they do not belong to their own culture of sounds, the evaluation of this situation is instantaneous, the person hears the sound and immediately classifies it as unpleasant [1] [2].

Even an open-plan office with acceptable noise levels, produces uncomfortable noise, causing more disruptions, auditory and visual distractions, and loss of privacy. Studies also show that the audible and intelligible conversation of co-workers disturbs and negatively affects the individual in tasks that require cognitive processing [3, 4].

Several disciplines, such as architecture, engineering, health, and psychology, have been studying the impacts of open plan office configurations on their occupants with different perspectives [4].

This could be observed from the data provided by acoustic consultancy Harmonia Acústica [5] that estimates that around 80% of its corporative

projects incorporated open plan offices configurations.

There are no laws, objective criteria or standards with rules and guidelines for open plan offices developed for the Brazilian reality. Only two existing standards are considered as assistance: ABNT NBR ISO 3382-3: 2017, which specifies methods to measure acoustical properties of office environments with furniture [6] and the standard entitled ABNT NBR 10152: 2017 "Acoustics - Sound pressure levels indoors to research" [7].

The great majority of the research in this area was held in other countries with difrferent realities and culture. Therefore, it is essential to develop an evaluation tool that considers the aspects and behavior of Brazilian workers.

In this paper, a preliminary study is presented on how to obtain criteria to give input to establish the Brazilian parameters, using the same descriptors as those that are consolidated internationally. Therefore, it is necessary to develop an assessment tool to identify the sources of annoyance and distraction.

It is presented the development of a questionnaire to evaluate the perception of people working in an open plan office. Subjective tests were applied combining based on scientific approaches that combine questions with semantic differential and rank order scale. The questionnaire developed for this study can be applied in the future for a large set of offices in order to obtain more data for the establishment of parameters for the acoustic design of the spaces, offering the possibility of improving the sound quality in these locations.

2. Objective

In this article it is sought to evaluate two open plan offices by means of a questionnaire, aiming to obtain acoustics objective parameters relevant to auditory perception, according to the Brazilian reality. In addition, relevant information abous sound sources and events were collected in this environment.

3. Methodology

In order to obtain the necessary data, cross-referencing the information and obtaining the desired results, the structure of the questionnaire was divided into relevant topics to this type of room, such as: personal information, comfort, disruption and privacy. Within these topics a series of questions were developed, and at least two questions referring to the same topic were applied

to correlate the answers and validate the reliability of the questionnaire.

The levels of perception, irritability and annoyance were acquired through questionnaire items with appropriate response scales, differential semantic, single-answer questions with *e.g.* "yes" and "no", and questions with different response options to be possible to classify them according to noise sources, creating a ranking and scale-type questions in which the respondent should assign a note on a predefined scale. This type of question is often used in satisfaction surveys.

Since it is a preliminary study with the intention of discovering relevant acoustic parameters, it was useful to add some "open" questions, where users are free to write a response. It is a convenient approach, once the questionnaire was applied to subjects working in an office specialized in acoustics consultancy, allowing the insertion of more specific questions.

It is worth to remark that it is necessary a particular attention to the reliability of the answers, a statistical property of answers that refer to the temporal stability, being necessary the retests with the same subjects, under the same circumstances to improve the subjective analysis.

Measument objective data was obtained according to the following standards: ABNT NBR ISO 3382-3:2017 [6] and NF S 31-199 - Acoustique - Performances acoustiques des espaces ouverts de bureaux [8], allowing an intersection with the subjective data.

3.1 The Subjects

Co-workers who answered the questionnaire previous knowledge about acoustics and most of them consider themselves sensetive to. During worktime, their professional activities varies from indivdual to collective uniformly.

Table I. Gender and age of the subjects group

Personal characteristics	Description	Percentage
Gender	Female	57,1%
	Male	42,9%
Age	22 - 26	71,4%
	27 - 31	21,4%
	> 32	7,2%

3.2 Questionnaire application

The application of the questionnaire was carried out through an online platform, allowing them to be sent to all users, who responded within a deadline.

