Technical note

Acoustic comfort on board ships: An evaluation based on a questionnaire

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Abstract

An initial attempt has been made to understand factors that determine acoustic comfort for cruise ship passengers. Although no literature directly pertinent to the question could be found, use of elements from studies on railways coaches in a questionnaire administered to shipbuilder and sub-contractor professionals on board during sea trials was judged a relevant initial approach. The questionnaire, consisting of closed questions followed by open questions, was drawn up to assess acoustic comfort in relation to other factors (such as temperature or light) and to identify the main conditions causing acoustic discomfort. During two sea trials 100 questionnaires were completed. Acoustics, then temperature, are pointed out as the first two comfort criteria and the priorities for improvement. Creaking and squeaking noises, noise of engines and whistles from HVAC are the main reported causes of annoyance. The results of the investigation demonstrate the prominent role of acoustics in respect of ship-board comfort.

Keywords: Ships; Acoustic comfort; Questionnaire inquiry

1. Introduction

In recent decades, the naval industry has faced a growing concern from managers of ships as regards comfort in general and especially acoustic comfort. We...
were thus consulted about the issue by Les Chantiers de l'Atlantique, an important French shipbuilding company. However, it turns out that studies dealing with acoustic comfort on ships are almost non-existent. Railways coaches are fairly large, collectively inhabited moving spaces and, from the point of view of passengers, the acoustic environments of railways and ships could be considered as quite similar. Therefore a bibliographic study of acoustic comfort in passenger trains was performed. Although the relevant literature is less scarce, it is not copious.

1.1. Short overview of previous research

There are two distinct types of studies dealing with railway coaches comfort: (1) physical measurements; (2) psycho-acoustic approaches aimed at establishing the relationship between recorded sounds and their impact on passengers. In many cases, studies are striving to display from the noise environment inside a coach a linear relationship between the degree of annoyance assessed through subjective tests and several psycho-acoustic parameters calculated from recordings [1–3]. Different subjective tests have been used. People listen to a series of sounds and grade each of them on continuous scales according to adjectives such as boring or annoying that supposedly reflect subjective appreciation. In other procedures, sounds are listened in pairs in order to point out the most pleasant (or least unpleasant). However, the scope of these tests is limited. The authors mention for instance that some people stated having perceived differences between signals while being unable to set them on the proposed scales.

The formulation of the questionnaires used could be responsible for this situation. Most of them are closed questionnaires based on a number of pre-established adjectives, the differences of which being sometimes difficult to grasp. This is the reason why open questionnaires are used in the so-called “psycholinguistic” approach recently developed by the SNCF (the French National Railways Company), intended to addressing subjective appreciation and based on word analysis of free comments made by travellers [4]. This process could therefore overcome the aforementioned difficulty. However, the drawback of this approach is that too general instructions induce too miscellaneous remarks about comfort factors, amongst which few turned out to be relevant to acoustics. A questionnaire survey was used as well in a recent investigation [5] that, after an initial inquiry about both mood and personal attitude towards interior train noises of passengers, collected judgments about annoyance caused by noises from miscellaneous sources.

1.2. The proposed comfort concept

Several strong points emerge from these studies:

- Acoustic comfort appears as the prominent comfort parameter on modern railway coaches.
The sound pressure level in dB(A) is inappropriate to characterise the level of discomfort induced by noise inside a coach, and for a given sound energy level, spectral composition is particularly important [6–9]. The presence of low frequencies (up to several 100 Hz), as opposed to higher frequencies, particularly reduces the acoustic comfort of passengers in trains. Disagreement remains about importance of frequency peaks [2,3,6,10].

To our knowledge, except for a single experiment exclusively focused on sleep parameters with three young male subjects [11], the research domain about acoustic comfort aboard ships remains to this day uncovered.

The range of situations and acoustic environment encountered by passengers on board a ship is quite wide both in time and space and is related as well to their miscellaneous activities.

- **Time:** Cruise duration could be from only a few hours on a ferry boat up to several weeks for a high sea cruise. This parameter is likely to affect widely the attention paid to acoustic conditions.
- **Space:** Owing to the dimension and the lay-out of a ship, several places have to be distinguished. In the case of a ferry boat, a passenger could be waiting in a resting room: the conditions there are quite similar to those on a train, although the volume of room is much wider. If a person is eating in a restaurant or being entertained in a leisure room, the hearing criteria applied in inhabited buildings (RASTI, intelligibility, ...) would probably be more pertinent there. In the case of a passenger resting in a cabin, he or she is likely to be receptive to the structure-borne noise produced by engines and concerned about sound isolation from the corridor. A passenger could be strolling on the deck as well, and this is yet another different context.

