Microclimates on Automotive Seating and the Impact on Comfort and Performance

At the Institut für angewandte Ergonomie (IfaErg), the influence on concentration and performance of the microclimate at the passenger-seat interface is being investigated in cooperation with the Munich University of Applied Sciences (HM) and Inside Climate (IC). In addition to suitable measurement and testing technology, a research approach that has been further developed for comfort perception can provide new insights into the design of vehicle seats. This applies in particular to autonomous vehicles, as decreasing driving tasks increase the demands on vehicle seats.

WRITTEN BY

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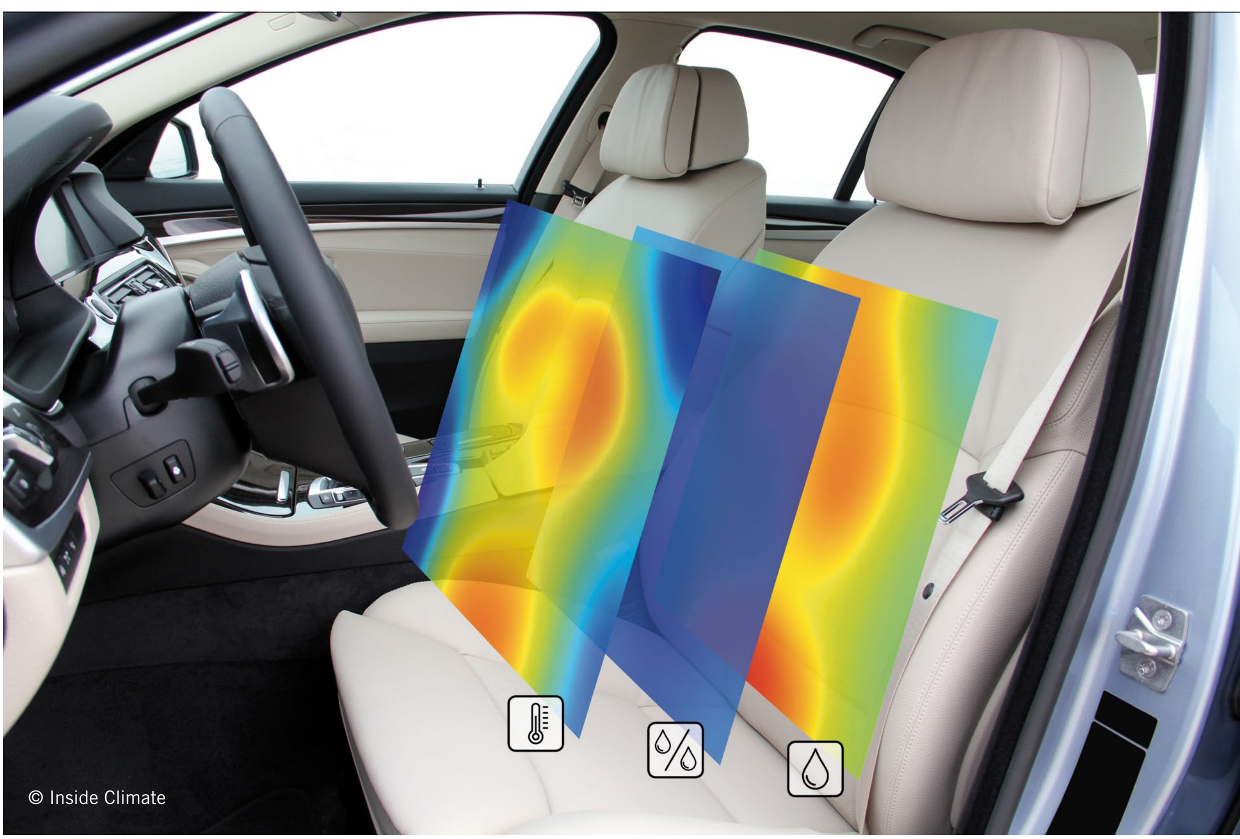

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1 REQUIREMENTS AND PERCEPTION

In connection with the increasing automation of driving, a future user portfolio for vehicle seats in commercial and passenger vehicles is emerging, which may include driving, reclining, and working positions [1]. In addition to safety aspects, automotive seating systems are expected to fulfill functional, ergonomic, and individual well-being requirements, **FIGURE 1**. These are related to the perception of comfort which in terms of evaluation can roughly be divided into biomechanical comfort and climate comfort. Both areas interact with their corresponding physiological consequences. It is known, that in the first phases of using seating and reclining systems, the biochemical conditions initially determine the comfort or discomfort and just after some time climatic factors add in. The latter can then take on the dominant role.

