Influence of cabin and cockpit environment on well-being and performance of flight and cabin crew – results from the HEACE project

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Health Effects in Aircraft Cabin Environment

www.heace.org

cockpit included, focus on crew,
passenger data in collaboration with TP FACE

Objectives of the HEACE project was to investigate the environmental condition and impact on human well-being and performance (1)

in the cabin of an aircraft (simulator)

in collaboration with

Building Research Establishment BRE, UK

Medical University Vienna, Austria

EADS Corporate Research Center

ITAP GmbH

and

… to investigate the environmental condition and impact on human well-being and performance (2)

in real flights

in collaboration with

Medical University Vienna, Austria

EADS Corporate Research Center

ITAP GmbH

Paragon Ltd

and

… to investigate the environmental condition and impact on human well-being and performance (3)

with data analysis und response model development

in collaboration with

Building Research Establishment BRE, UK

Medical University Vienna, Austria

LFME, University of Patras, Greece

CIRA, Italy

overview

- research objective / background /concept
- experimental design
- selected results from real flights
  - physical environmental parameters
  - PCA – space of perception
  - significant items / analysis ov variance (ANOVA)
- selected results from simulator facility
  - PCA – space of perception
  - analysis of variance
- summary /conclusion

comfort, well-being, health, performance...

- key issues for passengers and crew in an aircraft
- European research to enhance „friendliness" of aircraft transport, since FP5
- has significant impact on safety issues

projects related to aircraft cabin

- IDEA PACI (identification of a passenger comfort index) – CIRA *closed*
- HEACE (health effects in aircraft cabin environment) – Oldenburg University www.heace.org *closed*
- FACE (friendly aircraft cabin environment) – Alenia *running*
- ICE (ideal cabin environment) – BRE *running*
- *.....*

supported by the European Commission

environmental impact in cabin and cockpit

- sound and vibration
- air quality, draft, temperature
- passengers: seat comfort
- passengers: service by crew
- added values, specific to purpose of flight (e.g. successfull business trip, holiday trip)
- crew: mood/ friendlyness of passengers
- workplace in galley/ cockpit
- depends on „before-flight“ condition
- .....

objectives of the HEACE investigation

- to measure relevant environmental and instrinsic parameters (psychological, medical, „before-flight" condition, ..., and physical, e.g.vibroacoustics)
- to investigate the human response
- to develop some kind of a „human response model" in order to relate environment → response

concept

- to rely on measurements from in-flight/ real-world measurements
- to monitor precisely environmental condition
- to assess test persons‘ response with questionnaires, tests and measurement of medical indicators
- to correlate/ relate environmental parameters with subjective/ objective response
- to set up a simulator test facility with virtual reality, i.e to reproduce „real“ environmental parameters, in order to vary selected parameters
- to develop a (limited) „human response model“

experimental design

- monitor the environment (data logging all relevant conditions with certified instrumentation)
- design questionnaires (flight and cabin crew, additionally: passengers)

development of questionnaires
(to be used for simulator experiments and in real flight)

- previous experience
- interview of crew personnel
- selection of key words (adjectives, antonyms)
- revise list of pairs of adjectives
- estimate duration to fill-in
- design proper layout (reading electronically)
- design proper scale (magnitude estimation, „temperature" scale [e.g. ASHRAE], link to existing scales, anchor estimates)

questionnaires (crew)

- 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)

similar for passengers, except work-related items but additional comfort-related items

measured parameters

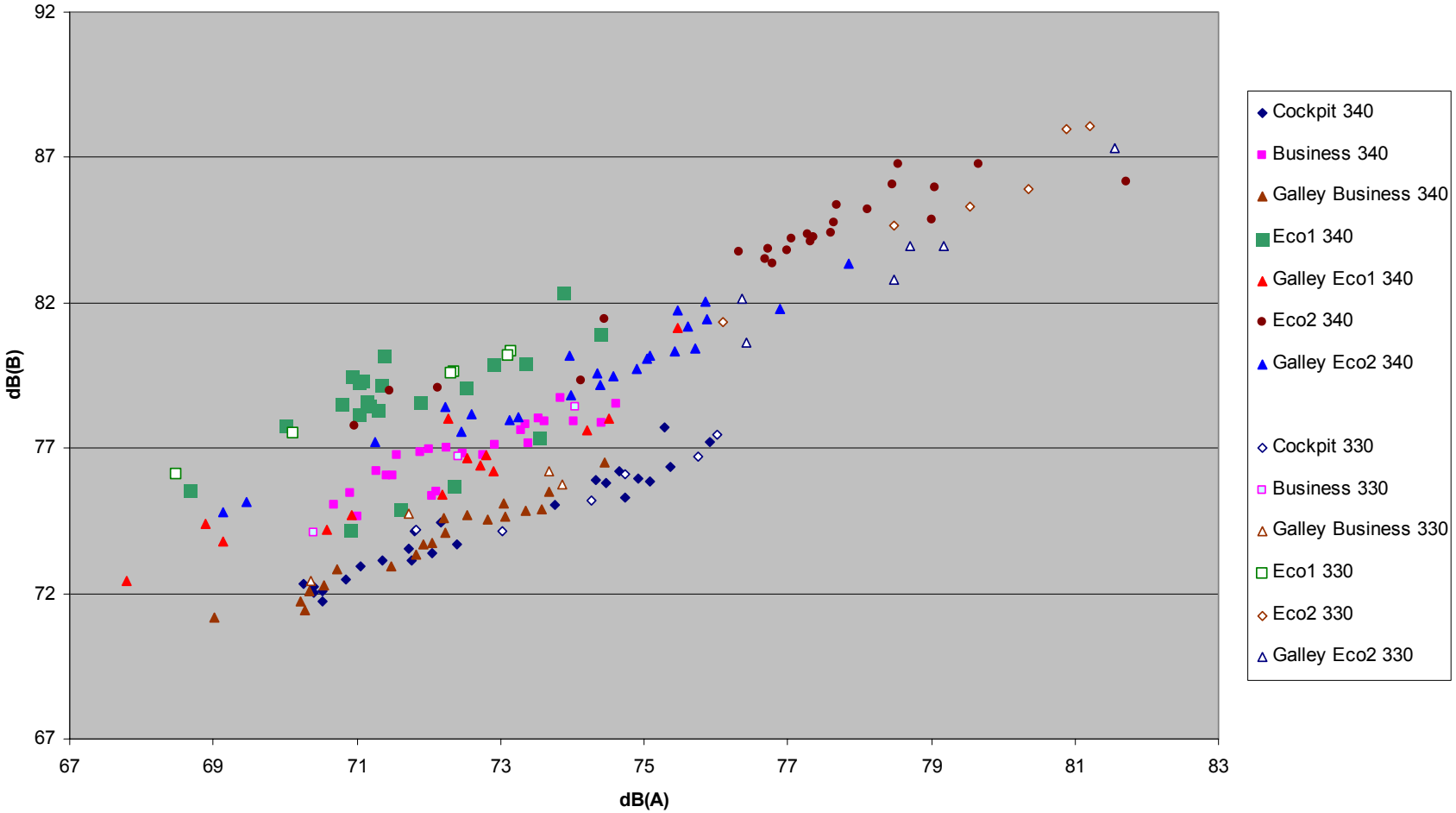
- Physical parameters
  - Sound and vibration (time history and Level)
  - Temperature
  - Humidity
  - Draft
  - Air quality (CO_2, CO, VOCs, number of germs)
- Physiological parameters
  - Heart rate and -variability
  - Blood pressure
  - Oxygen saturation
  - Salivary cortisol
  - Skin conductance

