Effects of noise on the comfort of cabin crew studied in an aircraft cabin simulator

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Abstract

Experiments in an aircraft cabin simulator are carried out to study the effects of controlled variation of environmental factors (air temperature & humidity; noise and vibration) on the comfort of passengers, flight and cabin crew. This paper describes unexpected order effects of sound perception and shows the dependency of environmental parameter assessments on the perceived comfort for the cabin crew.

1. Introduction

The impact of environmental factors as air climate (temperature humidity, draught and radiation), air quality (purity), noise/vibration, movements, lighting, …, on cockpit and cabin crew affects health performance and comfort aspects at their workplace including safety aspects.
The investigations and experiments in the multinational European project "HEACE – Health effects of aircraft cabin environments"[1] aim to develop a human response model that is capable to model the effects of environmental factors on flight and cabin crew at their work environment inside aircraft.
For the model development it is essential to understand the responses of flight and cabin crew to changes of environmental factors. As those changes (e.g. temperature or sound level changes) are difficult to be implemented during normal in-flight operation, experiments in cabin simulators have been carried out.
In the course of experimental campaigns effects of changes of environmental factors have been investigated with regard to flight and cabin crew as well as for passengers. The research on passengers' responses was done in cooperation with the European FACE Technology Platform (FACE – Friendly aircraft cabin environment).
This paper concentrates on the effects of noise and vibration level changes on the overall comfort of the cabin crew in the cabin and galley.

2. Experiments in a cabin simulator

For the transferability and validity of the results the conditions for the cabin crew during the experiments have to be as realistic as possible and as similar as possible to the work situation during real flights. Experiments have been conducted in cabin simulators in Vienna (Austria) and Garston (near London / UK)[3]. Here we refer to experiments in the ACE (Aircraft Cabin Environment)[4] of the English partner BRE (Building research Establishment).

The responses of the cabin and flight crew on the environmental parameter change were investigated using questionnaires, observations and physiological measurements. The physiological measurements and conduction of performance tasks for the cockpit and cabin crew were conducted by the Institute of Environmental Hygiene)[2] in Vienna.

2.1. Cabin simulator

The ACE Test Facility is a part of an Airbus A300 B4 (cockpit plus 11m cabin). It provides space for about 35 passengers in main cabin (seat spacing 950mm). The rear cabin can be used as research area (2.75 by 6m) or for additional seating.

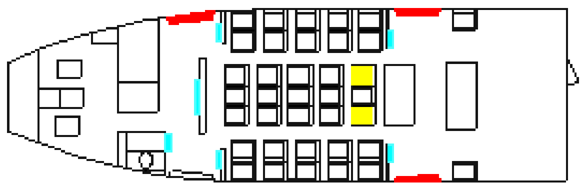


Figure 1: Schematic figure of the ACE (Aircraft Cabin Environment) with controlled climate (temperature and relative humidity) and noise and vibration

2.2. Experimental setting

The experiments are carried out in a a full 3x3x3 factorial design with the environmental factors: temperature (t), relative humidity (rh) and noise/vibration (n/v) with the possibility to study interactions. The factor noise/vibration is measured repeatedly.
The design was developed together with E. Groll-Knapp[2], M. Trimmel[2], G.Raw[3], H. Emms[3] and J. Seller[3]. Its scheme in table 1 consists of triple

combinations | n/v1 | n/v2 | n/v3 |. n/v1 in a defined temperature (tm; m= 1,2,3) and humidity (rhn; n= 1,2,3) environment. n/v stands for a combined noise and vibration condition with a sound pressure level of 70 dBA for n/v1; 73 dBA for n/v2 and 75 dBA.for n/v3 Each experimental condition is lasting for about one hour (see table 2). Then the sound and vibration levels are either increased (L+ upper part of the table) or decreased (L- lower part).

