Comfort

By Peter Vink

Definition

In many dictionaries (e.g., the New Penguin English Dictionary 2000; Van Dale 2000) comfort is related to design and described as “convenience of the interior, or things which bring bodily ease.” Many people probably associate comfort with the interior or with visible things such as footwear and clothing. However, most comfort research is focused on climate (Bazley, 2015). In the scientific literature many definitions of comfort can be found (Vink, 2005). Despite this ongoing debate, there are some issues that are generally accepted (Looze et al. 2003): Comfort is a construct of a subjectively defined personal nature, it is affected by physical, physiological and psychological factors and it is a reaction of a person interacting in the environment.

Figure 1 Products mentioned in more than 12% of the cases asking 120 industrial design engineering students in 2014 on the product that comes into their minds thinking of comfort.

Table 1. Clusters of Factors Influencing Comfort or Discomfort during Sitting (Zhang et al., 1996).

Discomfort	Comfort
- Fatigue	- Feeling refreshed
- Restlessness	- Relief/energy
- Pain/biomechanics	- Well-being
- Strains	- Relaxation

In the literature often a distinction is made between discomfort and comfort. Everyone pays attention to **comfort**. When buying a bed or a car, or flying across the ocean, comfort comes into play. Therefore, manufacturers of products such as seats, cars, beds, hand tools, and production lines strive for comfortable products in order to stay ahead of competition. Zhang et al. (1996) found that comfort is related to well-being, luxury, feeling refreshed and relief, while discomfort is related to fatigue, pain and restlessness (see table 1). **Discomfort** is more related to the physical aspects and of importance in preventing back, neck and arm problems. Hamberg et al. (2008) showed a relationship between self-reported discomfort and musculoskeletal injuries that will develop later. They longitudinally tracked over 1700 participants and showed that those reporting higher discomfort in their measurements in the back and neck region had an increased chance of back and neck complaints three years later. The risk was 2-2,5 times higher.

In design this knowledge can be useful. In a study of 15 contemporary office chairs (by Looze in: Vink, 2005), the levels of comfort and discomfort were measured by use of the chair evaluation checklist of Helander and Zhang (1997) by 79 subjects. This methodology is based on the theory of seat comfort mentioned earlier. On a 1-to-9 scale subjects had to rate their opinions (1= I completely disagree; 9= I completely agree) about 14 statements addressing the underlying factors of comfort and discomfort. The sum of the ratings yielded separate ratings for comfort and discomfort. In addition, the same subjects gave their ratings for separate chair elements. By a multiple regression analysis, the following regression equations could be defined:

Discomfort = 38.175 – 2.743 backrest uniformity – 2.431 seat pan uniformity (R^2= 0.273)

Comfort = 13.158 – 3.247 backrest comfort + 2.741 seat pan uniformity + 1.442 armrest comfort (R^2= 0.511).

This indicates that the uniformity of pressure distribution on the backrest and seat pan are important factors determining discomfort, whereas comfort is mainly determined by the comfort of the backrest and the uniformity of pressure distribution of the seat pan and, to a lesser extent, by the comfort of the armrest. Other elements such as softness of the seat, armrest material, and texture of the seat appear to be of a lesser importance.

The same procedure can be followed by other products. However, for aircraft interiors Ahmadpour et al. (2014) found that discomfort and comfort have the same underlying factors. In their studies they found that the seat is a dominating factor but proxemics (the direct environment of a person) and the social environment (neighbour or crew) need attention too to create a comfortable experience. In hand tools comfort is mostly determined by functionality and physical interaction using hand tools (Kuijt-Evers et al. 2004). However, the use of hand tools is mostly accompanied by feelings of discomfort. In the use of hand tools adverse body effects like cramped muscles, blisters, and inflamed skin underlie both comfort and discomfort. So, for hand tools the focus on functionality and preventing discomfort by designing tools that generate 'good' postures and a nice contact between hand and tool is important.

To study comfort and discomfort a model has been developed (Vink & Hallbeck, 2012). The model is intended to be 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. Vink and Hallbeck (2012) presented a comfort model (see figure 1) 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 an artefact (A) and a human (H) starts in an environment where the person is doing a specific activity (U=Usage). This interaction (I) can result in internal human body effects (B), 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).

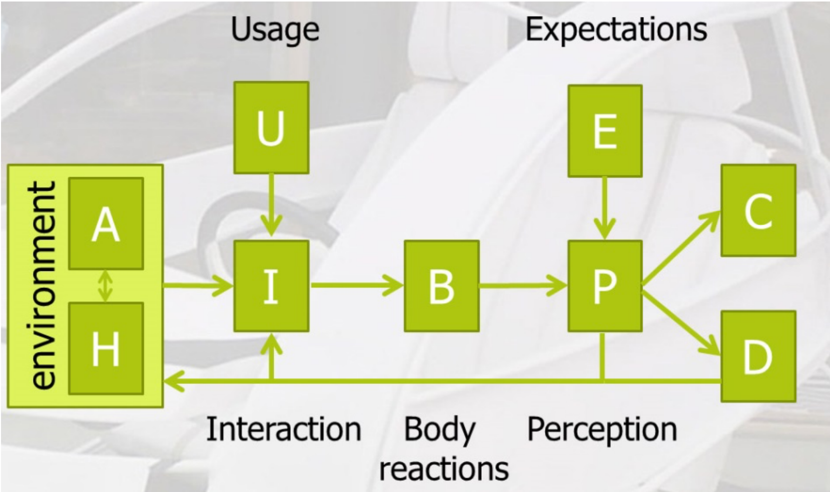

Figure 2. Comfort model: the artefact (A) and human (H) in the environment have an interaction (i), which creates an effect in the body (B). The expectation (E) in combination with the effect in the body creates a perception (P) and the decision comfort (C) or discomfort (D).