Comfort can be described by non-disruptive (pleasant) and by unpleasant sensations (“suffering” according to [2]). Local discomfort determines the global well-being and can influence concentration and performance.

2 COMFORT AND DISCOMFORT

According to the comfort/discomfort models developed by Zhang, Looze et al. and further revised by Vink and Hallbeck [3], comfort and discomfort factors usually occur in pairs and simultaneously, do not represent compensating opposites, and need to be investigated independently of each other. Discomfort is easier to quantify with objective measures than comfort, which can also be influenced by design or aesthetics, for example. In the local body climatization these models can be well applied. Locally different microclimates such as a warm-humid microclimate in a seat cushion or backrest area can thus be linked as a local discomfort in else climatically comfortable conditions in the vehicle cabin.

With regard to the effects of climate stressors on health, performance, work quality and safety, a wide range of facts are available in terms of full body climatization such as fine motor impairments in the cold, dehydration or an increase of heart and respiratory rates in the heat. Only few studies are found on local climatic discomfort [4, 5]. Especially, basic studies about the impact on performance and motivation are the exception. At least almost all research results on climatic comfort or discomfort from various industrial and public research institutes agree that the

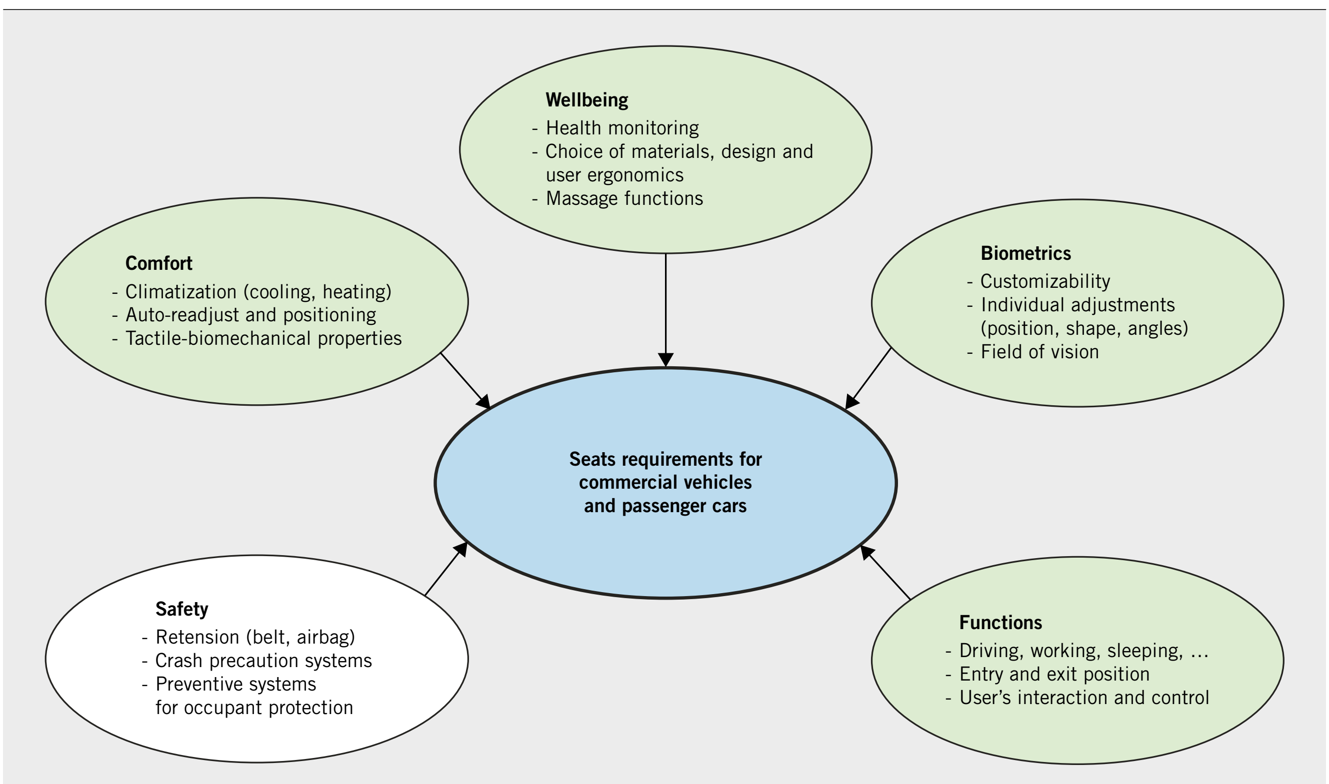

FIGURE 1 Areas of requirements on vehicle seats and their relevance for comfort (green) (© IfaErg)

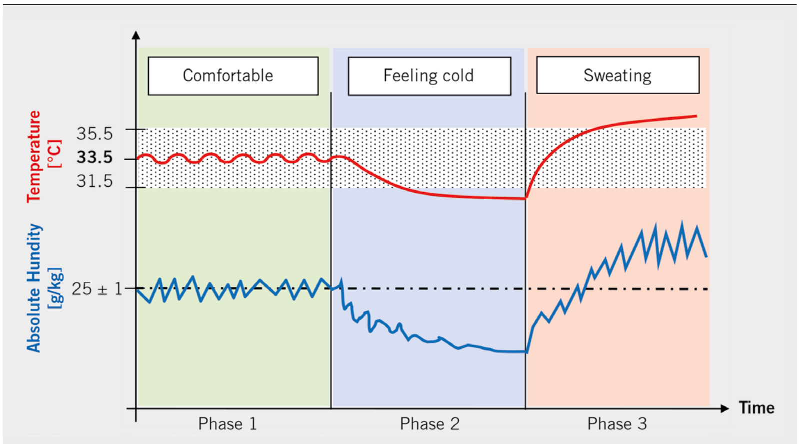

FIGURE 2 Schematics of the thermoregulative phases based on the microclimate parameters temperature and absolute humidity (© IfaErg | Inside Climate)