Table II. Relevant topics of questionnaire

Topics	Survey questions
Personal Information	Age
	Genre
	How many people work in the same environment as you?
	In your company do you own fixed station?
	Do you use headphones?
	How much individual and collective activity do you practice in your work?
	Do you think you listen well?
	How much do you consider yourself to be sensitive to noise?
Comfort	How comfortable do you feel in your work environment?
	As for noise, how do you define your office?
	How satisfied are you with the noise in your office?
Disruption	How satisfied are you with the ability to concentrate in your office?
	Do you find the noise of people talking in the office uncomfortable?
	Do you find uncomfortable noises that are not of conversations in your office (machines, steps, computer, phone, etc.)?
	Does any noise bother you in the office?
Privacy	How satisfied are you with privacy to chat in the office?
	Can you understand the conversations of colleagues who work close to you?
	Can you understand the conversations of colleagues who work far from you?

3.3 Physical environment

The analyzed offices present characteristics and furniture very representative of the Brazilian reality of offices, with laminate floor, acoustic mineral ceiling and wide windows. The offices layouts are presents in figures 1 and 2, and their corresponding areas can be seen in Table II.
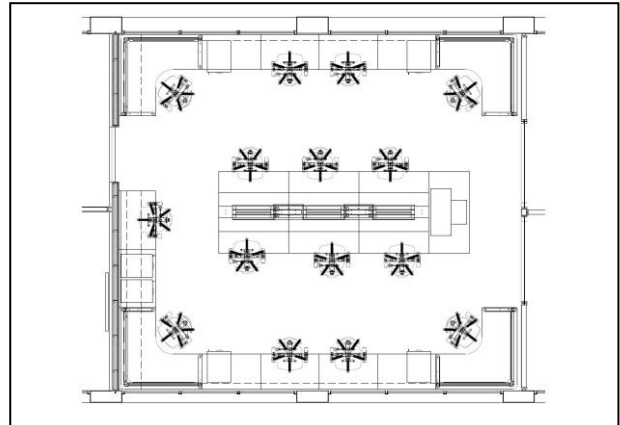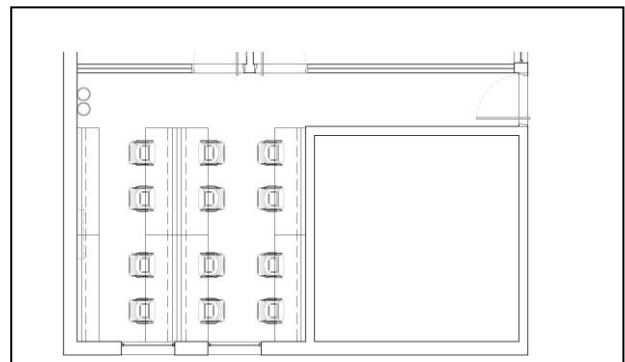

Figure 1. Office 1 Floor Plan

Figure 2. Office 2 Floor Plan

Table II. Area and workstations of the studied environments.

Studied environment	Area (m²)	Number of workstations
Office 1	42m²	16
Office 2	36m²	12