selected results from in-flight tests 12/ 2004

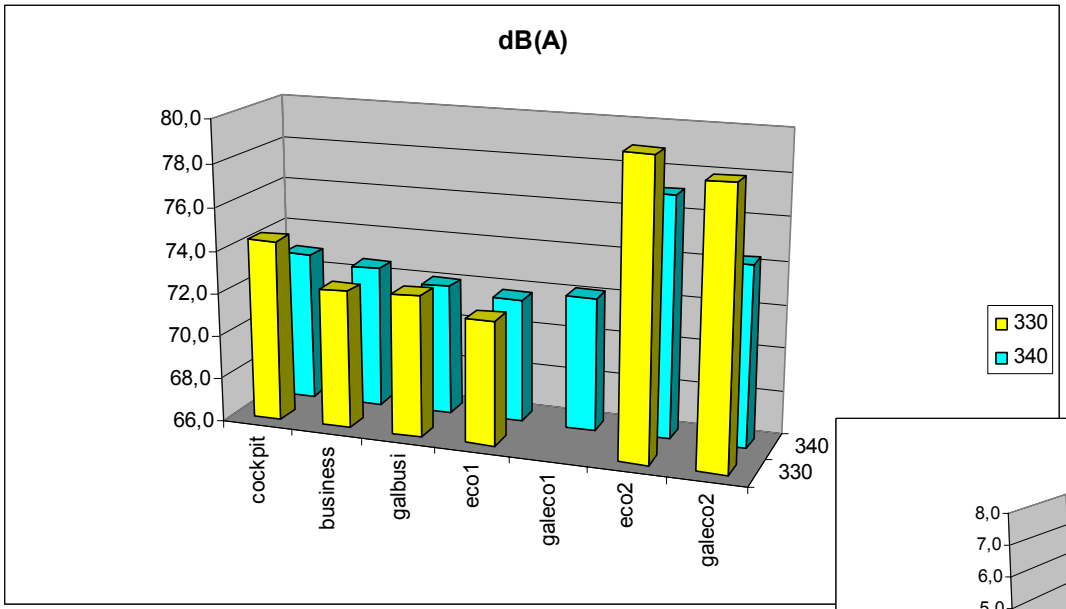
- 3 flights Vienna – Delhi – Vienna (about 8 h duration each)
- 3 flights Vienna – Tokio (Narita) – Vienna (about 12 h duration each)
- mesurements performed in galley, cabin, cockpit and crew rest compartment

- 132 cabin crew
- 30 flight crew

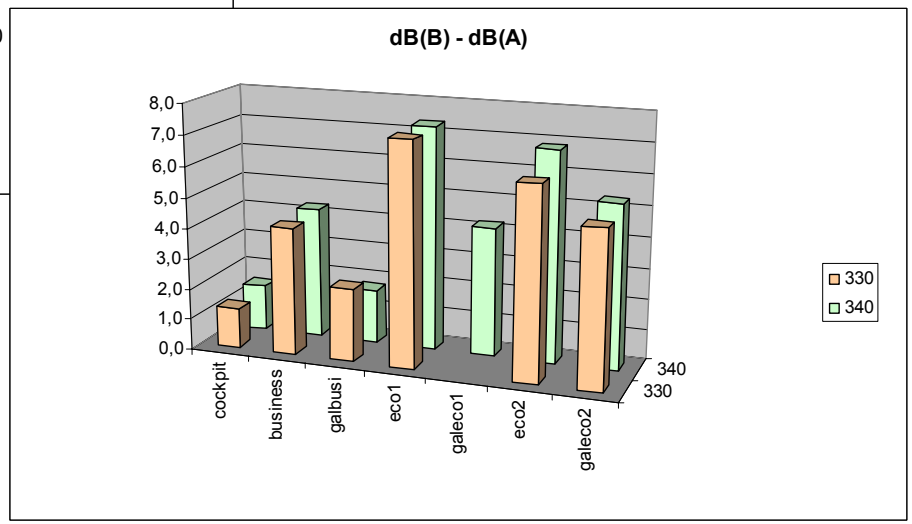
for example: dB(A) vs dB(B) levels (all cases)



Noise level distribution (along cabin)



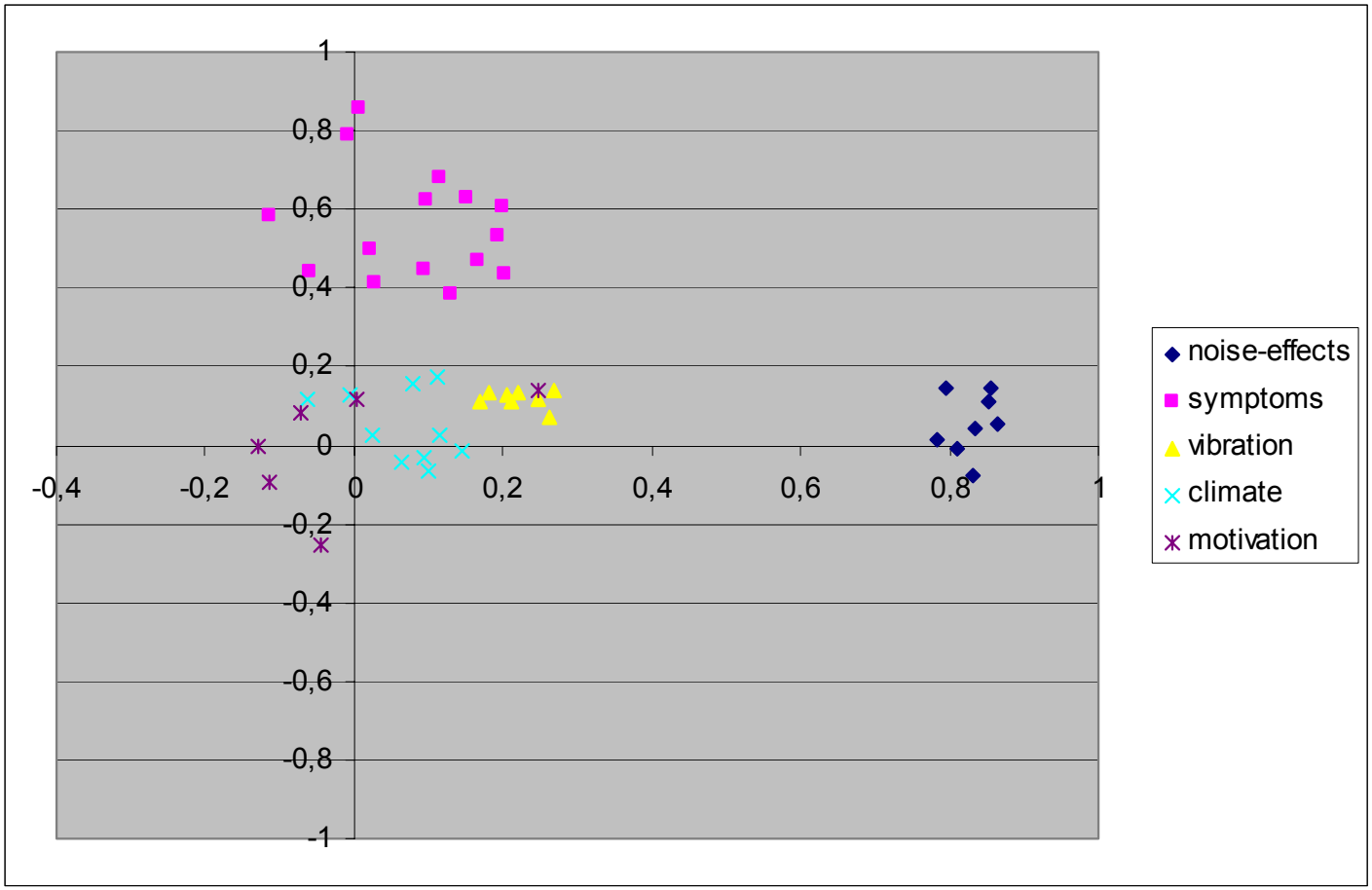
contribution of low frequency components