microclimate close to the skin is the decisive multidimensional indicator to assess thermoregulation effects and ultimately the comfort perception [6, 7]. By considering further biomechanical-tactile and skin-sensory aspects, such as biometric conditions, sweat related adhesive effects or wet spots, the ergonomic seat comfort can be determined.

3 THERMOREGULATION AND MICROCLIMATE

Based on the individual's heat production (energy turnover), the heat transfer, breathability and moisture management of the seat and backrest surfaces, which are usually trimmed with textile or leather, and the ambient cabin climate determine the formation of local microclimates. In conjunction with the pronounced sensitivity to temperature perception, and also the sensation of moisture (indirectly via tactile skin receptors), a precise comfort indicator is created.

After an analysis of numerous tests with seated, reclining, and differently clothed test subjects [8, 9], human thermoregulation behavior can be classified into three phases based on the microclimate parameters close to the skin, **FIGURE 2**:

- phase 1: thermally comfortable, moderate temperature fluctuations with up to ± 1 °C in the comfort range (31.5 to 35.5 °C) and equalized heat balance, low sweating for active endogenous heat regulation, low dynamic control activity of sensitive sweat release (absolute humidity)
- phase 2: tendency to freeze, skin temperature drops below the comfort range, risk of reduction of core body temperature, increasing heat demand and reduction of dry heat release (vasoconstriction, blood flow restriction) and humid heat release, almost no sensible sweating with very low absolute humidity and low control dynamics
- phase 3: tendency to sweat (overheating with increasing sweat production), increase in skin temperature beyond the comfort zone with a tendency to increase core body temperature, increasing heat release requirement (vasodilation, increased blood flow), extended sweating activity with increased absolute humidity and its control amplitudes.

