Prof.dr. P. Vink

The sweetness of discomfort

Designing the journey

Inaugural address

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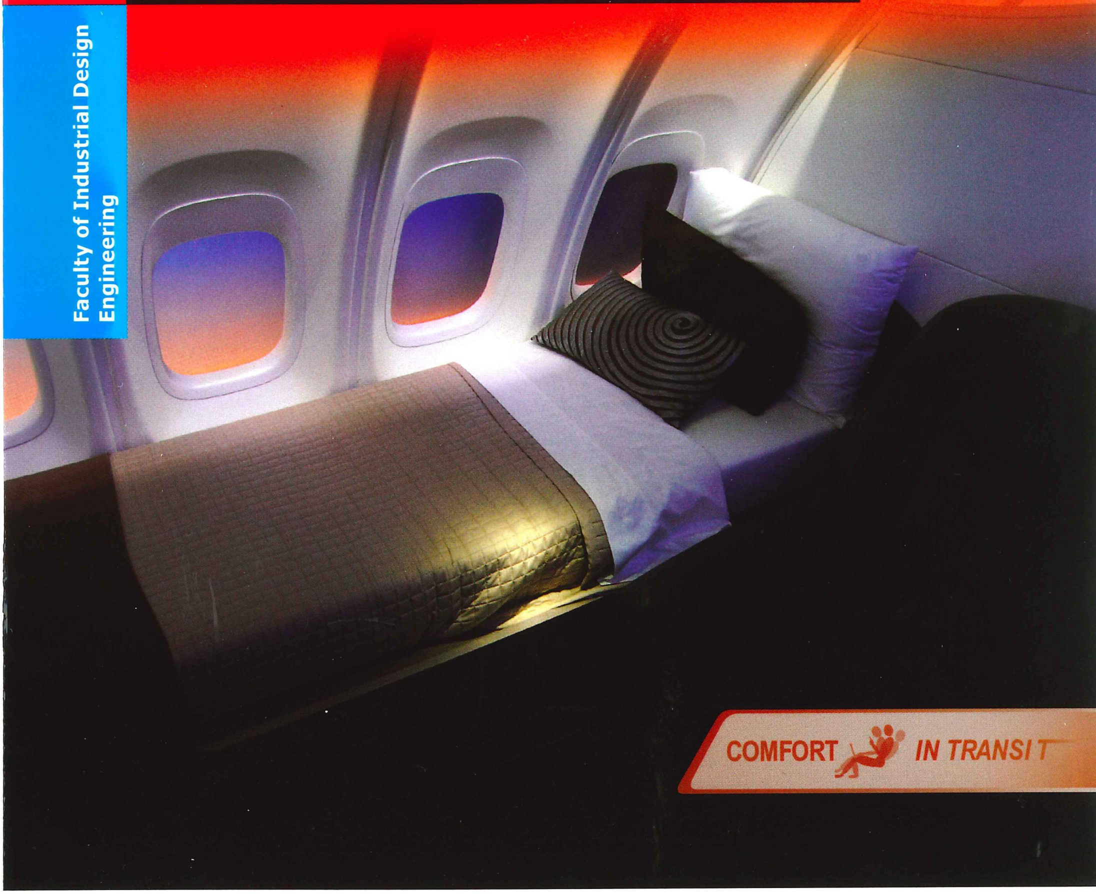
Faculty of Industrial Design Engineering



TU Delft Delft University of Technology

Challenge the future

The sweetness of discomfort:

Designing the journey

Intreerede

In verkorte vorm uitgesproken op woensdag 4 juni 2014 ter gelegenheid van de aanvaarding van het ambt van Hoogleraar Environmental Ergonomics aan de Faculteit Industrieel Ontwerpen van de Technische Universiteit Delft

door

Prof. dr. Peter Vink

Cover design by Corrie van der Lelie

Meneer de Rector Magnificus, leden van het College van Bestuur, collegae hoogleraren en andere leden van de universitaire gemeenschap, zeer gewaardeerde toehoorders,

dames en heren, ladies and gentlemen

Environmental ergonomics is adapting the environment to the person and the activity he or she performs. A rather good sleeping environment is shown on the left side of figure 1. However, on the right side of figure 1, several students have chosen to sleep during one of Professor Vink's lectures. There is no bed and the constant noise of talking by Professor Vink. This is not an ideal environment for sleeping.

Figure 1. A sleeping environment in an aircraft (left) and sleeping in a lecture room (right).

An ideal environment provides stimulus for people to perform their activities more comfortably. This lecture focuses on the elements of the environment that influence human comfort and human performance. The lecture consists of three parts:

I. Part 1 is a capita selecta of research in the field of environmental ergonomics.

II. Part 2 reflects on the connection between the human and the physical environment, using a comfort and discomfort model.

III. Part 3 concerns future research on the design of the journey.

The main point of this lecture is studying combinations of variation and stability of the human body during a journey and using moments of discomfort or low comfort to stimulate awareness of comfort. This knowledge is based on how our senses work and is useful for designing future products and environments for a comfortable journey.

Part I Examples of environmental ergonomics research

Effects of environments

We spend the majority of our time in man-made environments, e.g., houses, offices and vehicles. A man-made environment is different from a natural environment because it is built by humans. Some interiors are inspired by nature, a good development because the influence on human beings differs between a natural and a man-made environment. Park et al. (2010) showed the difference in effects between a forest and a city in an experiment that had 280 subjects walk in the forest and the city. Salivary cortisol was significantly lower (15.8% decrease), the average systolic blood pressure was significantly lower (1.9% decrease) and the heart rate was lower for subjects after walking in the forest as compared to walking in the city.

These physical parameters are related to stress and indicate a reduction in stress. Additionally, the experienced mood states were improved, e.g., less depression and lower tension. Another interesting observation of Park et al. (2010) showed that after 14 minutes of viewing a forest the same effects were shown as mentioned above. Assuming that "feeling more relaxed" increases the comfort experience, than it appears comfort is improved by exposure to nature. This means that for a preferred stress-free work environment a view on nature could be advantageous (see figure 2). There is no clear explanation for this phenomenon. Perhaps it is seeing the ideal balance between unity and variety. Post et al. (2013), from our university, had 27 subjects observe pictures of 12 car interiors. Results revealed that both unity and variety, although negatively correlated, positively predicted the aesthetic appreciation of car interior designs. It appears that good appreciation equates to the proper balance of unity and variety.