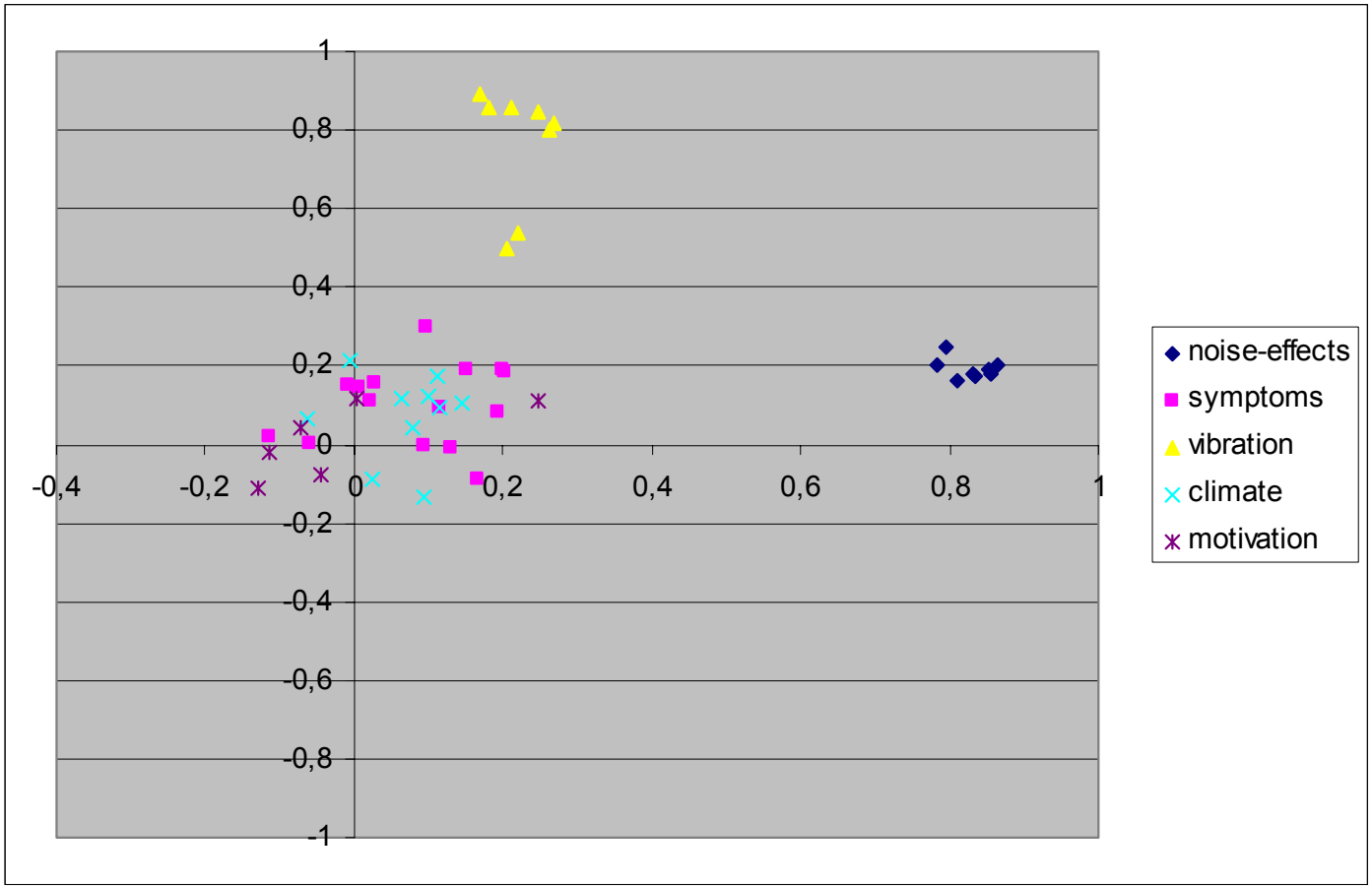
data reduction

- principal component analysis of all cases, i.e. all answers of all persons during each monitored environmental condition
  - clusters of similar perception, e.g. in 11 dimensions
    - noise – effects (distraction, annoyance, ...)
    - symptoms (headache, dizziness, ...)
    - vibration effects and motion
    - temperature, climate
    - motivation, concentration
    - air quality
    - activity (change of certain condition)
    - communication (incl. intelligibility)
    - draft and overall comfort
    - symptoms related to dry air
    - symptoms related to muscle/ jont pain

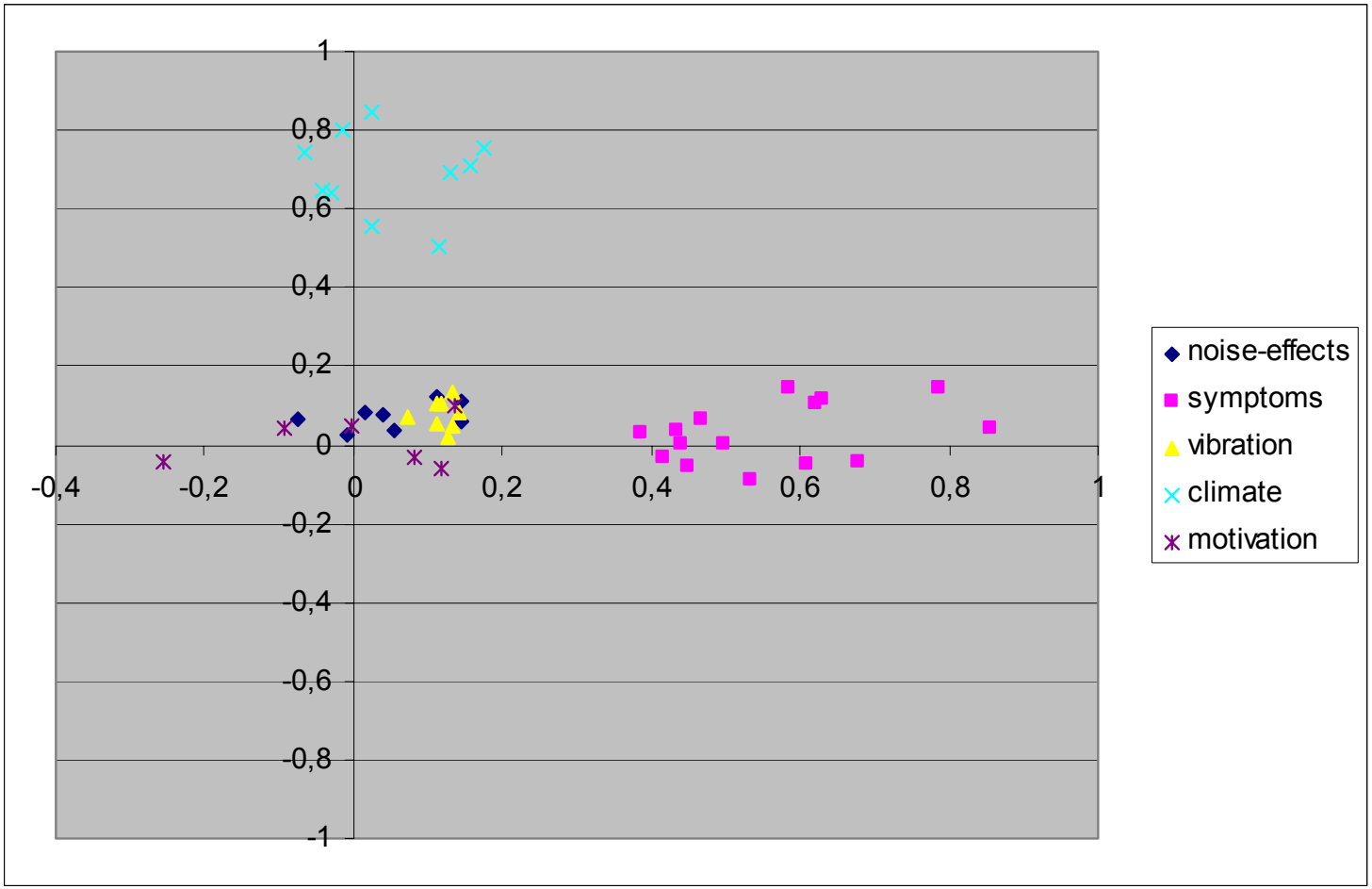
F1 – F2 plane (all cases)