From the correlations determined between the measured temperature and the humidity in the microclimate as well as the associated perception scores, the limits of thermal neutrality can be determined in the direction of warm to 35 °C temperature and 25 g/kg absolute humidity, **FIGURE 3**.

4 COMFORT PREDICTION AND PERFORMANCE ESTIMATION

In addition to physiological and thermoregulatory effects, especially in the case of local climatic discomfort, possible influences on performance indicators are of particular interest. In an ongoing pilot study, local climatic stress above the neutrality threshold is induced by back heating and evaluated by eight student test

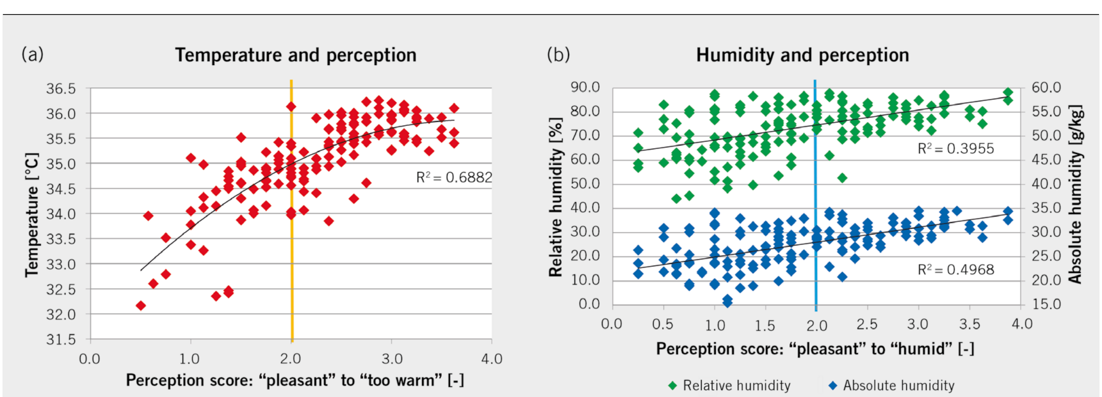

FIGURE 3 Regression analysis of comfort perception based on the microclimate parameters temperature (a) and absolute humidity (b) (© IfaErg)