Figure 2. A view of nature reduces stress (photo, Iris Bakker).

Another explanation for appreciation of nature is that there are indications that people prefer moderate levels of patterned complexity and sensory variability in the environment (Heerwagen, 1998; Cooper, 1968). Apart from appreciation, an environment missing sensory stimulation and variability can lead to boredom and passivity (Heerwagen, 1998; Schooler, 1984).

It could also be that nature has the right proportions. The golden ratio appears in all forms of nature, which is probably the most appreciated form. However, the preferred proportion differs between countries. Jung (2012) used a method, developed by Gustav Fechner in 1876, to compare the preference of a rectangle by 300 Japanese and 300 German subjects. The golden ratio was preferred by more than 15% of the subjects in both countries (see figure 3). The additional preferred proportions differ between the two countries. In Japan, more than 15% preferred 7:10 and 2:3, while in Germany 1:1 had a preference of more than 15% next to the golden ratio.

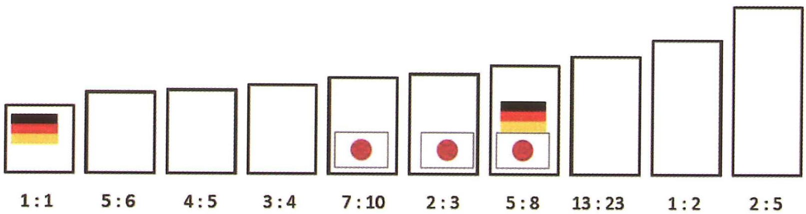


Figure 3. Choice for proportion of more than 15% of 300 subjects from Japan and 300 from Germany (Jung, 2012).

Environmental unawareness

Bakker et al. (2014) from our university, refers to Dijksterhuis (2009) who states that in general, humans are often unaware of the environmental characteristics that cause positive experiences. Being unaware of the golden ratio is not the only area of environmental unawareness. Recently, Boeing studied the experienced difference between two aircraft interiors for the same model airplane (McMullin, 2013). The Boeing 737 of Norwegian had a new sky interior, inspired by the Dreamliner interior, furnished with the same seats found in the traditional aircraft interior (see figure 4). The two interiors were compared for seating comfort by passengers. The results showed that 78% of the passengers felt that the seat in the new sky interior was more comfortable than the traditional aircraft seat even though the seat was the same in both aircrafts. This is an example of human unawareness to environmental characteristics that cause positive experiences.

Figure 4. The traditional Boeing 737 interior (left) and the sky interior (right) have influence on the way we perceive the seat.

Mellert et al. (2008) studied the impact of noise and vibration on the wellbeing of people during long-haul flights and in flight simulators. Apart from indices to characterize the human response, they found that noise has an important impact on health indicators, comfort and wellbeing. For instance, flight crew experiencing swollen feet are more aware of their foot situation under noisy conditions. The awareness increased 43% under noisy conditions, compared to quiet conditions at the beginning of the flight. Similar results were found for neck pain, with a pronounced pain increase of 57% as noise levels increased. These results show that questioning crew and passengers about noise is difficult because the noise itself may not be mentioned as a problem. The problems that people are aware of are mentioned and are influenced by the noise levels. The same influence could be true for lighting, pressure and cabin air quality. It makes sense that we are not continuously aware of what all our sensors record because there is too much information coming into our body by all sensors. The human brain selects the important elements. According to Dijksterhuis (2009) we unconsciously perceive much more than we realize and have the ability to retrieve unconscious information into conscious when it is needed or when we have to explain our behaviour.

Sensors do not sense absolute values

Thus, it turns out that sensors do not always make us aware of what they record. Apart from the awareness, sensors are not capable of recording exact absolute values. The ideal comfortable indoor temperature is for instance not one absolute value. For thermal sensation the just noticeable difference (JND) for humans is around 0.7° C (Lee et al., 1998). However, according to Hedge et al. (2009) it seems unlikely that simply reaching the JND will be a sufficient condition to actively let humans make efforts to change the environment. Probably for taking action more difference than 0.7° C is needed. Additionally, this is gender, age and activity dependent (Hedge et al., 2009).

Indoor climate studies have shown that there is not a singular comfortable indoor temperature. For example, comfortable indoor temperature is dependent on the outside temperature (De Dear & Brager, 2002). In the northern hemisphere, higher indoor temperatures are preferred in the summer than in the winter. The tolerances of thermal perceptions are not fixed within one season.

People who live or work in naturally ventilated buildings, where they are able to open windows, become used to this thermal diversity. Their thermal perceptions extend over a wider range of temperatures and the preferred comfort range is broader (De Dear & Brager, 2002). To say it simply: people get used to a wider range of temperatures and thereby broaden their comfort zone. Roelofsen et al. (2013) showed that thermal comfort is age dependent. Older people have a smaller range of comfortable indoor temperature than younger people.

Human sensors record fast changes more readily than slow changes. In a study by Kolarik et al. (2007) 52 subjects were asked to report differences in temperature whilst in a climatic chamber. Subjects did not distinguish a slow temperature increase of +0.6° Celsius/hour for the first 3 to 4 hours of exposure. However, as the exposure continued, a linear relationship between thermal sensation and temperature was observed. A higher level of clothing insulation increased the delay period.

Goossens et al. (2011), from our university, showed that small differences in pressure under the buttock are not noticed. They made a hole in the seat and replaced it with a round contact surface area with a diameter of 10 cm. The pressure was 26.5 kPa and a difference lower than 2.7 kPa was not noticed. For a larger area and the same pressure (diameter 20 cm) a difference was noticed only at 3.5 kPa.