### 1.3. The questionnaire method

The present study seems to be the first ever performed on the issue of acoustic comfort on board ships. Owing to this diversity of environments, it becomes obviously important, before focusing on specific studies, to perform preliminary investigations to draw a general outline of the issue. It was then decided that a carefully drawn up questionnaire was the best way to evaluate the importance of acoustic comfort on cruise ships, to discover possible weaknesses, and to clarify whether a further psycho-acoustic study was relevant.

It first appears necessary to rank the acoustic factor amongst others comfort criteria such as visual environment, climatic conditions, ergonomics or vibrations sensation; closed questions are pertinent to this purpose. Then, with an appropriate choice of open questions, the disturbing noises and the places and situations where they are suffered from could be identified for subsequent studies.

Besides, direct questioning of real customers during cruises brings up both practical and commercial issues, since it is not known how those people would react. An
initial investigation especially demands caution. For this reason, before embarking in an extensive study involving cruise passengers, it was preferred to design a questionnaire meant for professionals working aboard ships during sea trials and to analyse answers. Expectations of real passengers are very likely to be different from those of professional teams. However, the latter have to live, work and rest for several days on shipboard, and with due caution some interesting results could be extracted from this initial investigation.

The next section explains how the questionnaire was designed, results obtained from closed and open questions are detailed in the following section, then we propose an analysis and a brief discussion of the results of this investigation before putting forward concluding remarks about acoustic comfort as it is likely to be felt by cruise customers.

2. Questionnaire construction and analysis

Two three-day sea trials on two different ships provide the opportunity to perform the study. The population involved in answering the questionnaire included shipbuilding and subcontractor professionals. The conditions they were submitted to during trials were very particular, and sensibly different from those offered to cruise customers. They involve intense work, life and housing conditions only in crew (not passenger) cabins and restaurant and during fitting-out work in progress in the ship.

Since it was not feasible to directly interview the people involved, it was decided to distribute a questionnaire to be filled in at any free time and to collect those completed at the end of the trial.

The questionnaire was anonymous. It was written and answered in French. It includes two parts. The first part with closed questions was intended to identifying the population and exposing the major problems regarding global comfort aboard cruise ships.

The following information was requested:

- Date, time and place where the file was filled in.
- Age and sex of the person (man/women).
- Professional group (Technician/Engineer) and occupation.

A distinction was drawn between shipbuilder and sub-contractor people lest their respective points of view should differ.

The persons were invited to rank according to significance the comfort criteria relevant to a trip on board a ship (“From your point of view, what are the features of comfort during a cruise?” – “Pour vous, dans le cadre d’un voyage sur un navire, qu’est-ce qui caractérise le confort?”) and were offered the following choices:

- Visual.
- Temperature.
Acoustics (noise, ...).
Lighting.
Ergonomics (bed, seats, ...).
Others (please specify): ...

The persons were then invited to tick off the factors or criteria that, in their opinion, needed particular improvement. The same items as above were offered.

The second part deals with acoustic comfort itself: from open questions (i.e., to be answered to with a sentence), the persons were invited to express freely their individual point of view about nature and origin of perceived noises and to enumerate the most uncomfortable places inside the ship. Four questions were asked:

- “In your opinion, which noises are intrusive?” (“Quels bruits vous paraissent dérangeants?”)
- “Why?” (“Pourquoi?”)
- “In your opinion, which places are uncomfortable from an acoustic point of view?” (“Quels sont les lieux qui vous ont paru inconfortables sur le plan acoustique?”)
- “Why?” (“Pourquoi?”)

Two or three lines for free comment were offered.

The questionnaire assumed a complete confusion between “acoustic noise”, emitted by the miscellaneous sources on board, and the way it was transmitted to different places all over the ship, which should be more related to “room acoustics”. In particular, noise emitted from the machinery and transmitted through the structure and noise produced by the structure itself were not distinguished. Only the acoustic environment as a whole from the point of view of a human subject was considered.

A first set of 45 completed questionnaires was collected in March 2002 aboard a ship designed for Mediterranean cruises. A second set of 55 completed files was obtained in April 2002 aboard a ship built for the American market. The average response rate was about 70%. These sets were first studied separately to make sure that merging them in a common analysis process was coherent. Since identical indications were obtained for all criteria, statistical analysis of closed questions and semantic classification of open questions could be jointly performed.

