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EVALUATION OF REACTION TO NOISE AND VIBRATION IN AIRPLANES. AN INTERDISCIPLINARY APPROACH ON ANNOYANCE MEASUREMENT

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ABSTRACT
When carrying out a survey on noise and vibration in airplanes different subject-centered methodological procedures have been taken into account to develop a suitable measurement procedure. The survey focusing on perception of sound and vibration was conducted with about 600 subjects from different European countries regarding to flight situations in jets- and propeller airplanes and helicopters. The tests carried out concerning helicopter flight situations with 132 subjects included real flight and mock-up situation had similar approaches in so called mock-ups (laboratory equipment) and real flight situations. Procedures and results of these tests will be presented with respect to improvement of social surveys especially addressing the meaning of noise and vibration in a defined environment.

1 - INTRODUCTION

When sound and vibration are judged concerning comfort or quality, various dimensions structuring this procedure have to be taken under consideration. Necessarily, since the subjective judgments will be influenced by different moderators, the methods have to be adapted to the objectives under physical, psycho-, socio acoustical, and psychological aspects [1]. Related to the procedure developing a comfort index concerning flight situations the evaluation process on combined effects of sound and vibration integrating interdisciplinary concepts and first results will be presented. Due to the given situation in the two tests the presentation will focus on the meaning of field studies in such research work on sound and vibration.

2 - EVALUATION

When starting to conceptualize the evaluation of sound and vibration in airplanes based on a review of the relevant literature it became obvious that an adequate measurement procedure did not exist. A step by step pretest procedure using the CIS-method [2] in field and laboratory pretests with an expert group as well with naive test persons lead to a context orientated semantic differential concerning jet- and propeller airplanes on the one hand and helicopter on the other: 15 adjective pairs with regard to airplanes and 20 adjective pairs regarding to helicopters (Table 1).
Both of the semantic differentials have 10 identical adjective pairs including the 5 psycho acoustic descriptors loudness, roughness, sharpness, tonality and fluctuation strength [3], another 10 are specific concerning the helicopter, 5 are specific regarding airplanes. Additionally, the questionnaire covered social data like age, gender, profession, flight experiences as well as an overall judgment of the test situation.

ITEMS OF THE SD		Helicopter	Airplane
bearable	unbearable	**X**	**X**
comfortable	uncomfortable	**X**	**X**
threatening	harmless	**X**	**X**
shaking	calm	**X**	**X**
vibrating	not vibrating	**X**	**X**
dangerous	safe	**X**	**-**
pleasant	unpleasant	**X**	**-**
oppressing	liberating	**X**	**-**
well-sounding	ugly-sounding	**X**	**-**
crumpled	smooth	**X**	**-**
rotating	still	**X**	**-**
strong	weak	**X**	**-**
shrill	dull	**X**	**-**
palpable	impalpable	**X**	**-**
pushy	reserved	**X**	**-**
muffled	not muffled	**-**	**X**
acceptable	unacceptable	**-**	**X**
regular	irregular	**-**	**X**
monotonous	varied	**-**	**X**
high-frequency	low-frequency	**-**	**X**
loud	quiet	**X**	**X**
rough	not rough	**X**	**X**
tonal	not tonal	**X**	**X**
unsteady	steady	**X**	**X**
sharp	not sharp	**X**	**X**
		20	**15**

Table 1: Semantic differential.

3 - FLIGHT TESTS

The helicopter test series have been carried out with 25 subjects (13 female and 12 male) taking part at the real helicopter flights and 107 subjects (45 female and 62 male) at the helicopter simulation tests in the mock-up, 25 of them took part before in the real flight test.
Both tests have been conducted following a similar procedure: in a communication room the test persons became familiar with the test procedure and were then lead to the helicopter flight or to the mock-up. 5 flight situations were presented twice in a randomized order: hover, 60, 100, 120, and 140 knots. Each flight situation was evaluated using the semantic differential for helicopters in the native language of the Ss (Italian). After the flight or mock-up test the test leader brought the test persons back to the communication room where they answered to the final questionnaire.

4 - RESULTS

First results demonstrated in the mean **semantic profile** concerning the flight situation 140 and 100 knots show the differences of judgments regarding the two flight situations 5 and 3. As an overall interpretation it turns out that the flight situation 140 knots is less comfortable than flight situation 100 knots, it is less pleasant, not dangerous but more vibrating and rotating, it is loud and palpable while the situation 100 knots is more comfortable, more pleasant, not at all dangerous, threatening or unsteady, not so loud etc.
Carrying out the **factor analysis** concerning the 5 flight situations 3 factors were detected each: the items well sounding, pleasant, comfortable, and bearable are describing the factor 1 explaining for all flight situations more or less one third of the variance, except in flight situation 1, second run, where the comfort related factor is explained by 51 %. In the mean time the complimentary items are strong, oppressing, unsteady, but especially the items loud and rotating differ in the factor loadings concerning the 5 flight situations (fig. 3, fig. 4). It is obvious that the real flight situation plays a significant role. The comparison to the mock-up evaluation may explain these findings as well as the comparison to the findings of the jet- and propeller mock-up evaluations.
Basically, the three factors could be detected regarding to each flight situation which may be described by comfort, vibration, and psycho acoustic parameters (Table 2). A special attention should be given to