Sensors act dependent on history

As is described above, humans are not constantly aware of all the input from the environment recorded by sensors, but humans are capable of actively selecting the information received from the sensors. This point is illustrated in a study by Helander et al. (2000).

The researchers chose a method traditionally used in psychophysics to determine sensory thresholds, i.e., for loudness or brightness. Typically the loudness of a sound increases from a low value (or decreases from a high value) in small increments. For each increment a test participant responds with a, "no" or "yes", until the sound is heard (or no longer heard). Using a method inspired by loudness or brightness, Helander et al. (2000) found just noticeable differences (JND) for seat adjustments. The subjects stood in front of a chair and the height, seat pan angle or back rest angle were changed. The subjects were asked to report if the chair was "too high" and "too low." Using this method of constant stimuli just noticeable differences (=JND) were determined. It appeared that for chair height the JND was 1.5 cm, seat pan angle 1.2° and backrest angle 1.7°. In another study subjects adapted or adjusted the seat themselves. The chosen chair settings were also affected by the initial setting. For example, a high initial setting of the seat height led to a high selected setting and a low initial setting led to a low value, probably as we are used to this position. The corresponding values for these not noticed differences were almost double: chair height (2.5 cm), seat pan angle (4°) and backrest angle (3°). The results show that if the reference value is far away, humans are less accurate in defining differences.

Design using human sensor knowledge

The design consequence of the Helander et al. (2000) study is that investing money to improve chair adjustability to ranges lower than the resulting values may not be wise. The fact that the previous value does influence our comfort experience should be considered in seat design. Theoretically the seat might feel softer after having experienced a hard surface. This was recently checked in an experiment by PhD candidate Van Veen et al. (2014) of our university.

Van Veen et al. (2014) showed that after sitting on a hard wooden stool, a test seat feels significantly softer than sitting in a comfortable chair and then sitting on a test seat (see figure 5). Van Veen et al. (2014) covered the test seat with a white blanket and told the subjects that the seat differences would not be shown. In fact the seat was not changed. This information was not relayed to the test subjects. Before the test, subjects were instructed to sit on the stool and the luxury chair to become accustomed to the environment. Half of the subjects began with the 'hard stool' conditions and the other half began in the 'luxury soft chair' condition. At the same time the next day the subjects arrived to test the 'second seat' and the condition was changed again. The results show for the pre-condition "stool" (the chair feels soft: 1 = I don't agree, 9 = I agree) a rating of 6,75 ± 1,94 on a 9-point scale and for the pre-condition "luxury chair" a rating of 4,96 ± 2,46 which was significantly different. The theoretical assumption is that precondition influences the sensation appears to be true. Sitting on a hard surface in the precondition makes the tested seat feel softer.

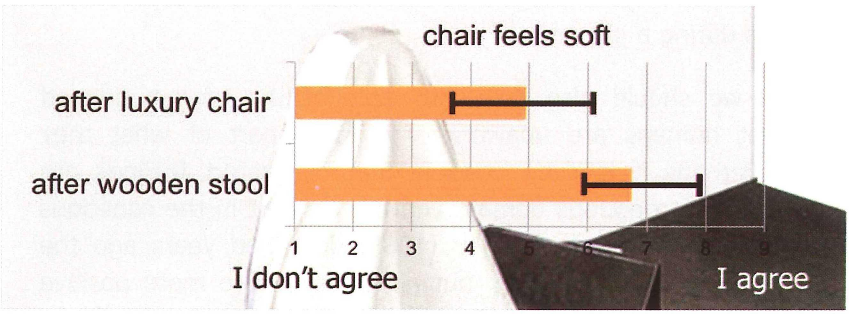


Figure 5. The experienced softness of a chair after the precondition stool and after the precondition luxury chair (Van Veen et al., 2014).

This knowledge on how human sensors work is useful for design. For instance, providing hard wooden seats to airline passengers waiting at the gate would make the airplane seats feel comfortable by comparison. Or even better design a seat that is initially hard and can be transformed into a soft seat. The softer seat is experienced as better and more comfortable because we use the knowledge how human sensors work and because the user becomes aware of the softness: this is the sweetness of discomfort.

In the third part of this lecture it will be shown that it is important not to design one isolated element in a journey for a traveller, but rather look at the complete journey and perhaps add moments of discomfort to increase comfort later. Of course it is not known how much or how often discomfort or low comfort should be administered to create a comfortable feeling or how long the discomfort effect lasts. It is also not known if this effect is the same for all sensors and products. In the research domain it is well-known that a 'within subject design' has advantages over absolute values because absolute values are difficult to estimate by the subjects. Relative effects are more measurable. In product design this phenomenon could be used more by creating products that change during use or consist of different comfort experiences during a journey.

Of course we should also take into account the aforementioned finding that humans are unaware of a large part of what they perceive. Perhaps it is even possible that discomfort feelings are created in the unconscious domain and the comfort in the conscious domain. On the other hand Frijda (1988) described years ago the principle of comparative feeling: human emotions are more positive when we are aware of a worse situation, which shows that awareness of the less good situations might help in creating positive experiences.

The phase before sensing

Part of experienced comfort is dependent on what the senses feel prior to the comfort experience. It is not really rocket science to understand that after walking or running before entering the airplane the seat is probably more comfortable then after waiting for three hours in a chair at the gate (Vink & Brauer, 2011).

However, more is happening during the phase prior to the comfort experience. The comfort experience is also dependent on expectations. In a study by Vink & Brauer (2011) there was no significant difference in comfort scores between business class and economy class in a study among 10,013 air travellers. This phenomenon can be explained that at the moment of booking the scale for comfort is determined and within that scale subjects give the ratings for comfort. If the upgraded passengers in this study are separated from the other business class travellers, and these are compared with the business class passengers, the difference is highly significant, with a higher comfort rating for the upgraded group. In the latter case the comfort was higher on the virtual scale determined at the moment of booking. Therefore, expectations may play a role when rating a comfort experience. Polaine et al. (2013) described a family booking a ticket that had no information about their assigned seats. The family, with small children, was unable to find out if they all would be seated together during the flight. During various stages preceding the flight i.e., booking, checking in, phoning the airline and arriving at the gate, their insecurity increased that resulted in a high stress level and that much stress influenced the entire journey.