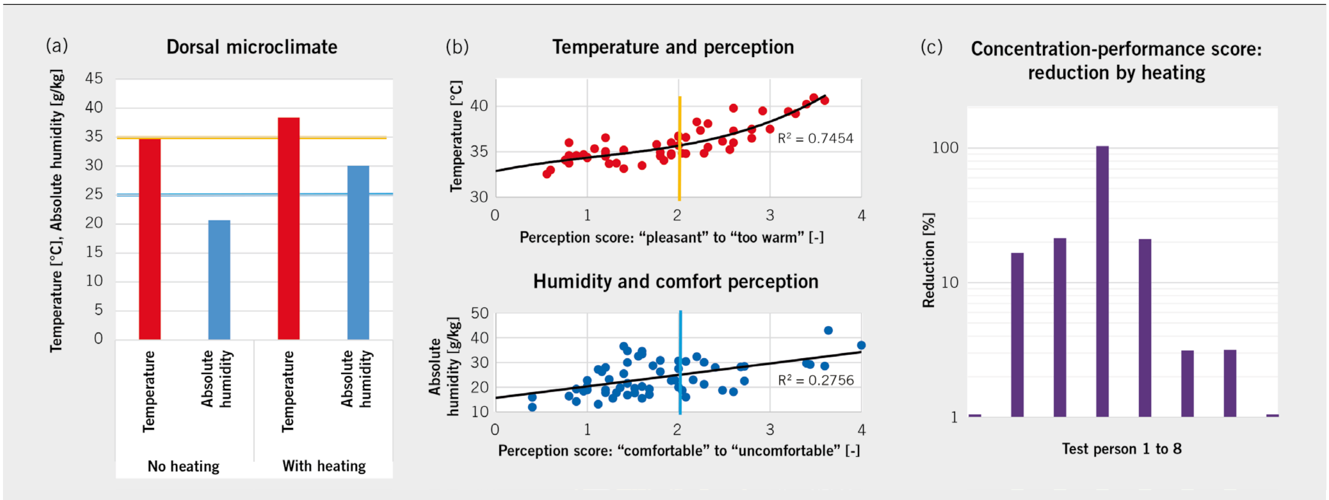

FIGURE 4 Microclimate (a), comfort rating (b) and performance indicator of the d2 test (c) from seat tests with and without dorsal/backrest heating (population N = 27) (© IfaErg | Inside Climate)

subjects (5 male, 3 female) over the duration of exposure. The impacts on concentration and performance are quantified and correlated with the subjective sensations that occur. One-hour sitting tests are carried out under a defined ambient and clothing situation. The microclimate close to the skin is recorded dorsally and ventrally using special sensors (SweatLog system). The comfort perceptions are documented with and without climate stress. At the end of the test, a d2 concentration performance test is carried out. Each test is repeated once for validation. The results with and without heating are compared with the total of 27 data sets obtained in this way.

Initial result analyses show:

– The induced microclimate is formed above the comfort limits with increased sweat production, **FIGURE 4** (a).
– The physiological parameters of core body temperature and pulse rate show no significant changes between the tests with and without back heating.
– The ventral microclimate measured in the chest area (sternum) shows almost no changes between the tests with and without back heating.
– The subjective perceptions of microclimate temperature and humidity in **FIGURE 4** (b) correspond well with those previously determined in **FIGURE 3**.
– Despite the locally limited and moderate climate stress in the back area (dorsal), the global perception of comfort is influenced by this, but as expected, it is weakened in comparison to the local perception of comfort.
– In six out of eight test subjects, there was a statistically significant decrease in the percentage concentration performance value under local thermal stress, **FIGURE 4** (c).

The latter is all the more significant as no studies have been found to date that quantify performance losses under local climatic discomfort.

The inter- and intra-individual scatter that occurs in microclimate measurements with test subjects can be mostly compensated by a human-physiologically adapted simulation with climate dummies. A direct interpretation of the generated microclimates requires a high thermo-physiological correlation between simulation and test subject as well as a suitable measurement technology. The combination of simulations with sweating test dummies

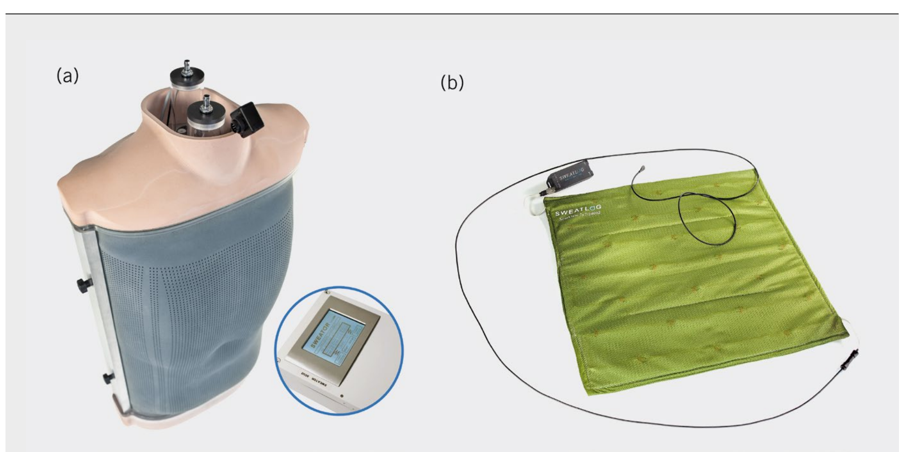

FIGURE 5 Sweator for human physiological microclimate simulations (a) and measuring mat (b) for recording temperature and humidity distribution on a seat surface (© Inside Climate)