3.4 Analysis

The ambient noise analysis of the occupied office will be further investigated in the paper by Borin, named "A case study on Irrelevant Speech Effect assessment at open plan offices using Equivalent Modulation" which will be presented in this same conference.
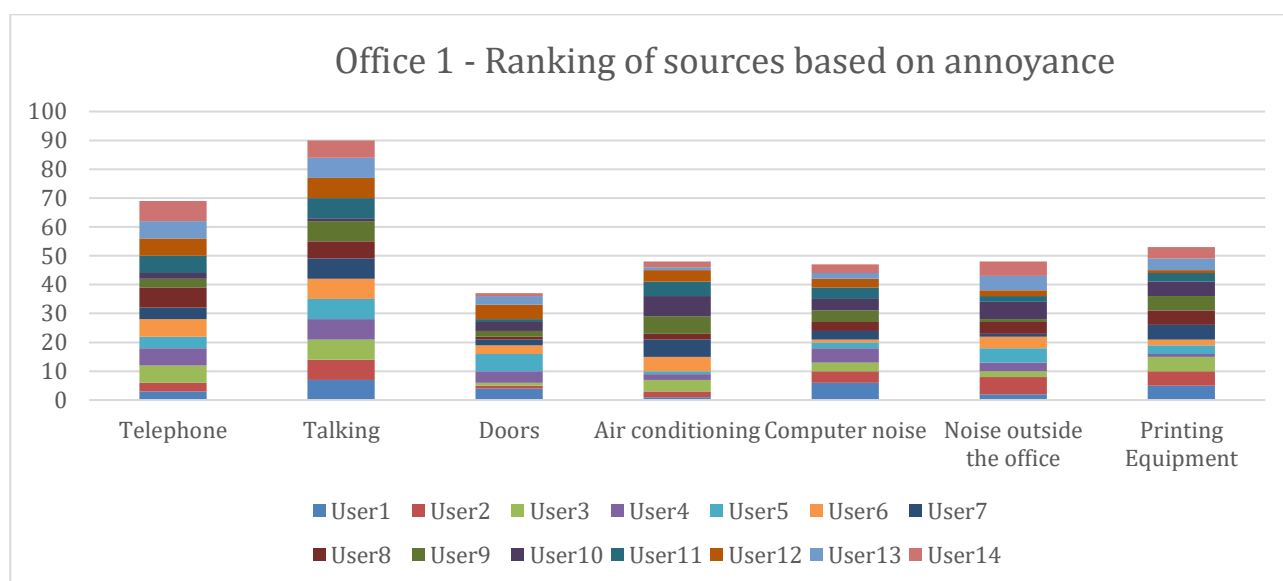
4.   Results

The analysis in this paper is centered on the results of the rank order scale questions. The first had the intention to evaluate de annoyance related to typical sound sources in open plan offices. On the other hand, the second rank scale aimed to verify what is the most crucial factor for the users to do their jobs. The factors were Concentration, Silence, Interaction, Privacy and Communication. Based on that, the other questions supported the analysis of this ranks, and the comparison with objective parameters, such as $D_{2,S}$, r_{D},e $L_{p,A,S,4m}$.

The first analysis concerns the sound sources in each environment. It can be observed in the Figure 1 that in the Office 2 the external noises are the most annoying source. Besides that, the Talking and the Air Conditioner System had relevant score of annoyance. On the other hand, the Office 2 had the "Talking" as the main annoying source and the Telephone as the second one. When asked to write what source annoyed the user the most, the "people talking" was the most present in the answers. This means that the users from the Office 1 understood as external noise people talking outside the office. Furthermore, in the same office, 77,8% of the users responded that there are some annoying sources. However, they classified the environment as intermediary about the noise, and feel satisfied with it. In the Office 2, circa 93% of the users answered that they are annoyed with some noise, classified the environment as noisy and intermediary satisfaction tending to dissatisfaction.

As almost all the users, in both offices work in fixed workstations, the sound sources with higher score are the ones in proximity of them.