Additionally, the first visual interaction influences comfort as well. Kuijt-Evers (in Bronkhorst, 2001) showed that 49 experienced office workers evaluated one out of four office chairs negatively based on visual information. The four seats were exactly the same physically, only the colors differed. Three seats were light colored and one was brown. The first impression was that the brown colored seat would be less comfortable. The first seating experience after this visual inspection also resulted in lower comfort ratings. However, the brown chair was evaluated positively and equal to the other chairs after use for more than an hour of office work. It is a question if the color brown is still perceived as less comfortable today. Nonetheless, it shows that the first impression influences the comfort experience.

Part II Physical environment, comfort and discomfort

Connecting environmental studies

The above mentioned examples of environmental ergonomics research show that viewing nature has positive effects and humans are generally unaware of the effects interior characteristics have on their comfort levels. The sensors recording the effects of the interior characteristics are not good at recording absolute values and are not capable of sensing small differences. The sweetness of discomfort could be that our sensors adapt to a slow increase in discomfort and that the phase, after discomfort, could be consciously experienced more comfortable. Expectations play a role in discomfort and comfort as shown in the experiment of booking a flight. The scale is set at low values, and unexpected positive experiences could result in extra high ratings. To connect the different studies on the effects of the environment and products in the environment, a comfort model is made (see figure 6). The model is intended to be useful for unraveling the process of comfort and discomfort perception and to position objective measurements during the process from first interaction with the product to perception.

Comfort model

Vink and Hallbeck (2012) presented a comfort model (see figure 6) inspired by the model of Moes (2005) and De Looze et al. (2003). This model simplifies the steps that influence the comfort and discomfort experience. The interaction (I) between a product (P) and a person (P) starts in an environment where the person is doing a specific activity (U=Usage). This interaction (I) can result in internal human body effects (H), such as changes in the human sensors, tactile sensations, body posture change, blood flow changes and muscle activation. The perceived effects (P) are influenced by the human body effects, but also by expectations (E). As previously mentioned, expectations influence our perception and thereby our comfort or discomfort score. The outcome is feeling comfortable (C) or it can lead to feelings of discomfort (D).

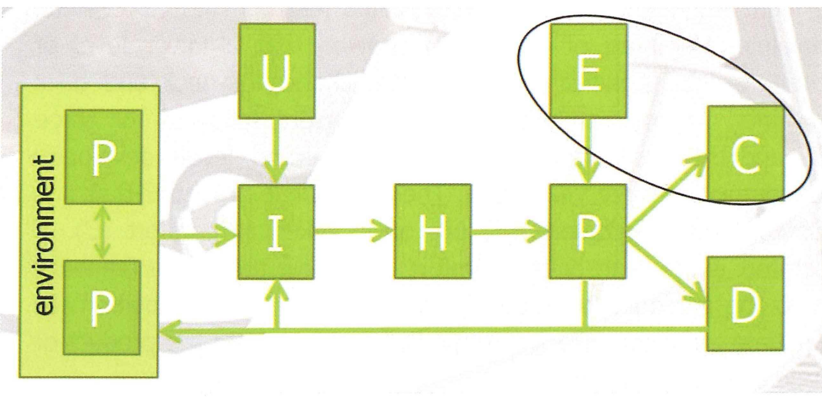


Figure 6. A comfort model. The Product (P) and Person (P) are in an environment. Usage (U) causes an Interaction (I) between the person and product, which causes human body effects (H). Then it will be Perceived (P) in the human brain, which is influenced by Expectations (E) and could give a certain Comfort (C) and Discomfort (D).

It can also result in both comfort and discomfort. Helander and Zhang (1997) influenced the comfort research field by distinguishing comfort and discomfort based on questioning seat users. Based on questionnaires by Zhang et al. (1996) and Helander and Zhang (1997) discomfort is related to physical characteristics of the environment, e.g., posture, stiffness and fatigue. Absence of discomfort does not automatically result in comfort. Comfort will be felt when more is experienced than expected. The usefulness of this division is affirmed in other areas of the body as well by a study of Kong et al. (2012) showing that the comfort scales did not appear to be useful for high gripping forces (>65% MVC), but discomfort scales did. Therefore, it is better to use two different scales: one for comfort and one for discomfort. It is possible that both comfort and discomfort are experienced simultaneously. For instance, you may experience discomfort from your seat, but have a feeling of comfort created by a nice flight attendant. The discomfort could result in musculoskeletal complaints. Hamberg et al. (2008) showed that a lower level of discomfort does significantly reduce the chance of neck and back complaints. Approximately 1,700 subjects were followed for three years and the participants with higher discomfort levels developed more complaints three years later. There is a circle around E-C as it is assumed that expectations (E) are often linked to comfort (C). If discomfort is too high or the comfort is too low there is a feedback loop to the person and product in the environment. The person (P) can initiate a change, like shifting in the seat, adapt to the product or change the task/usage.

Usage

The use of a product in its environment does influence comfort and discomfort. This is illustrated by two activities that occur in bed. It is obvious that while sleeping, less light is preferred than while reading. Figure 7 shows the comfort level during the day for 77 students. The highest level of comfort during the day is reached while lying in bed with the activity of 'sleeping'. Another experiment (Vink et al., 2014) shows that smart phoning is significantly more comfortable and the operating performance significantly better in an upright sitting position as opposed to lying horizontal in bed. The number of typed characters was 172.8 (sd 37.8) per minute sitting and 147 (sd 34.6) lying (p=0.006) and the number of mistakes did not differ significantly. This shows that a relationship between performance and comfort exists. The experienced comfort is dependent on the activity or task users perform. Usage is an evident comfort influencer.