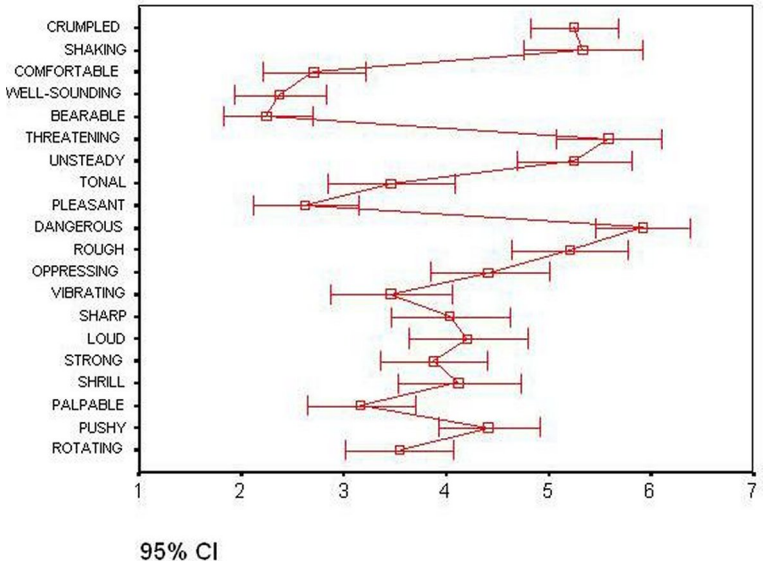

Figure 1: Flight situation 3 (100 knots).

the items "rotating" and "loud". It looks like that rotating is of different perception in a hover situation than in the flight, the same is true for loud. Again, further analyses are necessary.

Flight situation	Factor 1 (%)	Factor 2 (%)	Factor 3 (%)
hover	29,803/51,822	20,230/11,935	10,297/10,948
60 knots	27,136/36,941	24,936/20,411	13,414/12,510
100 knots	25,604/43,556	19,922/15,711	13,939/11,190
120 knots	28,670/26,985	18,058/21,001	15,453/17,009
140 knots	27,482/36,734	20,867/17,478	11,859/13,042

Table 2: Factor analysis on the 5 flight situations, 1./ 2. run − explained variance.

5 - DISCUSSION

The first results concerning the evaluation of the real flight situation will be discussed here from the methodological point of view with regard to social surveys. Definitively, the process conforming the evaluation procedure to the objectives lead to two different semantic profiles concerning airplanes and helicopters. The results demonstrated here show that a specific combination of items in a semantic differential which is developed based on the objective enables to explore the perception adequately. A similar approach in a project regarding car interior sounds intensify such findings [4,5,6,7]. With respect to international studies it has to be taken into account that the semantic differential was developed in German, intercultural differences concerning the judgments have to be discussed by the cultural background and with regard to the contextual conditions given by the native language. Further analyses of the data in the real flight conditions as well as in the mock-up will necessarily give an extended impression.

6 - CONCLUSION

This part of the study was conducted in the defined environment "helicopter" but the act of adapting the procedure should be discussed regarding the improvement of social studies. The idea is to transform the procedure of adaptive measurements to social studies.

Evaluation of sound and vibration has to include the contextual conditions in a given situation in a laboratory or such a real situation like the real flights. Going towards the evaluation of soundscapes in urban areas, measuring environmental noise has to focus on different aspects like the structure of urban areas, people living in those areas, architectural and social parameters designing those areas, and acoustical and visual parameters.

Judgments on soundscapes in residential areas depend on multiple factors like environment, noise source, characteristic of noises, number of noise events over a day, subjective experience with noises, and social situations. Judgments on flight situations with regard to sound and vibration include in a similar way

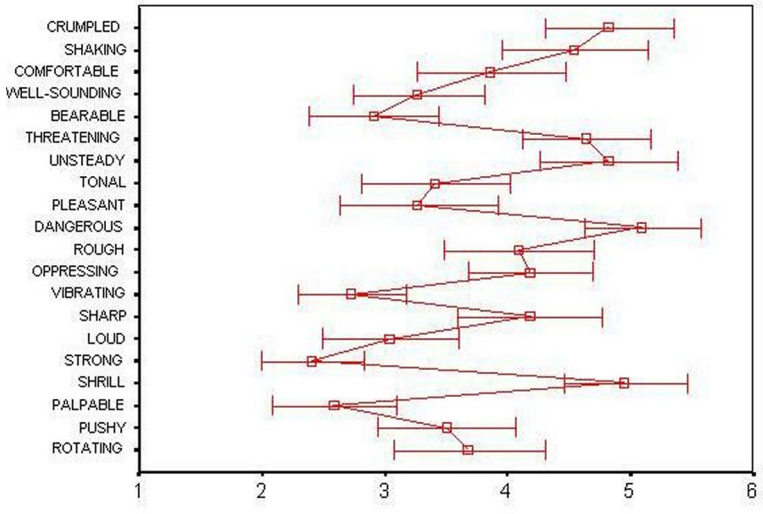

Figure 2: Flight situation 5 (140 knots).