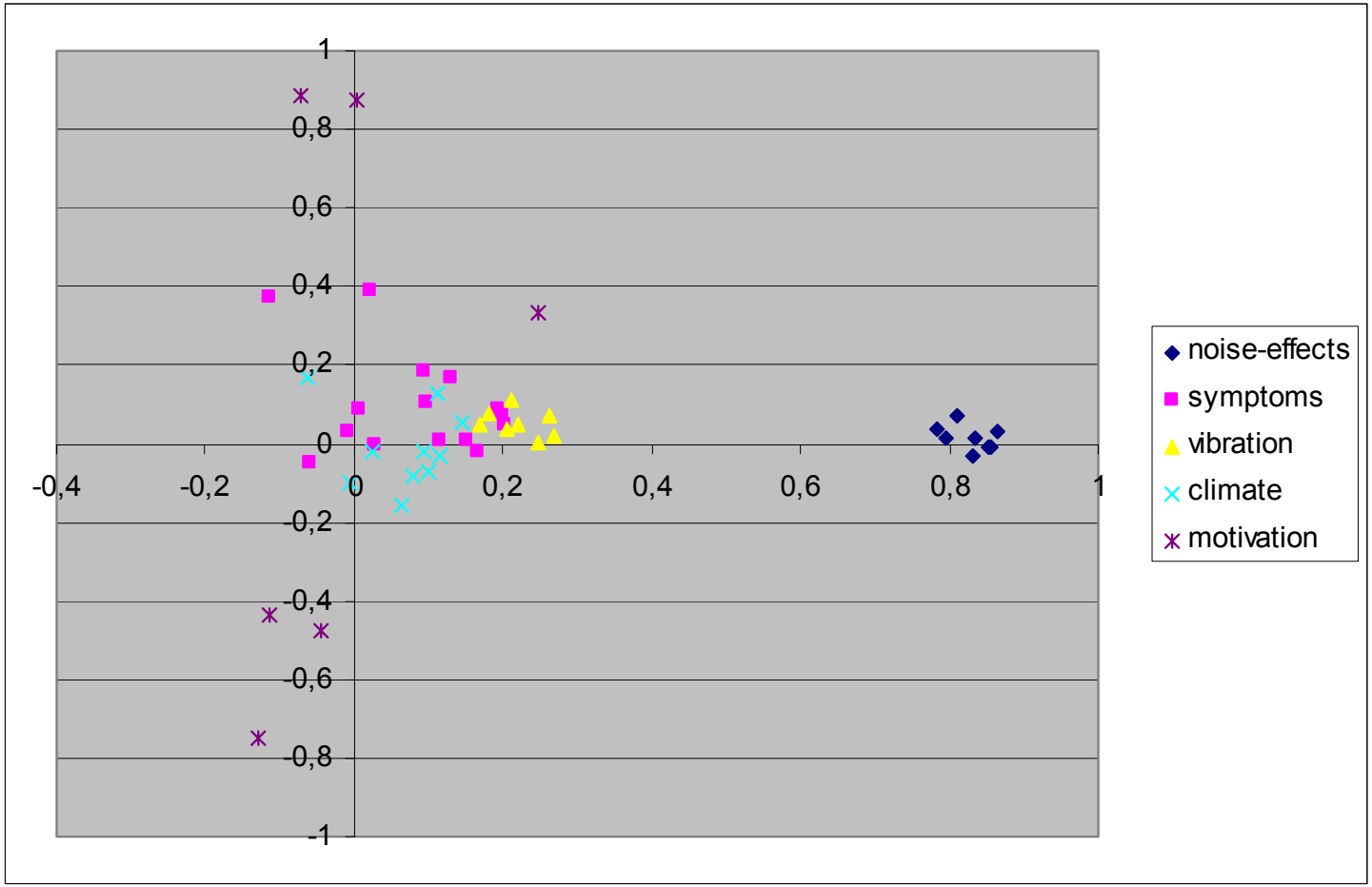
F1 – F3 plane (all cases)



F2 – F4 plane (all cases)



F1 – F5 plane (all cases)



HEACE: Work share in data analysis

- statistical analysis (BRE, UVIENNA and UNOL)
- ANN, artifical neural network (CIRA, UNPA)

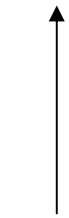
- UNOL: Focus on questionnaires and physical environmental parameters
- UVIENNA: Developed classes of highly significant medical and health indices
- LFME (UNPA): Developed a two-stage ANN with a mean error of prognosis of about 0.5 units (7-scale)

ANOVA

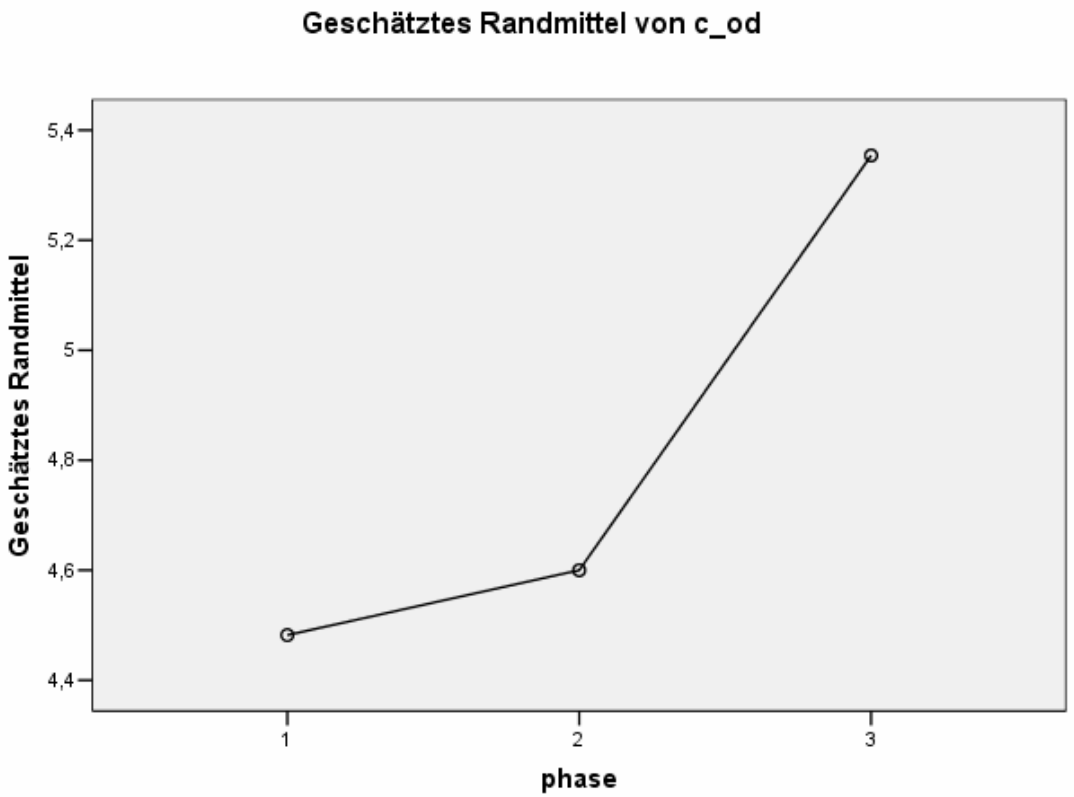
- analysis of variance reveals or rejects relationships between variables
- looks at significant differences in distribution of answers/ reactions related to specific environmental conditions, e.g. noise level
- does not require linear correlation or functional dependency