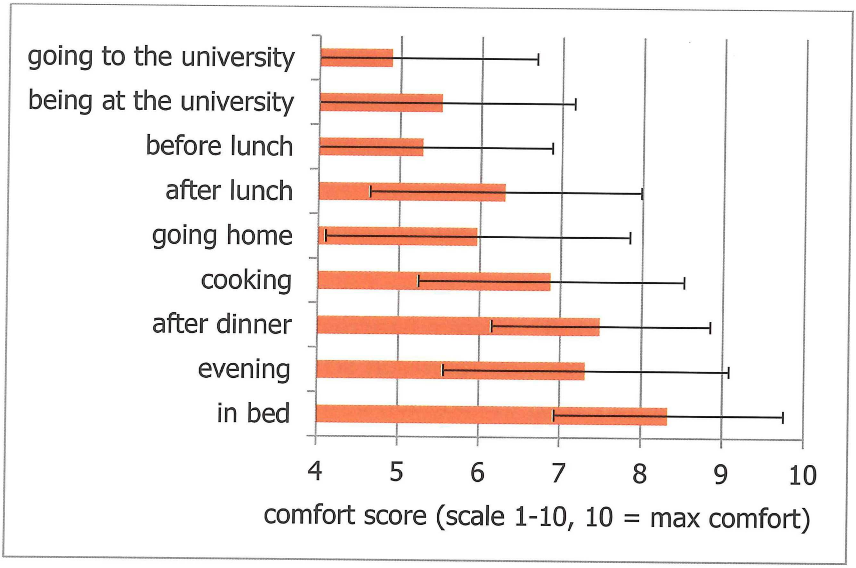


Figure 7. The average comfort (+sd) of 77 TU-Delft students during a day end of November 2013.

Another example of the dependency on usage is shown in a study by Groenesteijn et al. (2009). Ten participants were asked to sit for three hours in an office chair. Results showed that for VDU work a more upright position is preferred (back rest angle 105°), while for reading, a reclined back rest of 124° is more comfortable. Based on a literature study, Groenesteijn et al. (2009) discuss that back muscle activity, recorded with EMG, is lowest at a 120° back rest angle. However for VDU work this angle forces the neck to flex too much.

Figure 8. A screen in front of a person (left) should have different back rest angles than a screen mounted to the ceiling (right).

For watching a television screen Rosmalen et al. (2009) found an ideal back rest angle at 130° where a headrest and the head could be reclined. This is ideal when the television screen is placed in a high position. For an aircraft seat, the position of the IFE screen influences the back rest angle strongly (see figure 8). The fact that it pays off to design seats that fit the relevant activities is shown in a project where activity specific train seats were designed for the Long Island Railroad (Bronkhorst & Krause, 2005). It appeared that 83% of the passengers preferred the resulting seat to current seats because they were activity based.

Interaction

The interaction with the product usually starts with a visual interaction of the product in its environment. It is the first sight. This first sight influences comfort as is described above in the 'brown seat experiment'. The environment is also mentioned in the model. In figure 9 the color of the product from a human point of view is dependent on the colors of the environment. All the seats are the same color however, they look different because the three chairs on the right have a yellow line in front whereas, the left three chairs have a purple line in front.

Figure 9. All seats in this picture are the same color, but we see differences due to a difference in the environment.

Usually, there is also a tactile contact between the person and the man-made product or physical environment. Fenko et al. (2010) show that in most products of the initial sensory contact is usually visual, later (in their case after a week) other sensors like tactile and auditory sensors play also an important role. De Looze et al. (2003) describe that many studies show a relationship between pressure distribution and discomfort. Zenk et al. (2012) describe an ideal pressure distribution for a BMW 7-series based on years of research with TU Munich and BMW (e.g. Hartung, 2006). A short term test that included 84 subjects showed lower discomfort ratings in the 'ideal distribution'. In a long term test, eight participants drove three hours in their own preferred position and in the position that was adapted according to the pressure distribution of figure 10. Results showed that the latter was associated with significantly lower discomfort values. The first results of the research of PhD candidate Kilincsoy show that the ideal pressure distribution in a sedan and SUV are close to these values. Many companies in the automotive industry use these values to validate their seats.

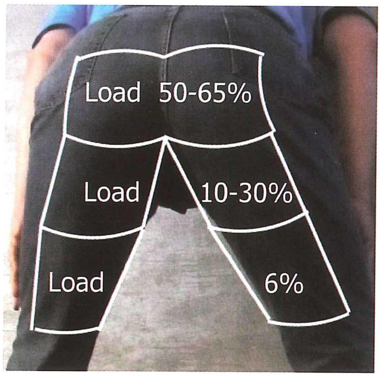


Figure 10. Ideal load distribution according to Zenk et al. (2012) and Hartung (2006), plotted on a buttock.

Human body effects

The interaction (I) can result in internal human body effects (H), such as changes in the human sensors, tactile sensations, body posture change, blood flow changes and muscle activation. Kong et al. (2012) showed that processes in the muscle are related to discomfort while delivering grip forces. The 72 male subjects showed high ratings of discomfort for the high levels of force, while they showed low discomfort for the low levels of force. While seated Le et al (2014) measured the human body effects (H) muscle oxygenation, EMG and pressure mapping, an interesting finding for tall subjects was (>1.71 m) that EMG in the neck and upper back had a relationship with discomfort. Pressure in the lower back and upper leg had a relationship with discomfort for a selection of subjects and a decrease in blood volume in a leg muscle (m. biceps femoris) had a relationship with buttock, upper leg and knee discomfort for a selection of subjects. The study of Le et al. (2014) is useful for optimizing a product by using an objective measurement related to discomfort.

Perception

Perception comes after weighing the input received from the human sensors and comparing the information with expectations. There are methods available for recording the first impression, such as measuring the activity of the muscles in the face (e.g. m. zygomaticus) and the FaceReader to see the first reaction by human beings. Hazlett and Benedek (2005) used the activity of the m. zygomaticus (Hazlett & Benedek, 2005) to see how people reacted to a computer screen design. This is a muscle that plays a role in laughing. FaceReader is one of the systems measuring lines and remarkable point at the face and estimate emotions based on these patterns. This FaceReader is capable of detecting six basic emotions. Terzis et al. (2013) showed that FaceReader is capable of measuring emotions with an efficacy of over 87% during a computer-based assessment. Apart from these more objective measurements many questionnaires and ways of performing interviews are described in studying the perception of comfort and discomfort (Vink, 2005), which varies from one VAS scale 0 (no discomfort) to 10 (maximum discomfort) to a diary with questions to be completed during weeks of use.