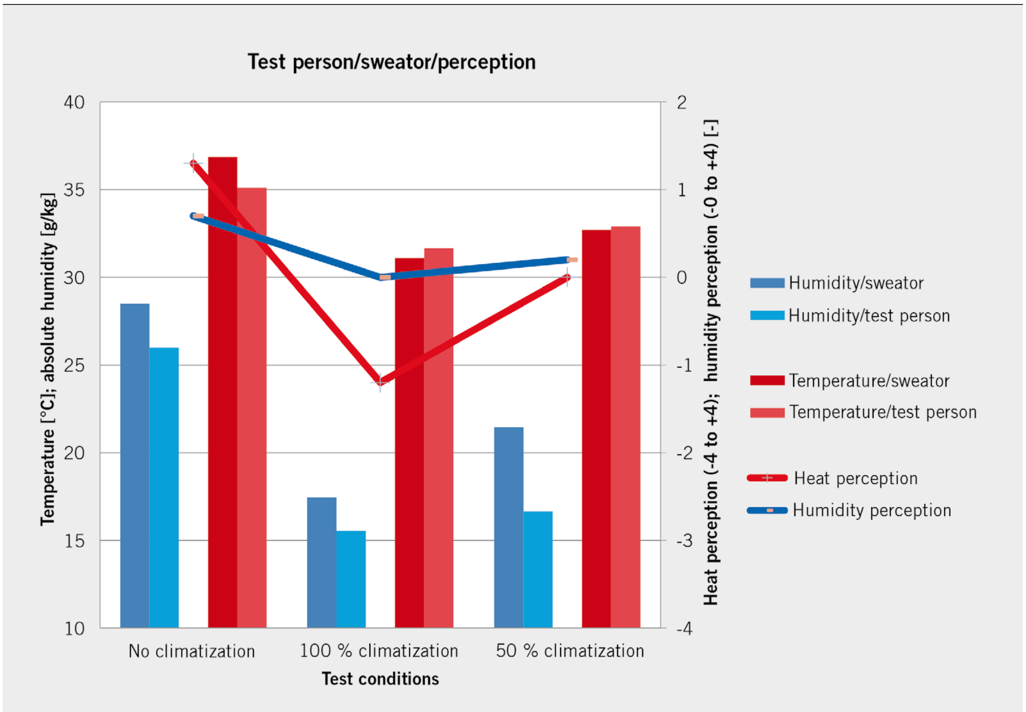

FIGURE 6 Comfort correlation from subject and simulation tests on seating surface with differently induced conditions (© IfaErg)

such as the Sweator from Inside Climate and corresponding climate measurement technology, **FIGURE 5**, generates comparable test results and allows to gain reproducible and valid comfort predictions due to the correlation of sensations, **FIGURE 6**. In conjunction with the quantified influence on performance indicators, this also guarantees a performance assessment.

5 SUMMARY AND OUTLOOK

Seating comfort being highly decisive for the user acceptance is determined by a large number of influencing factors which develop as biomechanical-tactile and climatic sensations. Climatic perceptions gain the upper hand from periods of use of less than one hour and determine the overall comfort, even if there is only local climatic stress. The decisive indicator for this is the microclimate close to the skin. Numerous studies have shown the comfort limits to be warm and humid with a microclimate temperature of 35 °C and an absolute humidity (as a measure of sweat production) of 25 g/kg.

(Patho-)physiological reactions and changes in performance in the event of whole-body climate stress are widely known. However, it has not yet been quantified how local climatic conditions that can occur on vehicle seats affect the perception of comfort and performance indicators. A corresponding research approach has already been able to show in a preliminary study how localized back heating affects comfort and, in particular, concentration and performance. This approach now opens up further options for quantifying local discomfort states as well as possible gender- and age-specific differences.

Human physiologically adapted climate dummies should be used to compensate for the usually greater variability due to inter- and intra-individual subject scatter. These must guarantee a realistic relevance to the real usage situation in the generated microclimate. The limitation to heat and moisture transmission measurements, for example according to DIN EN ISO 11092, is simply not sufficient for a valid comfort prediction.

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