flight phase: Development of air quality

stuffy

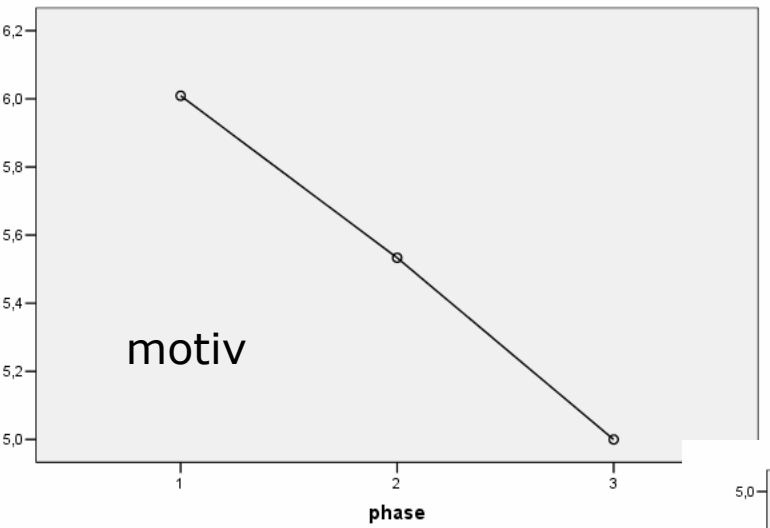


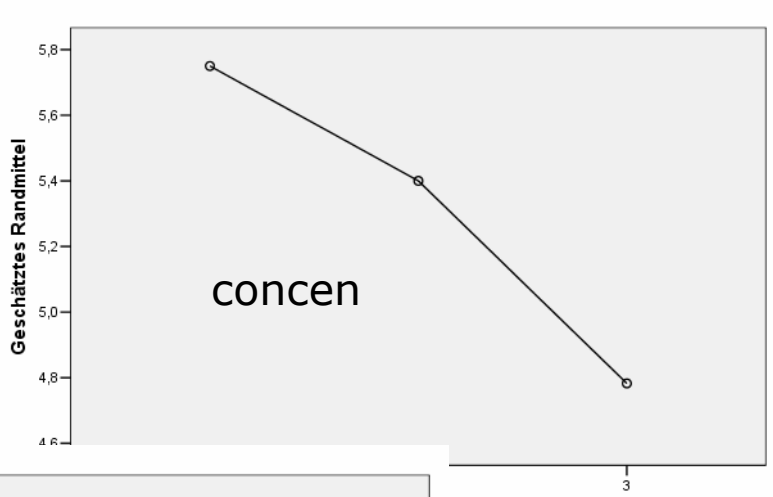
fresh

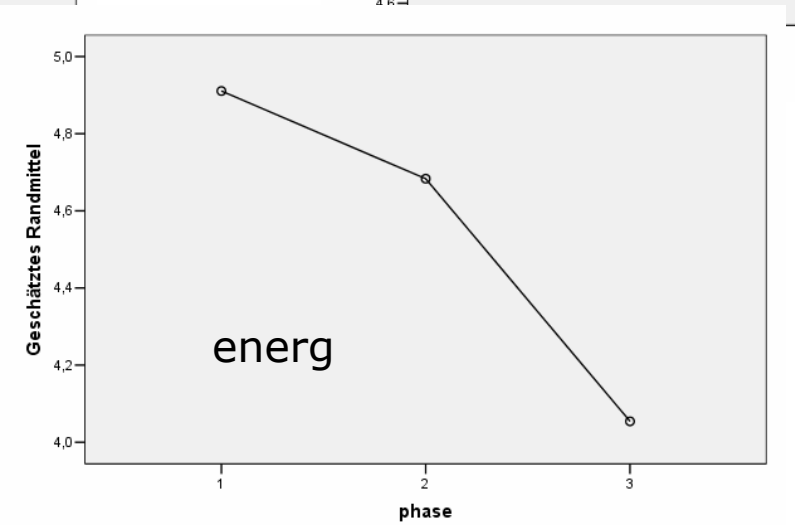


error < 1%

flight phase: Decline of motivation, concentration, energy







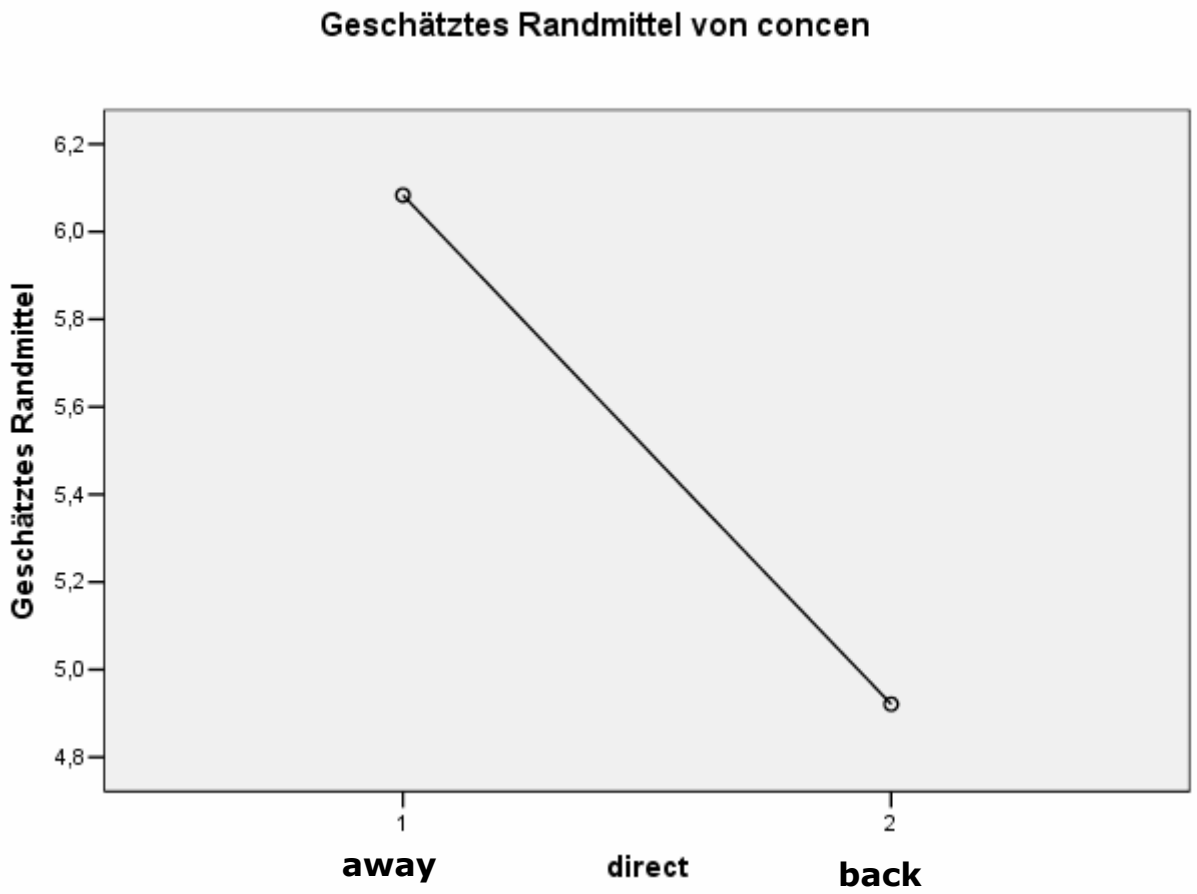
Err 10 %

concentration depends on flight direction

(away from home, back to home)