Feedback

After feeling discomfort or comfort the product may need adjusting, or another activity should be chosen, or the environment needs a change or adaptation i.e., adapting or changing the thermostat to achieve a comfortable interior temperature. This is the arrow shown in the model back to the most left block. Additionally, the usage could be changed by adapting behavior.

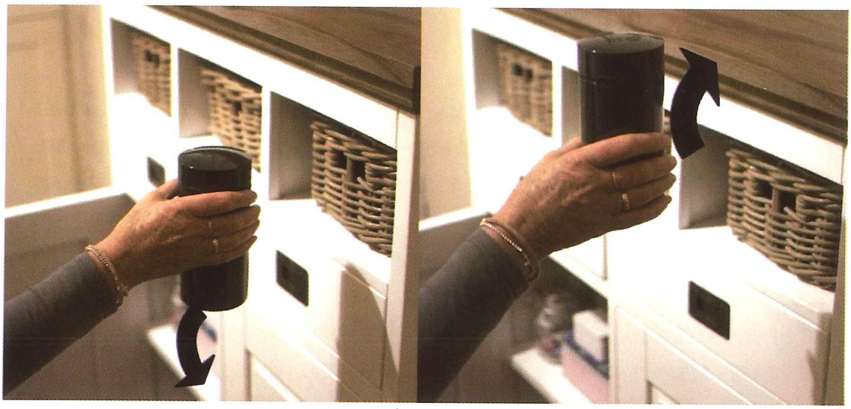


Figure 11. The anticipated end-state comfort determines hand position: moving down, the hand is high on the object (left), moving up, the hand is low on the object (right).

An example may be to change the usage in the way an object is picked up or placed somewhere. It may be so important to feel comfortable at the end phase of handling a product that intuition determines the unconscious choice of how to pick up a product. Rosenbaum et al. (2012) showed that human movements are influenced and anticipated by the most comfortable end-state of an action. In order to move an object from the kitchen worktop to the high hanging kitchen cabinet, people normally place their hands low on the moving object (see figure 11). The comfort of the end-state is leading. Picking up an object at a high level and moving it downwards, places the hands high on the moving object. This seems to demonstrate that we prefer the discomfort first and the comfort later. Dignat and Eder (2013) affirmed this effect, but also showed that the end-state comfort effect was reduced in conditions where a model performed the first movement and the participant performed the second movement. It shows that comfort determines human behavior, but it also shows that first sight of the environment or exemplary behavior influences usage.

Application of the model

The model is useful for unravelling the process of comfort and discomfort perception and to position objective measurements during the process from first interaction with the product to perception. The model is useful for measurements required to optimize a part of a product or service. Each block can be measured in a different way. Interaction can be measured by pressure distribution; human body effects, by blood flow or EMG; perception by facial expressions; and comfort and discomfort by questionnaires. Franz et al. (2012) developed a headrest using these measurements. They found by adapting the product, the pressure (H) was changed and so was the discomfort (D). This was input for the development of the ideal form of a head and neck rest with special foam that is soft on the neck, firm for the head and bendable to give side support for the head and neck.

Part III Future research

The comfort in a journey

A disadvantage of this model is that it does not show the comfort and discomfort effects over time. As described earlier, the sense of the softness of a seat is dependent on the hardness of the previous seat and other sensors are influenced by previous experiences as well. Temperature is experienced differently when coming into an interior from a cold environment as opposed to coming in from a warm environment. Retreating in and out of dark and light spaces influences our sensors. Our senses see the interior of an airplane differently when emerging from a dark jet way than when entering the airplane by stairs in open air. In fact the journey starts earlier. The moment of booking the flight could be of influence.

Future research of the Chair of Environmental Ergonomics will focus on this journey. The hypothesis is that making all steps in the journey highly comfortable does not automatically make the whole journey comfortable. Perhaps phases of discomfort or low comfort should be allowed to stimulate more awareness of high comfort or low discomfort level: "the sweetness of discomfort". Of course the discomfort should not be so high that it makes the whole journey a terrible experience. Introducing a bed of sharp nails or introducing sounds above the pain level is not planned as an object of study yet. The challenge is to find the ideal balance between comfort and discomfort experiences for the entire travel journey. Additionally, the methods are studied in such a way that it will be relevant for design.

The main direction of future research at the Chair of Environmental Ergonomics is:

Finding the ideal combination of discomfort and comfort experiences to create the highest comfort and defining measuring methods to study the physical effects.

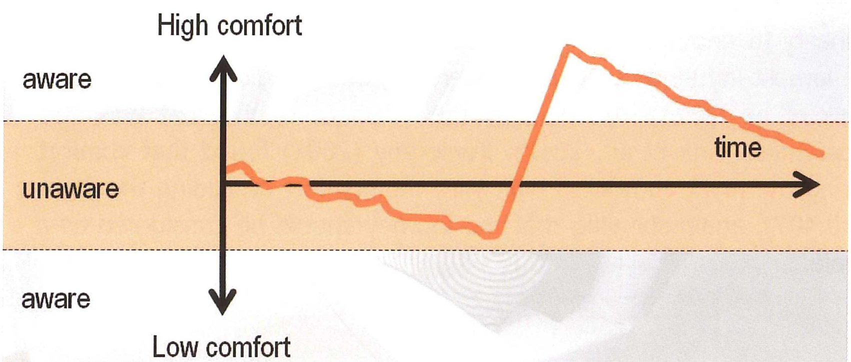


Figure 12. Hypothetical curve of how the comfort reduces slowly and then increases steeply, causing humans to become aware of sensory variability.