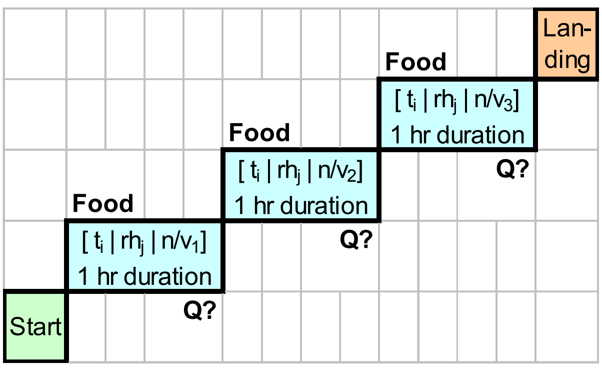
Table 1: Experimental design (L+: sound and vibration levels increase / L- sound and vibration levels decrease)

L+	t1			t2			t3		
rh1	n/v1	n/v2	n/v3	n/v1	n/v2	n/v3	n/v1	n/v2	n/v3
rh2	n/v1	n/v2	n/v3	n/v1	n/v2	n/v3	n/v1	n/v2	n/v3
rh3	n/v1	n/v2	n/v3	n/v1	n/v2	n/v3	n/v1	n/v2	n/v3

L-	t1			t2			t3		
rh1	n/v3	n/v2	n/v1	n/v3	n/v2	n/v1	n/v3	n/v2	n/v1
rh2	n/v3	n/v2	n/v1	n/v3	n/v2	n/v1	n/v3	n/v2	n/v1
rh3	n/v3	n/v2	n/v1	n/v3	n/v2	n/v1	n/v3	n/v2	n/v1

During one 'flight' three different settings of the acoustic&vibration environment are tested: 70dBA|73dBA|75dBA or 75dBA|73dBA|70dBA. During one flight the temperature and the relative humidity within the cabin are held constant.
A 3x3x3 factorial design requires 27 different factor combinations to be tested. The whole set of experiments is repeated once. As we tested three factor combinations during one flight which lasts for about three hours and a half 18 flights are required. All flights are conducted on different days. Because of the test design every test person evaluates three experimental conditions during one flight.

Table 2: Simplified time history of an aircraft flight



2.3. Questionnaires

The cabin crew had to fill in one pre-flight, one post-flight and three during flight questionnaires. The latter three are identical and contain following main areas:

- health and well-being (30 items)
- environmental conditions (45 items)
- control over environment (8 items)
- relative comfort contribution (18 items)
- effect of the environment (18 items)
- ability to work (8 items)
- alertness and mood (9 items)

The cabin crew also had to accomplish performance tasks and physiological measurements were carried out during their entire work. The questionnaires were developed together with E. Groll-Knapp[2], M. Trimmel[2] , G.Raw[3] and H. Emms[3]

3. Results

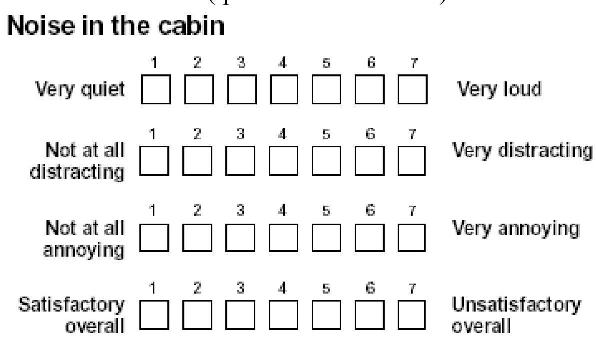
During the 18 flights experimental results have been gathered from:

- 18 Pilots
- 70 Flight Attendants
- 364 Passengers

The actual paper will concentrate on some aspects of the cabin crew questionnaire data with relation to the effects of noise.

3.1. Loudness, distraction annoyance and satisfaction with noise in the cabin – order effects

The sound in the cabin is adjusted to the sound in a real aircraft. It's level is changed after each hour during flight in such a slow rate that the level change can hardly be detected even by experienced acousticians.
In the set of the 7 point scales that are used to assess the cabin environment conditions the following four ones are related to noise (questionnaire extract):



Comparing the answers for the four items by cross correlation coefficients it turns out that the answers for distracting, annoying and the satisfaction are rather similar, so that annoyance is chosen as a representative item. It will now be investigated together with the rated loudness.