3. Results

3.1. Closed questions

Statistical results from answers to closed questions are shown in Table 1.

The population concerned was essentially male: 93% in the first set and 82% in the second. Moreover, it should be underlined that 80% of the people interviewed were less than 45 years old.
In order to classify out the different criteria in terms of significance, it was then calculated how frequently the relevant criterion appears as one of the two first important referred to. It shows out (Fig. 1) that here acoustics scores highest (39%). Then come, ranked in decreasing importance, temperature, ergonomics, visual and lighting conditions.

<table>
<thead>
<tr>
<th>Professional category</th>
<th>Sea trial A</th>
<th>Sea trial B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Les Chantiers de l’Atlantique</td>
<td>76%</td>
<td>76%</td>
</tr>
<tr>
<td>Worker</td>
<td>9%</td>
<td>0%</td>
</tr>
<tr>
<td>Technician</td>
<td>47%</td>
<td>45%</td>
</tr>
<tr>
<td>Engineer</td>
<td>44%</td>
<td>55%</td>
</tr>
<tr>
<td>Sub-contractors</td>
<td>24%</td>
<td>24%</td>
</tr>
<tr>
<td>Worker</td>
<td>6%</td>
<td>8%</td>
</tr>
<tr>
<td>Technician</td>
<td>19%</td>
<td>38%</td>
</tr>
<tr>
<td>Engineer</td>
<td>44%</td>
<td>31%</td>
</tr>
<tr>
<td>Service</td>
<td>–</td>
<td>23%</td>
</tr>
</tbody>
</table>

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The results of the question about the factor needing improvement are shown in Fig. 2. Acoustics again was mentioned by 44% of the people as the criterion to be improved, far ahead of others factors.

The outcome from these two questions appears consistent with the growing demand for acoustic comfort, which is exhibited out of the questionnaire both as the most prominent factor of comfort aboard a ship and as its weakest point.

3.2. Open questions

Semantic classification of open answers was done. Since there were relatively few completed files, it was possible to gather the miscellaneous remarks written on them and to aggregate them in accordance with their sense, without use of computerised treatment. In this way we secured a precise and comprehensive interpretation of stated judgements.

3.2.1. Intrusive noise

In answers to the question “Which noises are intrusive to you?” (“Quels bruits vous paraissent dérangeants?”), 92% of the people mentioned noises that can be classified into the following clusters:

- **Squeaking, clattering, cracking, creaking noises (“Crissements, claquements, craquements”):*** This cluster refers to noise caused by movements of partitions, doors and ceilings (29% on both sets).
- **Noises of engine, stabilisers and bow thrusters:*** These refer to low frequency vibrations and a continuous background noise (22% on both sets).
- **Ventilation and whistles (“Ventilation et sifflement”):*** According to these answers again, a continuous background noise is emitted, that is more high-pitched and is not perceived as a vibration (28% on both sets).
bullet **Alarms and calls**: These refer to sudden, unexpected events liable to occur at any time in the day (5% on both sets).
bullet **Heavy sea against the hull** (“**Paquets de mer sur la carène**”): This is mentioned only in the first set of responses because of bad meteorological conditions.

### 3.2.2. Acoustically uncomfortable places

80% of the people gave answers in this section. The most uncomfortable places mentioned are:

- Cabins (31%).
- Crew restaurant (21%).
- Spectacle hall (7%).
- Machines (7%).

Owing to their low percentage of mention, others places are not significant. For instance, the relaxation room, an important place as far as acoustic comfort is concerned, turns out to have no major problem.

### 4. Discussion

#### 4.1. Importance of acoustic factor

It was obvious from overall reading of the short questionnaire file that acoustics was the main or even the only concern of its authors. Thus a bias could have been induced, especially since people more sensitive to noise would have been more inclined to take the (however short) time to answer the questionnaire and give it back at the end of the trial, and others to throw it away. There is no way of avoiding such a bias when using a short questionnaire file, and it is difficult as well to estimate its effects when merely analysing the collected files. We should conclude at this stage that acoustics is a comfort criterion of prominent importance, but leave stronger confidence to further study.