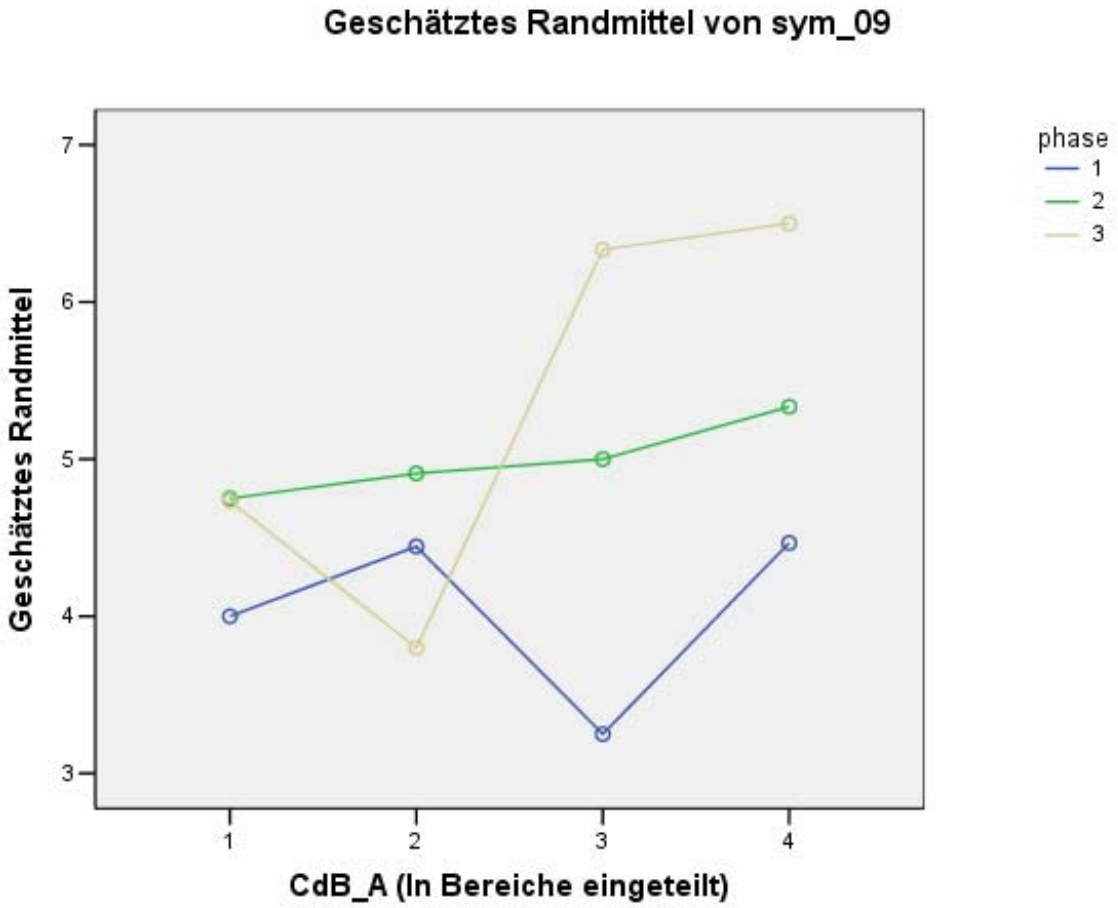
high

low



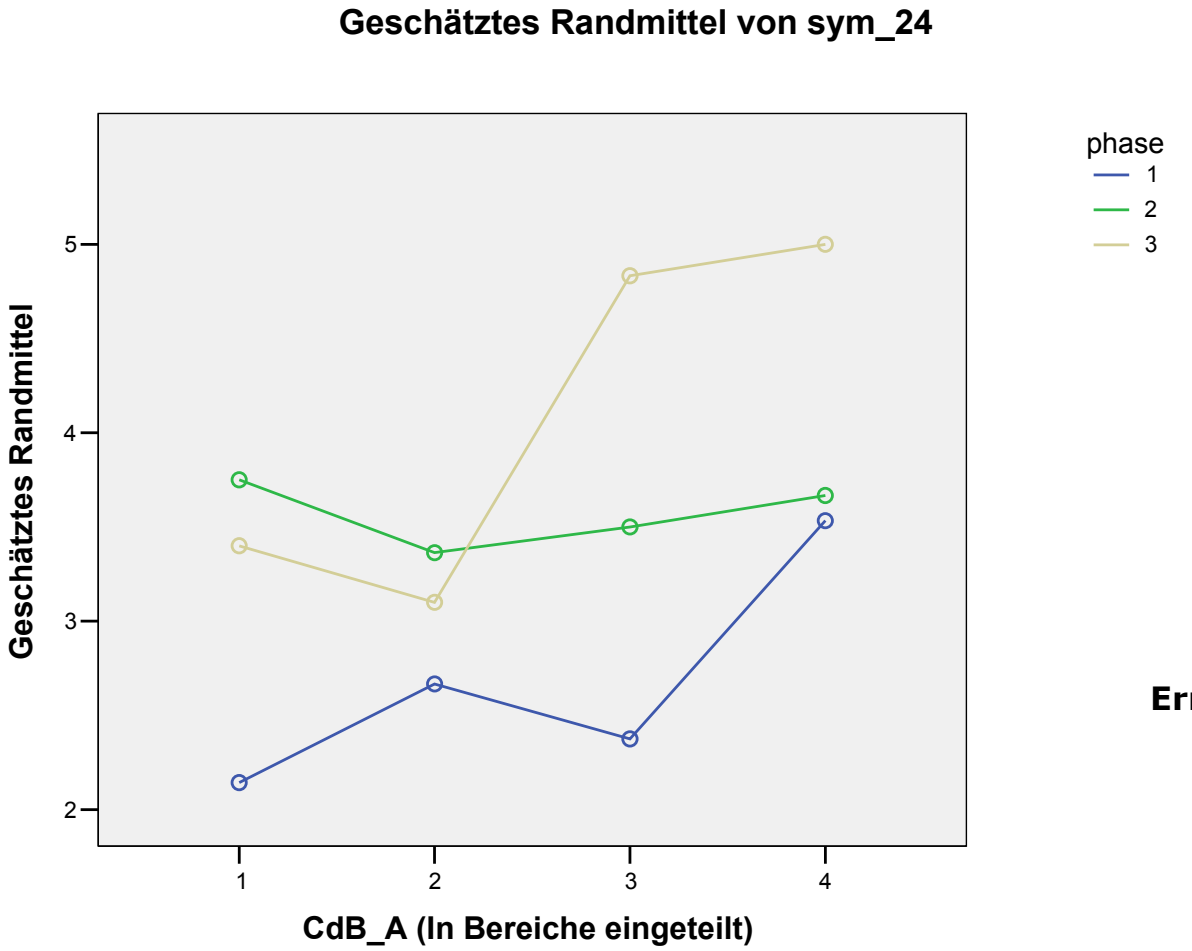
Err < 0.1 %

increase of symptoms (dry skin/ nose) **with noise level AND flight duration**



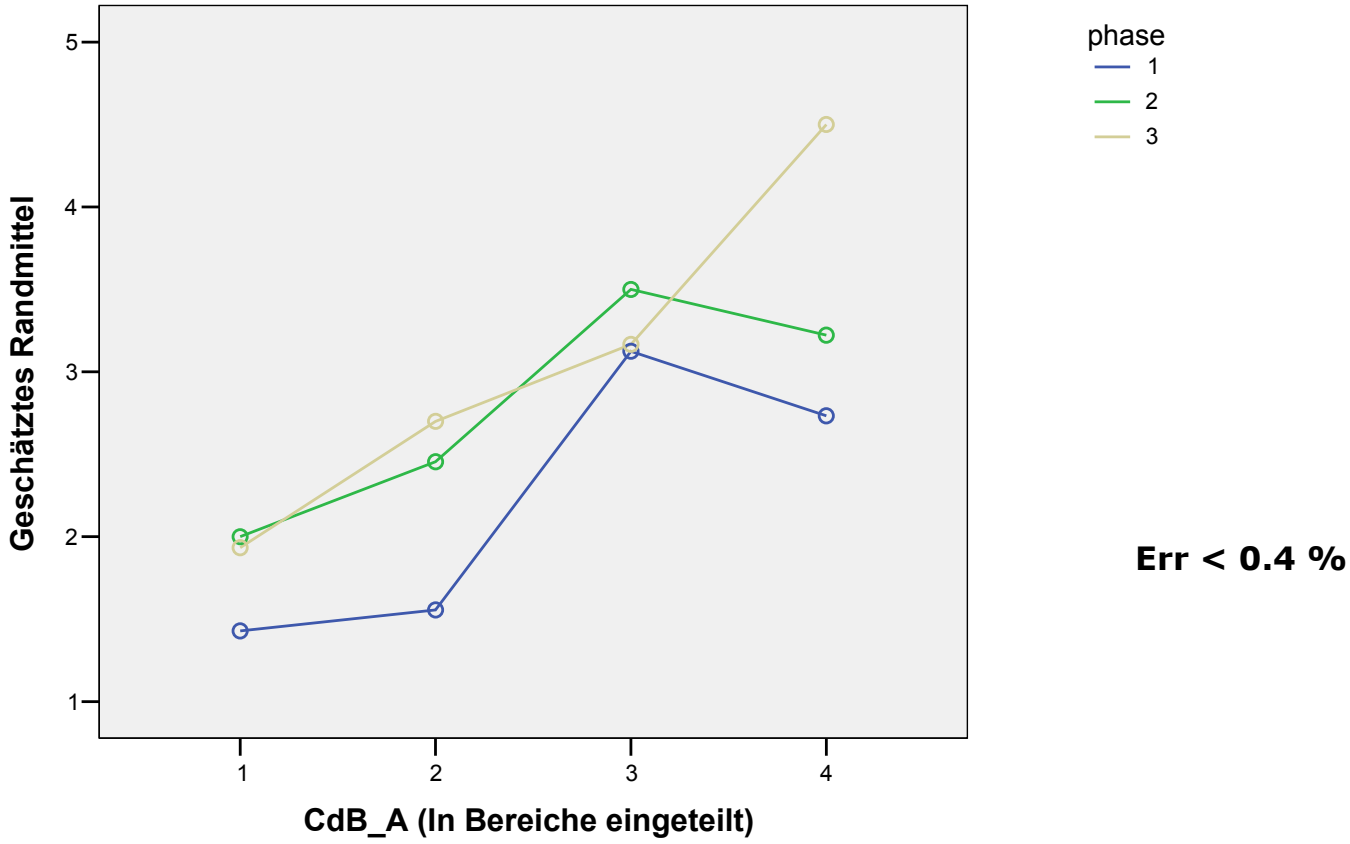
Err 1%, 5 %

increase of symptoms (swollen legs/ feet) **with noise level**



Err < 0.3 %

increase of symptoms (muscle/ joint pain in neck) **with noise level**



Err < 0.4 %

simulator experiments

- must provide the possibility to design an appropriate environmental condition
- but have only restricted virtual reality
- how much do simulators resemble real flights?
- are results comparable between real flights and simulator flights?

experimental design

- comparable questionnaire design (as in real flight)
- physical preparation of simulator for optimal virtual reality
  - pre-tests in the AUA-simulator in Vienna
  - main tests in the ACE in Watford (BRE)
- monitor the environment (data logging all relevant conditions)

AUA simulator in Vienna

simulated flight at AUA emergency trainer in Vienna

wired pilot in simulated flight

ACE at BRE in Watford

test persons

altogether

- 22 flight crew members
- 86 cabin crew members
- 544 passengers

crew was professional,
passengers were selected at random
in cooperation with the FACE techology platform