Are there significant answer differences in the three different noise conditions (70, 73 and 75 dBA)? And is there a difference between ratings during a flight when the sound level was raised (together with the vibration level) after each hour compared to the situation where the level was lowered? In the latter case the 75 dBA condition begins at once after the start, the medium level is always the same (73 dBA), and the average sound level at the end will be 70 dBA.

The mean answers (together with the 95% confidence intervals) for the loudness questions are shown in Fig. 2 separated into the cases of noise level increase and level decrease during the flight.

An ANOVA taking into account the replicated measurements for the noise conditions during one flight is calculated to check whether the answers are significantly different with regard to the environmental factor sound level and the order of presentation. It turns out that there is a significant difference of the answers with respect to the noise level and to the order of presentation.

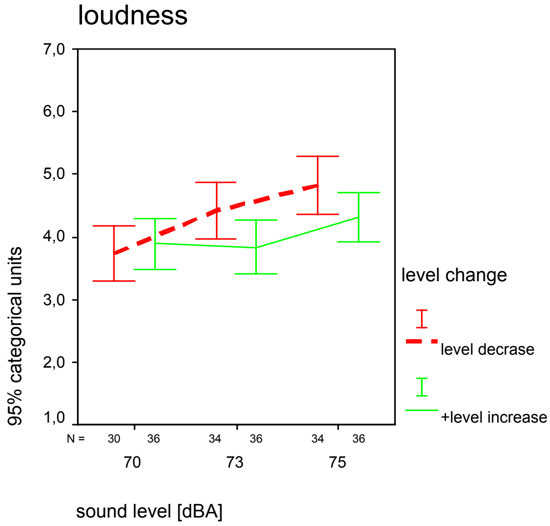


Figure 2: Subjective loudness of cabin crew as a function of the dBA-level in the cabin. The dotted line shows the loudness for increasing level: 70 dBA first, then 73 dBA and 75 dBA. The loudness for a 75 dBA-level first, followed by 73 dBA and again 70 dBA is drawn with a solid line. Each level is held constant for one hour and judgments are made at the end of each hour. Order effects can be observed when comparing both loudness curves.

This surprising effect also holds for the loudness rating of the passengers. For them the effect is still more pronounced.

The answers of the cabin crew for the noise annoyance item yield the opposite behavior (See Fig.3). In the case of noise level increase during flight (green solid line) the annoyance ratings increase in a way as one would have expected already for the loudness assessments. On the other hand there is no real decrease of the annoyance if the highest level condition level condition comes first (dotted red line) and if the level is decreased during the flight according to the experimental plan.

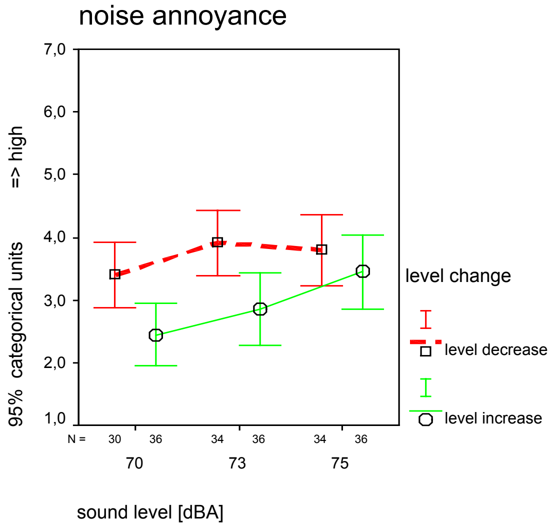


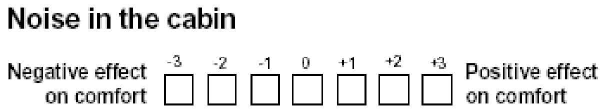
Figure 3: Annoyance of cabin crew as a function of the dBA-level in the cabin. The dotted line shows the annoyance for increasing level: 70 dBA first, then 73 dBA and 75 dBA. The annoyance for a 75 dBA-level first, followed by 73 dBA and again 70 dBA is drawn with a solid line. Each level is held constant for one hour and judgments are made at the end of each hour. Order effects can be observed when comparing both annoyance curve. In contrast to the loudness judgments the annoyance ratings show a significant difference for the increasing level case between the 70 and 75 dBA levels.