#### 4.2. Relevant or irrelevant factors in acoustic comfort

- **Age**: We have mentioned already that 80% of the respondees were less than 45 years old. It may be that elderly customers, usually the most numerous of cruise passengers, would have a different perception of noise and different needs as regards comfort. This hypothesis is backed up by the answers of the people aged 45 or more in our professional population which seem more critical. It could be a sensible idea to perform further investigation with an older population.
- **Sex**: Clearly, the proportion of male and female subjects to be found in a genuine passenger population is expected to be more evenly balanced and, as a consequence, the perception and standpoint of that population towards comfort aspects could differ.
Professional classification: Executive engineers tend to insist on sensations and feeling, while technicians and professionals are more concerned with technical aspects such as the type and origin of noises. Thus more information is likely to be collected with several professional profiles as this was the case in the present study. No significant difference of perception was noticeable between professionals from Les Chantiers de l'Atlantique and sub-contractor teams.

Place where the questionnaire was filled: This factor does not appear to influence the answers. For instance, the most noisy places are not necessarily those where the questionnaires were completed.

Weather and sea conditions: An initial question was raised about the interference of other environmental factors (such as temperature, lighting, other people activities and so forth) on acoustic comfort experienced by passengers, since hearing sensation should be influenced by these conditions [12]. It was especially foreseen that particular conditions affecting passengers aboard a ship (such as pitching and rolling) were likely to increase their sensiveness to a bad noise environment. One of the sea trials covered by our study was affected by adverse weather conditions. However, it turned out that sea noise was mentioned more often while no other significant effect was induced.

Time of day: No effect of this factor is found either. This may be attributed to the continuous character of activity during sea trials.

4.3. Origin of disturbing noise and their effects on people

The initial intent of the study was to identify subjective impressions of acoustics in a cruise ship environment. When analysing files, we found out that people quite often insisted on their personal reaction to noise. The study indeed did not consist of sound quality tests performed in a laboratory, where rather passive subjects are requested to answer questions related to the subjective character of sounds. On the contrary, people involved in sea trials regarded the ship as their working environment. Since they had a mission to fulfil, and needed resting periods as well for that purpose, they were induced to judge the acoustic environment as a factor that could influence their activity, and as a consequence were responsive to its characteristics.

Squeaking, clattering, cracking, creaking noises: They were repeatedly attributed to defects in design or assembling, or lack of proper isolating materials.

Ventilation and whistles: There was much insistence on noise disturbances caused by ventilation. This constant, regular noise annoys people and gets on their nerves. According to many collected remarks, ventilation combined with air circulation inside the ship is source of very disturbing whistles. As these noises are not fundamentally related to navigation, an improved design of ships should reduce them.

Noises of engines are more closely related to ship constitution. Sea noise is a natural phenomenon, might not be necessarily unpleasant to a passenger in the context of a cruise, and, according to some people, should not be suppressed. These
two phenomena are unavoidable during deep sea cruises and are not likely to be easily corrected either. Nevertheless, they are sometimes considered as major disturbances.

- Alarms and calling are too barely mentioned to deserve further analysis.

With regard to effects on people, multiple facts are recorded. Most of the collected answers mentioned that regular and haunting noise kept people from sleeping whenever in the day or the night. Resulting tiredness is the obvious cause of the other reported troubles such as annoyance and irritation. This underlines the significance of acoustic comfort and the consequences of an acoustically inadequate environment aboard a cruise ship.

4.4. Places of discomfort

Answers to open questions demonstrate that particular rooms are felt as more uncomfortable:

- Crew cabins, where ventilation and creaking are especially disturbing.
- Crew restaurant, where engine vibrations are most intrusive.

Considering the whole collection of completed questionnaires, it appears that some disturbing noises are felt only in certain parts of the ship. These include bow thrusters in the fore part and the main propeller in the aft part and water flow on the stabilisers in the middle of the ship.

5. Conclusion

The first results of a study about acoustic comfort on board cruise ships have been presented. A questionnaire was used to investigate the perception of professionals during sea trials. Some crucial points have been identified. However the conditions and context of the study should be considered when judging the following conclusions:

- Acoustics appears as the significant criterion pointed out among the miscellaneous criteria of global comfort: lightning, ergonomics, visual, temperature, ...  
- The influence of acoustic discomfort on people is to produce sleep disturbance and irritation.  
- The most irritating noises fall into three categories:  
  - Squeaking, clattering, cracking, creaking noises,  
  - Noise of engines,  
  - Ventilation and whistles.

Further work should include extensive tests in real or realistically simulated conditions. For instance, questionnaire-based inquiries in different places for different
types of ships, combined with simultaneous recording with further comparative laboratory experiments in mind, could help to expose the most unpleasant noises for cruise passengers and the resulting effects.

Acknowledgement

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References