Challenges

In finding the ideal combination of discomfort and comfort moments in the journey interesting questions are: when are discomfort and comfort experienced and which environmental elements are important to change and which should remain? How does the influence of the environment work and what are the dominant elements in the environment? The idea is that during the journey, patterned complexity and sensory variability should play a role. The sensory variability should have the principle of lowering the comfort (or increasing the discomfort) slowly (see figure 12) followed by boosts of comfort that are consciously perceived.

Several studies have taken the journey into account. Meyenborg (2013), of our university, questioned 114 air travellers on the priority of improvements after a flight. The outcome is not surprising: leg room, in- and egress, seat width and air quality were rated the highest. In another study of 10,032 participants, the factors having the largest influence on comfort were legroom, hygiene and the crew (Vink et al., 2012). Additionally, the influence of the seat was also substantial (Vink et al., 2012). Konieczny (2001) found that comfort during the flight correlated high with the comfort preceding the flight (r=0.407), again showing that the journey should be considered as a whole.

A refreshing journey

Meyenborg (2013) showed that for most travelers an important refreshing activity was walking through the plane for a flight of more than 6 hours (see figure 13). For both short and long haul flights about one third of the travelers felt most refreshed after food or drink. This is interesting and concurs with a study by Zhang et al. (1996) and Helander and Zhang (1997) stating that comfort is highly related to luxury, relaxation or refreshment, while discomfort is usually related to the physical characteristics of the environment, like posture, stiffness and fatigue. In theory, discovering what the refreshing activities are could increase comfort. The question is how many refreshing activities are needed to increase the comfort of the whole journey and what other ways, besides walking increases the refreshed feeling?

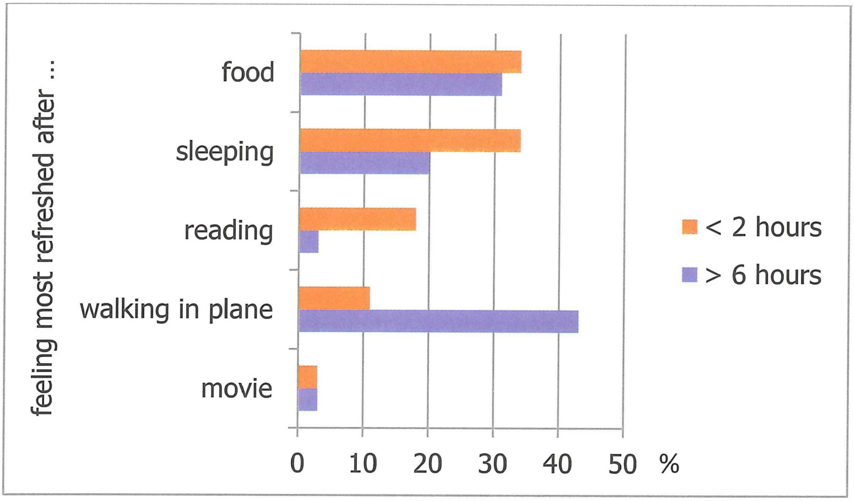


Figure 13. Percentage of air travellers (age 16-63 year; 70% German; n=114) reporting the most refreshing activity for their last short (<2 hour) and long haul (> 6 hours) flight.

Kamp (2012) compared gaming passengers with passengers reading and doing computer work during her PhD research. Kamp (2012) used a new concept titled, 'active seating', which consists of sensors placed in the upper part of the chair backrest to capture, the pressing backwards, of each shoulder separately. This 'active seating' was used to control a game and showed that a large part of the body of the passenger was activated. EMG signals showed that even the leg muscles are activated while pressing with one shoulder backwards. Twenty six subjects gamed in the rear seat using this 'active seating' while driving 30 minutes on a track, consisting of mainly highways. The gaming was done three times for five minutes, followed by five minutes of rest. On the same track these subjects had another drive of 30 minutes performing a more static activity. Thirteen started gaming and 13 gamed the second 30 minutes. Subjects felt significantly more refreshed after driving 30 minutes in the gaming condition with the active seat compared with the other conditions. The discomfort between the two conditions did not differ significantly, and corresponds with the findings of Helander and Zhang (1997) stating that discomfort was not related to 'refreshed', but to comfort. Seventy-nine percent of the subjects liked the system, and 85% reported that it was possible to do the movement in a car, although the car dynamics had a disturbing effect. If we apply this to an aircraft seat, the interesting question is how long and at what time during the flight should the gaming seat be activated to feel refreshed after the flight? This is a study that fits into the future research, *'finding the ideal combination of comfort experiences to create the highest comfort'.* This knowledge can be applied to various applications in other fields as well.

Variation improves comfort

The number of experts in the field of musculoskeletal loading promoting a seat or an office environment that stimulates movement is growing. Nordin (2004) states that based on a review of epidemiological studies, prolonged sitting in a restricted posture is a risk factor for musculoskeletal injuries. This is an argument to demonstrate the need for movement stimulation when sedentary activities are required most of the time. Lueder (2004) also states that based on a review of ergonomic studies, more dynamic sitting and more variation in posture reduces discomfort and is better for maintaining a healthy body. Large posture changes, like the abovementioned airplane walking and gaming have positive effects.

However, effects with smaller changes have also been shown. Franz et al. (2011) showed an increase in comfort by adding a light weight massage system in the back rest of a seat. An experiment with 20 drivers driving for approximately two-and-a-half hours showed that activity of the shoulder muscles was significantly decreased when using the massage system compared with driving without the system. This was recorded by placing electrodes on the muscles that record muscle tension of the M. trapezius pars descendens. The comfort was highly appreciated and there was no distraction. The system is now commercially available in a BMW 7-series.

Some important questions to ask are: What movements of what parts of the human body are needed to prevent discomfort and musculoskeletal complaints over time? What movements of what parts of the human body are needed to feel refreshed and comfortable after sitting a longer time? These questions are relevant for travel journeys, but also apply to sedentary jobs and office work. Is it possible to build in games, exercises, playful movements or other activities in a journey? There is also a maximum on what is possible and what passengers want to do. A few hours of exercising might be healthy, but may not be pleasant for everyone and may not be feasible. The right combination of unity and variation (Post et al., 2013) which applies to the evaluation and aesthetic appreciation of a product could be useful for design the combination of movement and static posture as well in a travel journey or office work.