The second analysis regards about the factors that matters to the activities the users do. It can be observed in the Figure 1-2 that concentration is the most important factor in both offices, the second one is silence and the third communication. In the Office 1 the users are satisfied with concentration capacity and 55,6% reported they are used to wear headphones, some for relaxing and others for concentration. In the Office 2, the users are not satisfied with this factor, and almost 93% wear headphones in the work. The main justification was to improve concentration. Regarding privacy, the subjects of both offices are dissatisfied. Furthermore, the users answered that they understand the close and the far talking in the respective offices. These aspects are also related to the factors Communication and Interaction. The last factor "Silence" is associated with the already mentioned answers about noise.
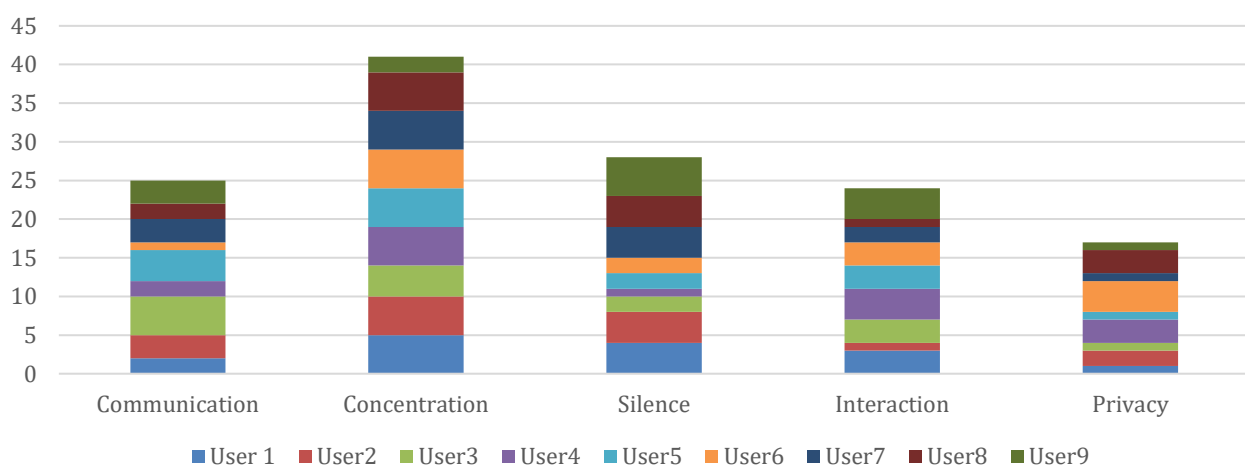
Office 1 - Important factors for carrying out activities
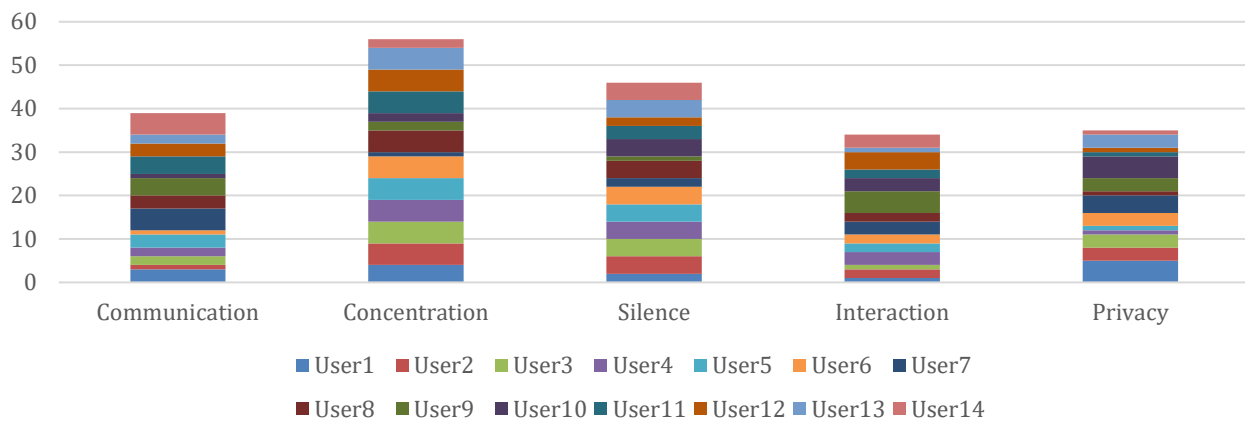
Office 2 - Ranking of sources based on annoyance
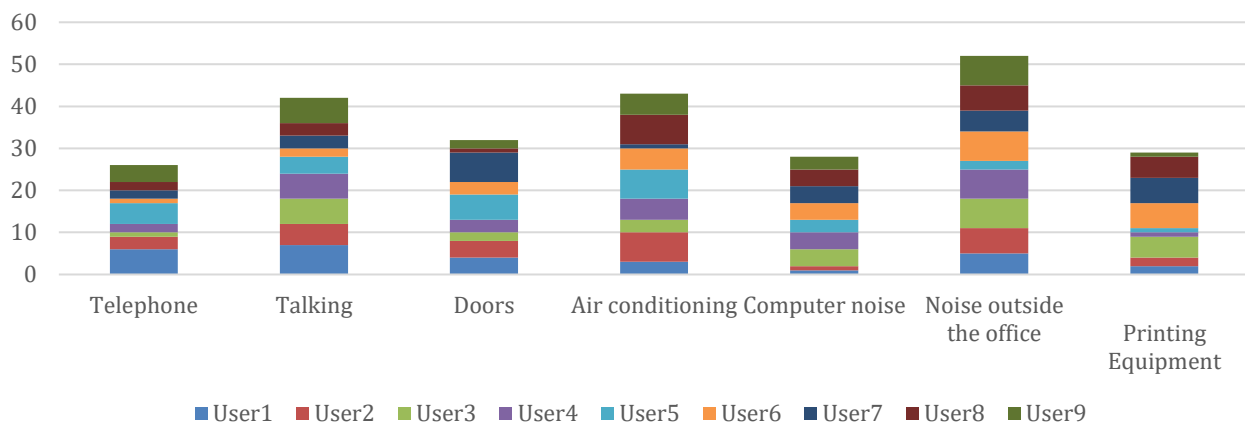
Office 2 - Important factors for carrying out activities

