

Development of human response models of comfort, health and performance

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investigation in collaboration with
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and
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EU Projects HEACE and FACE
www.heace.org and <http://face.aeronautica.alenia.it>

Research objective and background

Health, performance, safe operation are key issues for flight and cabin crew as well as for passengers, who additionally demand well-being and comfort in a supportive travel environment. European research aims therefore to enhance the “friendliness” of aircraft transport in the framework programs of the past and future. One objective is to improve the cabin and cockpit environment. Impact from the cabin environment on passengers is obviously caused by numerous factors like sound and vibration, motion, air quality, seat spacing, etc., but also by service, individual appraisal of travel needs, psychological and health status etc.. Similar environmental parameters and the complex field of man-machine-interaction are of major affect to the performance of the crew and influence the overall stability of the complex safety-critical system *aircraft*. To improve cabin and cockpit environment it is necessary to study the relation between physical factors and intrinsic moderators on one side with the set of relevant output parameters on the other side, which reflect e.g. well-being, or comfort, or health, or performance. A human response model provides a quantitative summary these relationships and could offer tools to optimize the environment inside aircraft in the design phase.

Results from three EU projects, IDEA PACI (identification of a passenger comfort index, Co-ordinator: CIRA, closed), HEACE (health effects in aircraft cabin environment, Co-ordinator: Oldenburg University, running) and FACE (friendly aircraft cabin environment, Co-ordinator Alenia, running) are background of the present report. In particular is to be pointed out that experiments reported in this presentation are conducted together with

- the British Research Establishment BRE in the new ACE – simulator and in air-quality measurements,
- the Medical University Vienna in the AUA emergency trainer and in medical, physiological, performance data acquisition,
- EADS-CRC, CIRA, University of Patras, Paragon Ltd., and itap GmbH in data acquisition and evaluation.

Concept and experimental design

For obvious reasons it is only possible to change the environmental conditions in a real flight within given rigid limits. Therefore, tests are designed in a simulator facility, which is tuned to reproduce “real” flight data in a virtual reality. Two simulators with certain vicinity to a real aircraft are used (based on parts of an A 300 and an A 320): The AUA trainer in Vienna and the Aircraft Cabin Environment ACE at BRE in Watford. Virtual reality is created in the simulators, based on real flight data. Acoustic, vibration, motion is to adjust in the AUA trainer, but only limited change in climate is possible. Air quality changes down to very low humidity are achievable in the ACE, acoustics is adjustable, but no motion provided. No simulator facility allows up to now changes in air pressure.

Additionally to establish realistic physical parameters in the simulator it is necessary to develop an experimental setting which resembles real flight situation as much as possible (check-in, in-

flight service, task load for crew etc.). Provided that the environment is configured as optimal as possible, a virtual flight is arranged for passengers and crew, and the response to changes of the environmental parameters is monitored. The human response is recorded with the help of questionnaires, psychological tests and with methods to trace physiological quantities. By revealing the relationship between independent and as such identified “input” parameters and defined, dependent “output” items a human response model is developed with the help of (linear and non-linear) correlation and other statistical methods.

Experiment

After numerous pre-tests a 3 x 3 x 3 full-factorial design was established in the HEACE project, varying the environmental conditions like:

- temperature: 21-22, 24-25, 27-28 °C
- relative humidity: 5-10, 15-20, 25-30 %
- sound and vibration: 70, 73, 76 dB(A) (+/- 0.8)

The objective is to study each mutual interaction of the parameters in the human response. The indicated variation reflects the fact that the target values are only provided for certain fixed locations in the simulator. Real actual values at different places in cabin and cockpit deviate from the given reference in the indicated way. The target values are adapted to real flight data and do not reflect by purpose extreme values. The experimental setting consists of three one-hour periods of a simulated flight, in which the climate-related variables are kept constant and the sound and vibration levels either increase or decrease according to the given three steps. About 100 crew members and over 500 passengers took part in the main tests of HEACE and FACE up to now. Crew members are “wired” to pick up physiological data, crew members have to fill in questionnaires which contain items on

- 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)

Passengers get a similar questionnaire, but with additional comfort-related items and none concerning workload.

Preliminary evaluation

Results are presented for the cabin crew members as an example to illustrate the methodology and human response development. An analysis of the variance of answers from the questionnaire gives insight into those parameters which might contribute to a model output, i.e. in simplified words: Those parameters, which do not seem to vary in response to environmental change or other variability of the input (including intrinsic, individual items) cannot contribute to a model by definition. The analysis of variance reduces some 150 items from the questionnaire to about 50. This number might be even further reduced to a half or third by applying more strict (statistical) criteria. A principal component analysis reveals the similarity of the different items, which cluster well. A two-dimensional space of perception explains about 80% of the variance in the answers of the cabin crew. One dimension is correlated with items related to sound and vibration, the other to the air quality. This result is of course to be expected by the experimental setting, if any environmental impact is assumed at all. The over-all comfort is fed by both factors, while the annoyance is more correlated with the noise. Assessment of work space is highly correlated with the over-all comfort in the answers of the crew.

Numerous correlations between different sets of input variables with subjective answers and with physiology parameters have been carried out up to now. These findings are collated in a flow diagram of 5 input vectors of a human response model, representing

- task load
- noise and vibration
- air quality
- psychological status
- physiological and health status

The basic concept of the model is as follows: The input vectors (each of higher dimension) are “evaluated” and transferred into an internal representation (sensation), which is partly accessible by the questionnaires and by physiological measurements. The internal layers have mutual connections (like in an artificial neural network) and may additionally include control loops. The output of the different assessments, which have to reflect different, physiologically motivated control loops of the human body are weighted and combined to three output vectors in the present stage of investigation, representing

- performance
- comfort/ well-being
- subjective and objective state of health

Each output vector has a low-dimensional base (of about 2 to 5).

Summary and outlook

Since real-flight investigations are only feasible under strictly limited control of the variables which might affect the human response, it is necessary to set up ground-based test beds which provide a simulation of virtual reality as close to real flight as possible. The adjustment and variation of a large set of control parameters is necessary since the subjective perception and assessment is driven by a multidimensional input. Mutual interaction is observed between different “inputs”, which must be taken into account in a quantitative human response model. A very high correlation is observed between the assessed importance of an environmental impact and the contribution of the respective parameter to the overall comfort. The quantitative human response model is derived from the statistical relation between different grades of processed “input” parameters, which is only possible, if the internal representations of the input are measured by psycho-physical and physiological means. Since the output vectors of the model depend on the application (passenger comfort, crew performance, etc.), different models are expected to serve the respective request. The running projects HEACE and FACE will contribute to the development of human response model, but not all input parameters have been included in the investigation, in particular the control of the cabin pressure was not involved.