NOTE: statistical basis

distributing questionnaires in ACE test rig

full 3 x 3 x 3 factorial design

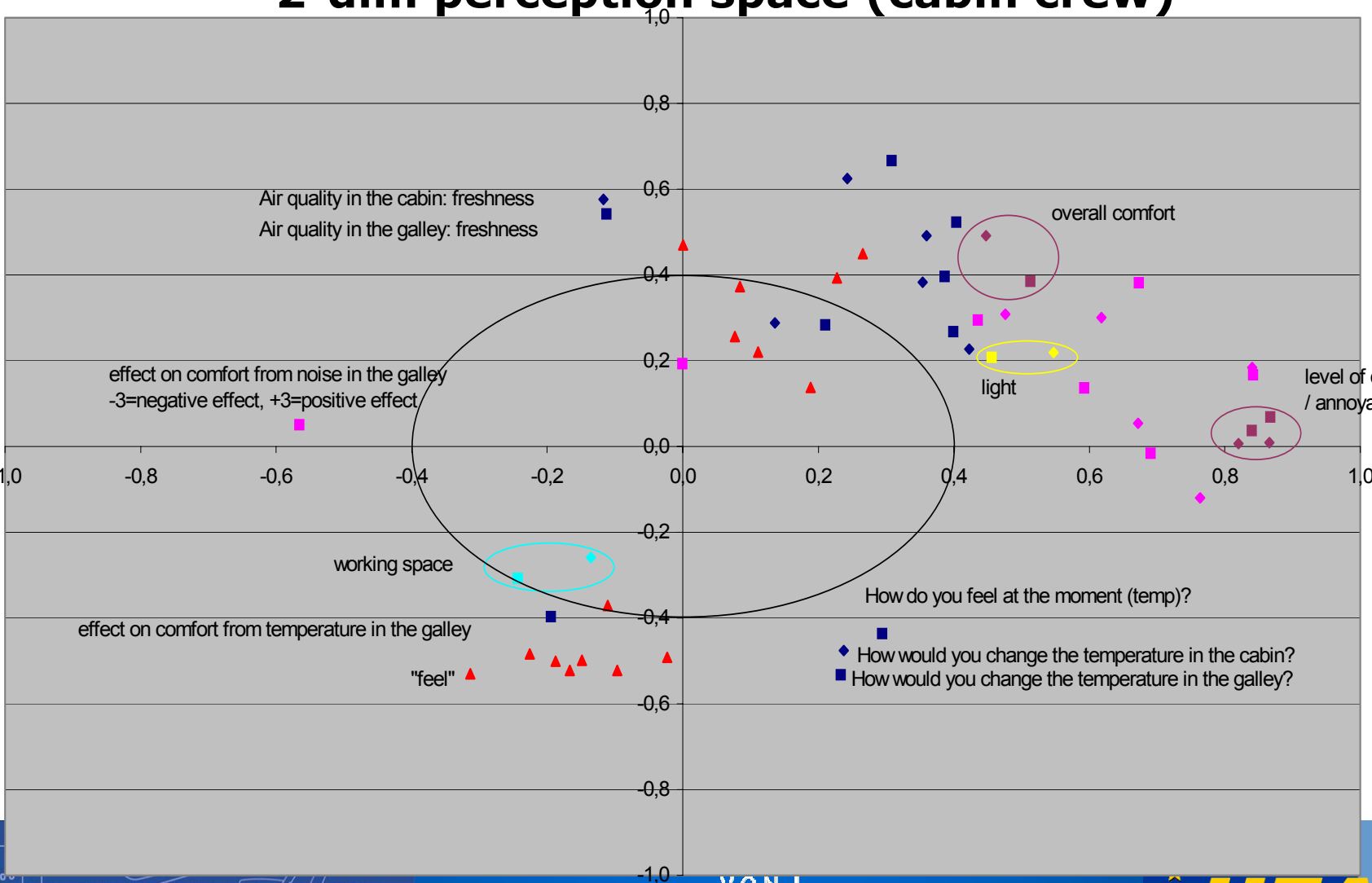
- temperature
  - **t**: 21-22, 24-25, 27-28 °C
- relative humidity
  - **rh**: 5-10, 15-20, 25-30 %
- sound and vibration
  - **s/v**: 70, 73, 76 dB(A) (+/− 0.5)
    [70–76, 73–78.5, 75–80.5 dB(A)]

in order to compare each variable with each other

data reduction

- variance analysis : 146 → 52 variables
- principal component analysis on 52
  - clusters of similar perception
  - two main dimensions
    - level of distraction/ annoyance [noise]
    - „feel" over-all [air quality]

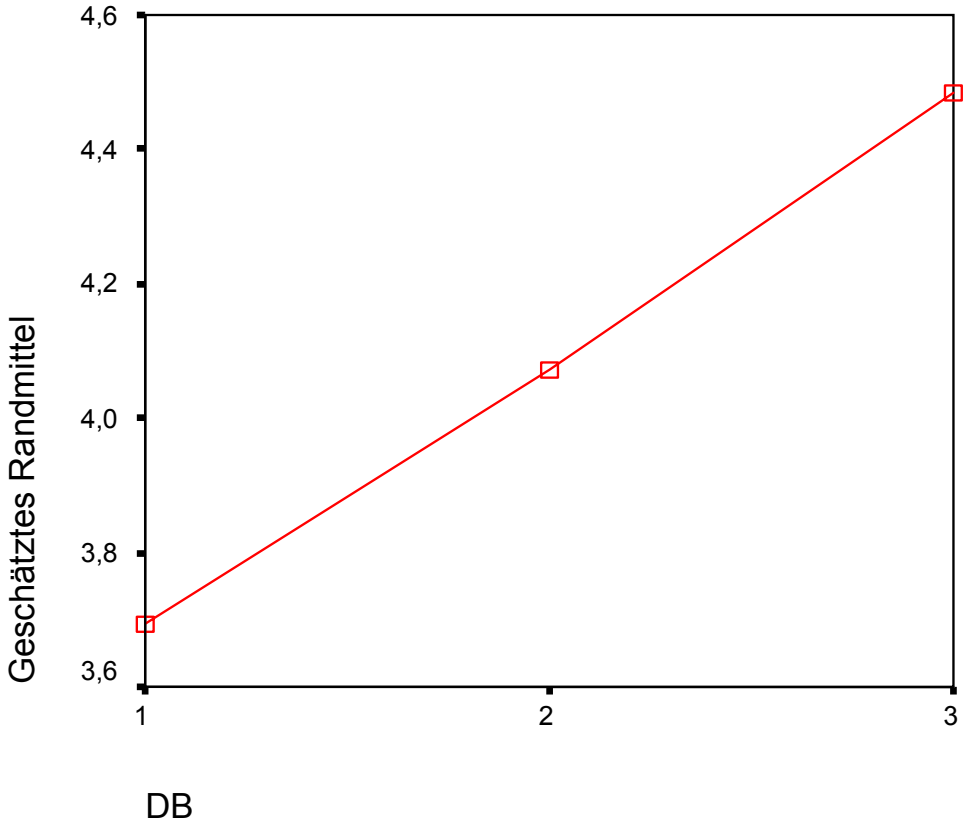
2-dim perception space (cabin crew)



ANOVA

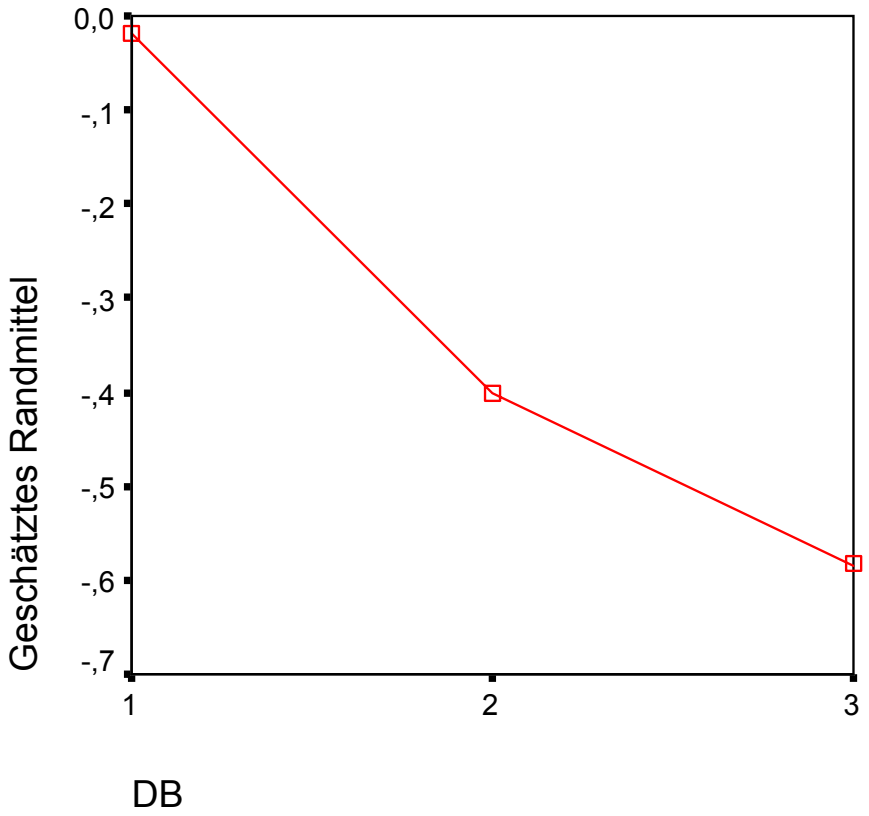
- analysis of variance reveals or rejects relationships between variables
- looks at significant differences in distribution of answers/ reactions in the sets related to the three (given) noise levels
- does not require linear correlation or functional dependency

levels relates significantly to perceived „volume of noise“ in cabin



Err < 1%

level relates significantly to „effect from vibration on ability to work in the galley“