Research in the future journey

The environment, the product, the service and the person will always be present now and in the future journey. Additionally, the need for a basic level of comfort and prevention of discomfort remains. The human sensors, effects in the body and perception play a role. This means that knowledge will still be valid in the future and the attempt of this Chair of Environmental Ergonomics is to continue studying the effects of physical environments and products on human comfort and discomfort.

There is a growing need for this knowledge. Attracting passengers will be more of a challenge due to the access of the basic knowledge of effects on comfort and discomfort for each product. Many companies are implementing changes to attract more customers. In the future more studies on the way sensors work and research on how experiences influence the whole journey is paramount. An example of the knowledge relevant for this topic are the activities people will perform in future and how previous activities and expectations influence the total comfort experience. While traveling, people want to perform different levels of activities (Kamp et al, 2012); ranging from more active to more passive activities. These activities influence body postures (Ellegast et al., 2008). In general, a mixture of variations in posture and stable postures is important (Lueder, 2004), and aligns with the psychological models that illustrate the way humans need a degree of patterned complexity and sensory variability (Heerwagen, 1998).It seems that although we have different sensors, the way information is processed in and from the sensors is similar for the ears, eyes and propriocepsis. It is interesting to apply this knowledge and validate the principle of using human sensor knowledge. Especially, if increasing the journey comfort by defining moments in the journey in which first comfort is reduced (or discomfort increased) slowly in the unconscious domain followed by boosts of comfort, which are consciously perceived. It could be that it only is true for a selection of sensors, which is also interesting to know.

A BWB interior study

It is important to look into the future of travel. Wang et al. (2014) propose an interior for a Blended Wing Body, influenced by the crowd well-being philosophy of Jie Li (see Wang et al., 2014). Based on a literature study and extensive studying of the travels of eight passengers, a concept interior was proposed for a Blended Wing Body (BWB) aircraft. The final design: a Crowd Well-being Blended Wing Body (CW-BWB) is a concept aircraft interior inspired by the 'compact city' metaphor (see figure 14). The centre of the airplane is an active zone imitating an active city centre while the periphery is a quiet zone similar to a suburb. Passengers have the ability to select their preferred area in the active zones by synchronizing with social media and categorizing themselves into various groups. In 2050, when social media shifts from 'portable' (mobile technology) to 'wearable,' the connections between individuals will likely be more digital than the present. Passengers who prefer more privacy have a quiet area including sleeping cabins located in the periphery. Activities are available i.e., taking a walk in the simulated nature, shopping or chatting at the central buffet in the city centre active zone.

It is the intention, within this Chair of Environmental Ergonomics, to build a BWB interior in the coming years to test effects of various elements on performance and comfort. Examples of the ideas to be tested are: effects of forming groups with similar interests, by using social media; effects of zones in the interior that facilitate specific activities i.e., working, sleeping and discussing; effects of variation in posture during a simulated flight; effects of a seat that feels hard and then changes to soft several times during the flight; effects of gaming, using many muscles and feeling refreshed; studying new seat elements, e.g., a seat that allows sleeping shown in the right picture of figure 1. These products will be tested and the outcomes will give broader, applicable input to new knowledge development.

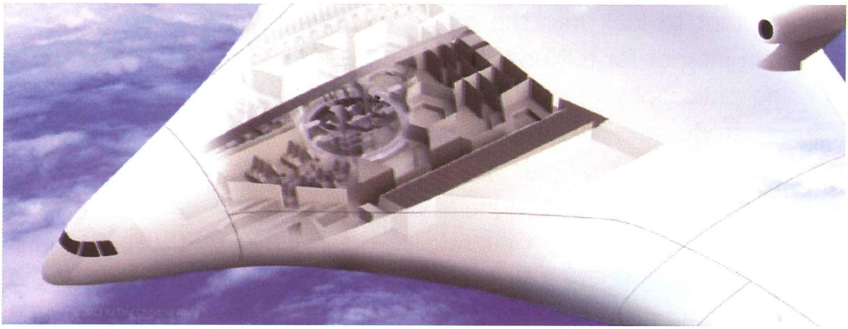


Figure 14. The design of the BWB interior of Wang et al. (2014).

The direction of design will be the combination of lightweight materials and comfort. However, this research is not by trial and error, but based on the sensing theory described above, the comfort model, and studies on variation of movements creating refreshing experiences that can be used to define hypotheses, a hypothesis founded in theory. Francis Bacon (1620) stated, *"the true method of experience, first lights the candle (hypothesis), and then by means of the candle shows the way (arranges the experiment); commencing as it does with experience duly ordered and digested, not bungling or erratic, and from it educing axioms (theories), and from established axioms again new experiments (test)"*. The rumor is that Francis Bacon died while conducting his own experiment. He bought a chicken to see how long its flesh could be preserved by stuffing it with snow. He contracted pneumonia while studying the effects of preserving food by freezing and died. It is not the goal of this Chair to allow researchers to die from their own experiments. On the other hand it would be an enormous achievement dying from a comfort experiment. The main influence of Francis Bacon is to conduct experiments based on a hypothesis and validate it by including questionnaires and interviews and measurements of the human body to see if hypothetical changes in the human body are found.

The effects of various new materials, new designs and interior elements will be explored. Also, studying the ideal combination of variations between postures and how this combination can be implemented into vehicle seating. The journey, as a whole, will be considered to discover how all the parts contribute and different combinations of the parts can improve the total comfort experience. Nature is an inspirational source, as mentioned above, and perhaps the ideal combination between unity and variety (Post et al., 2013) can be applied as well in body motion patterns. The continuation and collaboration of work on a smoother passenger journey with the Department of Product Innovation Management, who has so much knowledge already on the topic of the whole journey and recently developed a way to increase the airplane boarding time (KLM, 2013). This Chair of Environmental Ergonomics is positioned at the right university. Knowledge links will be established with the Department of Design Engineering developments of new materials, sustainability and manufacturability, as well as the faculty of Aerospace Engineering on future developments.

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