5. Discussion

In this section, the discussion about the results and the relation with some descriptors are presented.

It is important to highlight that both offices were classified, in terms of the activity, as offices with small amount of collaborative work. Based on that, in the Table III, it is seen criteria for good acoustic conditions in this type of office according to the NF S 31-199 and the suggested values from ABNT NBR ISO 3382:2017 [6].

Table III. Requirements and suggested values for good acoustics from [5, 7].

Descriptor	NF S 31-199	ABNT NBR ISO 3382:2017
$D_{2,S}$ (dB)	>7	>7
r_D (m)	-	<5
$L_{p,A,S,4m}$ (dB)	-	48

In the Table IV, it is presented the results of the measurements carried out on the paper *A case study on Irrelevant Speech Effect assessment at open plan offices using Equivalent Modulation* for these same offices.

Table IV. $D_{2,S}$, r_D and $L_{p,A,S,4m}$ of both offices.

Descriptor	Office 1	Office 2
$D_{2,S}$ (dB)	2,5	2,9
r_D (m)	>10	>10
$L_{p,A,S,4m}$ (dB)	54,5	54

According to the Table IV and comparing with the criteria in the Table III, the acoustic of these offices are considered insufficient. None of the criteria were attended. The low $D_{2,S}$ indicates a poor decay of the sound pressure level of speech and the high r_D indicates a great area of speech influence, which decrease the concentration and privacy. These descriptors are related with the answers in the questionnaires that reported a high comprehension of far talking, and the dissatisfaction of privacy and concentration. Besides that, the low $D_{2,S}$ depicts the high annoyance with the talking in the offices.

The descriptor $L_{p,A,S,4m}$ indicates a high level of speech sound pressure level, which also explains the annoyance with the talking in the offices. Comparing with the criteria, there are approximately 6 dB of difference. This is a high variation in terms of acoustics. However in the questionnaires, the subjects answers about noise did not represented such difference. This can be due the cultural aspects of the brazilian worker, that are more used to live and work in noisier environments. A proof for that is despite of their report of annoyance with the sources, the score applied by them in the satisfaction and noise rating scale questions do not reflect a high annoyance. Thus, this indicates, that a first approach in criteria for brazilian offices could be higher for this descriptor.

6. Conclusion

Despite of the number of sample not being enough to stablish the results, it is possible to give some directions to the criteria related to open plan offices, and to guide future researches about the theme.

For a first impression, the $L_{p,A,S,4m}$ could be higher in Brazil, which indicates also a lower $D_{2,S}$. However, more offices must be analyzed to confirm these impressions.

The subjective ratings of the offices support the conversations as being the main source of annoyance, since the workplace provides wispy sound decay levels, primarily explained by the lack of acoustic screens.

Despite the insufficient objective results on acoustic performance, the users did not manifest a high dissatisfaction regarding the acoustic condition as expected. A discussion about the cultural aspects may help to interpret this topic. It is also paramount to consider the use of headphones as a form of increasing the concentration, and to soften the disturbance effects.

It would be interesting to analyze with the same questionnaires other offices that attend the criteria; Thus, this could verify if the international criteria in the ABNT NBR ISO 3382-3:2017 [6] are also adequate for the workers in Brazil.

As a huge number of open plan offices projects being developed in Brazil, this study will be continuously applyed in order to give input for a future standard with adequate criteria for Brazil.

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