If one assumes an increase of annoyance with time because of the workload for the cabin crew or other (integration) effects then the annoyance ratings might be explained. This would be in accordance with the fact that the passengers exhibit the same picture for annoyance as for loudness. But these speculation are not scientifically supported, yet.

Again it has been tested by an ANOVA that the noise annoyance ratings are significantly different for the different noise levels as well as for the order effects.

3.2. Relation between the environmental ratings and their effect on comfort

A number of items deals with the relative contribution of environmental factors to comfort. The following item refers to the effects of noise on comfort.



This item is representative for the other items that relate to odor, lighting, air-movement, vibration temperature humidity and movement. The used scales are the same as the one for noise. If the effect is negative, the corresponding number also is below zero.

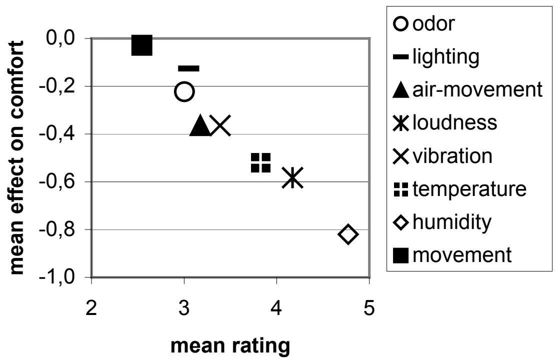


Figure 4: The mean effect of different environmental factors on comfort in the cabin are plotted against the mean rating that was given for the different environmental factor. It turns out that there is a strong linear relationship which means that the actual magnitude of the assessed factor is decisive for its effect on comfort. comfort.

How are these effect about impact on comfort related to the rating of the environmental factor themselves? To investigate whether there is a relationship the mean values of the effects of the individual factors are plotted over the mean ratings of the different environmental factors. It turns out that there is nearly a perfect linear relationship between the magnitude of the factor and its effect on comfort. This means the more pronounced a factor is rated the higher is its effect on comfort.

It must be stated here that this relationship is essentially valid between the magnitude of the factors (themselves) and their effect on comfort. The relationship is not so linear and well defined if the direct assessments scales of the factors – *e.g. loud / quiet for loudness, hot/cold for temperature, humid / dry for humidity* – would be substituted by the different satisfaction scales (*satisfactory overall / unsatisfactory overall*) which are also linked to the factors.
Obviously it is the perceived strength of the environmental factor itself and not its satisfactory or unsatisfactory effect which is judged to have a major impact on comfort.

4. Conclusions

In a long lasting flight experiment in a aircraft cabin simulator order effects in the perception of sound are detected. This order effect interesting because the presentation time for one sound level is about an hour. Additionally the level change to the next situation is conducted so slowly within a few minutes that the level alteration is not perceived consciously. E.g. a sound level *increase* did not lead to an appropriate increase in loudness. On the other hand a *decrease* of the level resulted .in an expected decrease of judged loudness. For the item noise annoyance the effect was reversed. The loudness anomaly is also observed for the large group of passengers tested.
For a set of environmental cabin parameter as temperature, humidity, loudness, a linear relationship between the direct perceptual ratings and the effect of the factor on comfort is observed. The (negative) factor's effect was more pronounced when the perceptual strength of the factor is high.

5. Acknowledgements

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6. References

[1] http://www.heace.org
[2] http://www.univie.ac.at/umwelthygiene/
[3] http://www.bre.co.uk/services/Acoustics.html
[4] http://www.aeronautica.alenia.it/face