Err < 1%

Increasing level with time: Significant impact on

- noise in cabin
  - level of distraction (3 %)
  - level of annoyance (1 %)
  - overall satisfaction (< 1 %)
- perception of vibration (< 2 %) and movement (< 1 %)
- symptoms (< 1%)
  - lethargy/ tiredness
  - difficulty in concentration/ remembering
  - swollen or heavy legs/ feet
  - headache

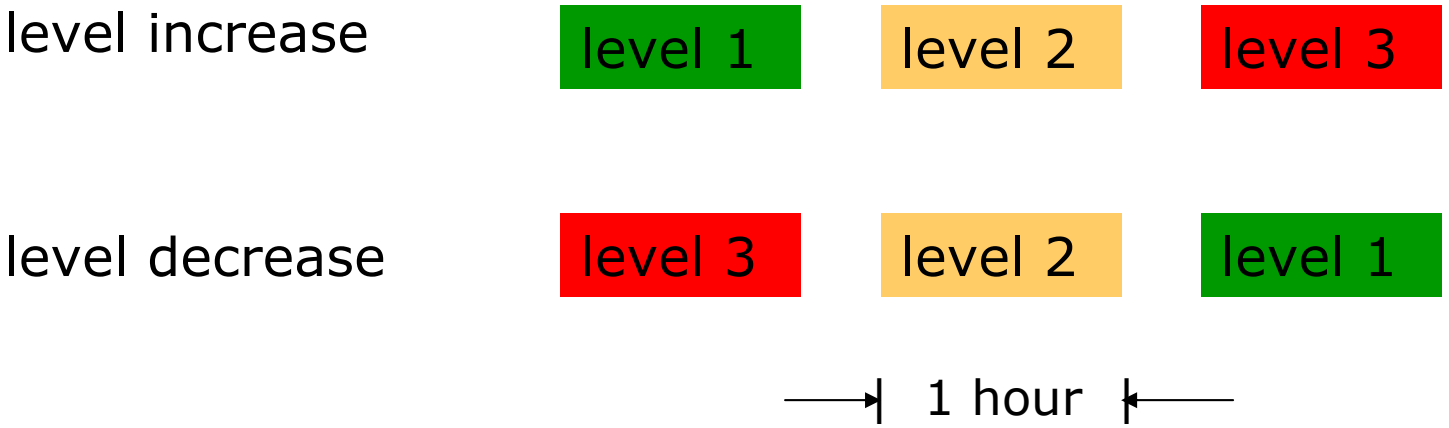
significant impact of dB-level on

- peceived volume of noise (< 1 %)
- perceived level of vibration
  in cabin and galley (2 %)
- the effect of vibration
  on comfort in the galley (2 %)
- the experienced lethargy/ tiredness (2 %)

NO significant impact of dB level on

- „overall satisfaction with noise“
  in the cabin (10 %)
- perceived level of annoyance due to noise
  in cabin (5 %) or galley (26 %)
- anything related to air quality and temperature
- any symptons like dry nose, swollen feet, headache etc.

3 x 3 x 3 design

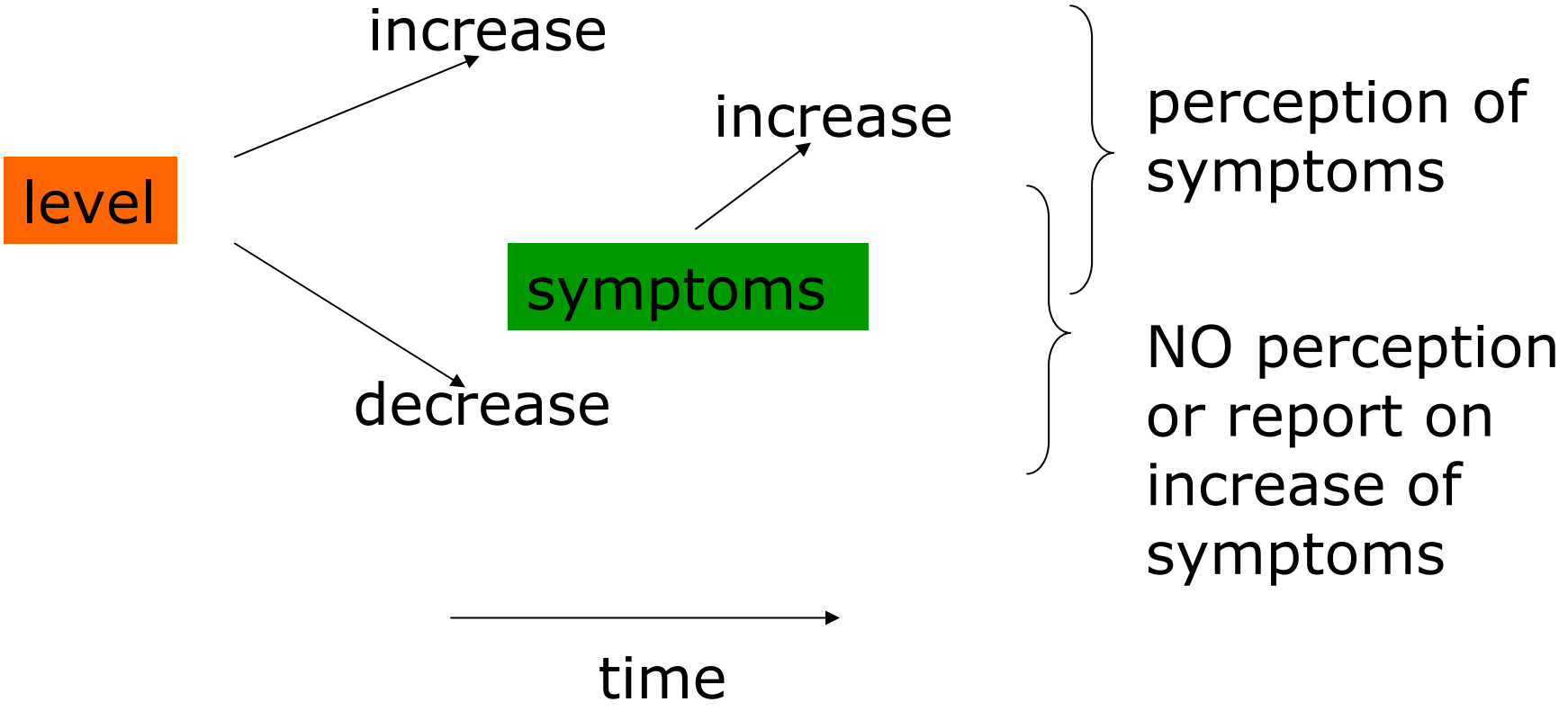


temperature and humidity kept constant

decreasing level with time

- NO impact on previous items
- only on perceived
  volume of noise in the cabin (2 %)

change of perception with time



summary

- simulator experiments and real flight experiments reveal significant impact of environmental conditions at the workplace of cabin and flight crew on health, well-being, comfort, performance etc.
- the observed relationships with the cabin environment (which is determined by construction) are moderated by fixed conditions (e.g. flight direction, flight duration, personality of a crew member…)
- flight duration is an important moderator

conclusions

- modelling human response is very complex and has to take into account numerous interfering parameters
- a model has to comply with a high-dimensional input vector and a multidimensional output vector
- each group of subjects (pilots, cabin crew, passengers) requires specific modelling

- investigations on comfort, health, performance during real flight are highly time, effort, and costs consuming
- validation of simulator experiments with real flights are still incomplete - test beds must provide an excellent virtual reality