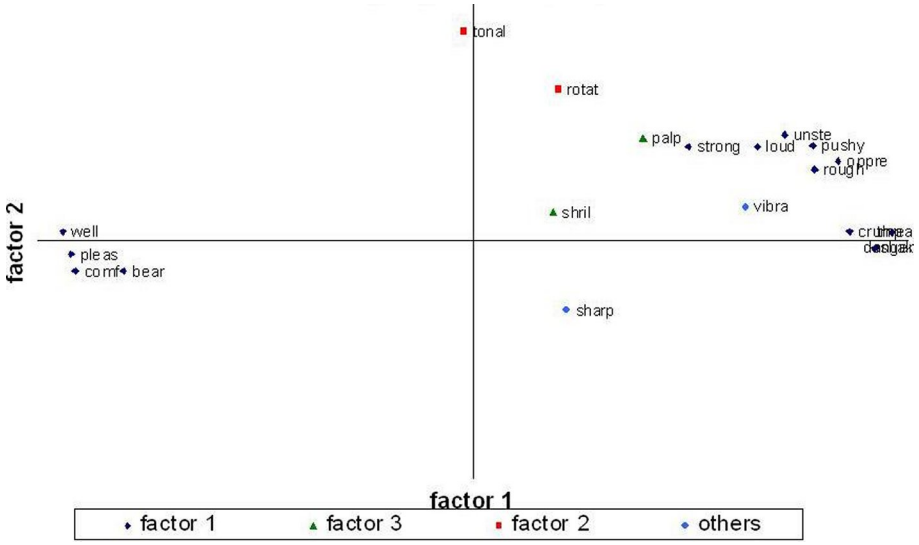

Figure 3: Flight situation 1 (hover).

a wide range of variability. Since social environment and lifestyle shape up the psychological and social conditions on short as well as long term intervals, it is concluded that the basis for the variability of reaction to a specific soundscape or environment is subjectively defined.

Considering the contextual conditions of noise annoyance judgments is one important procedure regarding the measurement on annoyance towards noise sources. A measurement is needed, which refer to objective and subjective parameters. The structure of the residential area, the combination of noise sources, the soundscape are for the judgment of annoyance as well important as subjective parameters which are relevant by the people's point of view, moreover the relationship of both define the background for assessments.

The combination of methods with different sensibilities for subjects' work during a process of perceiving, describing and/or evaluating noise in such an environment is necessary for a reliable and valid analysis and interpretation of data. Therefore noise annoyance research, research on soundscapes as well as studies on acoustical comfort need an interdisciplinary procedure, methodologically including acoustics, physics, psychology, and sociology. The multidimensionality in a given social situation of evaluation has to be taken under consideration. Future research work is urgently needed.

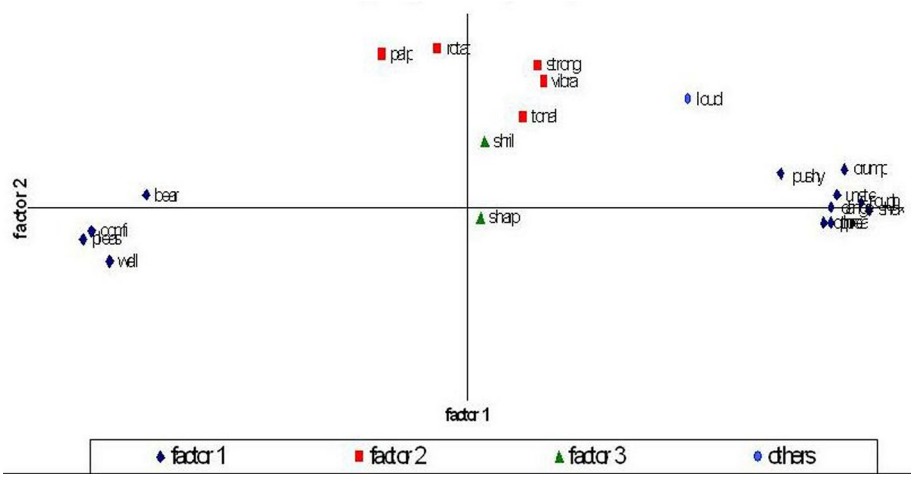

Figure 4: Flight situation 3 (100 knots).

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