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 by a study of Kong et al. (2012) showing that the comfort scales did not appear to be useful for high gripping forces, 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 at the same time have a feeling of comfort created by a nice flight attendant.

USAGE: The use of a product or artefact in its environment does influence comfort and discomfort. This is illustrated by two activities that occur in bed. It is obvious that while sleeping the comfort is high in bed. However, an experiment (Vink, 2014) showed 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 (t-test for paired samples: p=0.006) and the number of mistakes did not differ significantly.

INTERACTION: The interaction with the product usually starts with a visual interaction of the product in its environment. It is the first sight. 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 colours differed. Three seats were light coloured and one was brown. The first impression was that the brown coloured 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. 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 3. Results showed that the latter was associated with significantly lower discomfort values.

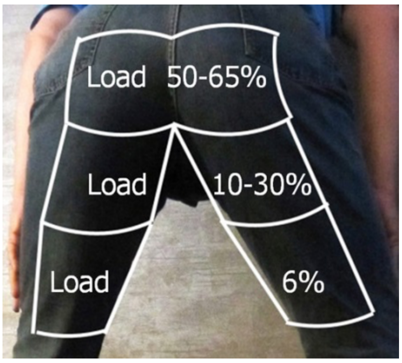

Figure 3. Ideal load distribution according to Zenk et al. (2012) and Hartung (2006), plotted on a buttock

BODY REACTIONS: The interaction (I) can result in internal human body effects (B), 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 (B) 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.

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. musculus zygomaticus) and the FaceReader to see the first reaction by human beings. Hazlett and Benedek (2005) used the activity of the m. zygomaticus to see how people reacted to a computer screen design. This is a muscle that plays a role in laughing.

Methods

There are many methods to study comfort and discomfort. As described above it is a subjective phenomenon, which means that in fact participants using the product or service can be asked for their comfort experience after using the product. An example of a method is used by Veen et al. (2014). After using the product the participants are asked to mark the experienced comfort using a pen on a scale 1–10 (with 1 = no comfort at all, 10 = extreme comfort). A frequently applied method to study discomfort is LPD. The local perceived discomfort (LPD) method is first introduced by Grinten and Smitt (1992) and later often applied (e.g. Hiemstra-van Mastrigt et al., 2015). It consists of a body map with 22 regions (see fig. 4). The participants are asked to rate perceived discomfort in the body regions on a 10-point scale (ranging from 0 = no discomfort to 10 = extreme discomfort, almost maximum) at the start and several time using the product. The LPD scale is sometimes trained by holding a 1 kg load in the hand and the arm horizontal. After a while the arm cannot be kept horizontal anymore and maximum discomfort (10) is experienced in the shoulder.

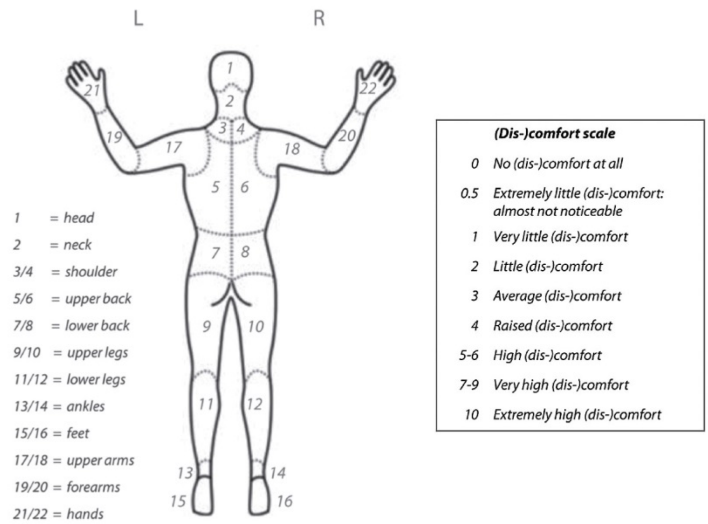

Figure 4. The local perceived discomfort (LPD) method. Participants are asked to rate perceived discomfort in the body regions on a 10-point scale.

Applying the LPD method

In Applying the LPD method subjects are generally asked to complete a local postural discomfort (LPD) questionnaire (see figure 4) after each condition (old and new). The difference per region is usually compared per person and using the Wilcoxon test significant differences can be calculated. This method may be old, but it is still useful in seat testing and used, for instance, by Bronkhorst and Krause (2005) and Groenesteijn (2015). In this method, subjects are first taught the Borg scale (0-10) (Borg, 1999). They are asked to hold a 1 kg weight in a horizontally sideward extended arm. At first, they feel very little discomfort. As time goes by, this moves up the scale towards extreme discomfort, until the point at which they can no longer hold the weight (=10). The subjects are then shown a body map containing several regions, and asked to put a score in the regions where they feel discomfort (Van der Grinten and Smitt, 1992). Usually, the shoulder region receives a score of 10.

The advantage of this method is that it reveals the location of the areas to be improved, which provides input for redesign. The method is not useful for short sitting sessions in a comfortable chair (less than an hour), however, as it takes time for discomfort to be noticed. The method can also be used in a simpler manner. After spending time in the seat, subjects can be asked to put red crosses on the body map where they feel discomfort, and green crosses where they feel comfort.

To understand more about the background of the comfort or discomfort also measurements on processes in the human body are used. Pressure distribution is for instance used to measure the pressure between seat and human body (see figure 4). EMG (measuring the muscle activity, see https://www.youtube.com/watch?v=k0uSpYd_Ics) or blood flow (see https://www.youtube.com/watch?v=8VkxbrD6Uik) is used to measure effects in the body and the facereader (see www.noldus.com/facereader) can be used to measure facial expressions.

Applications

In designing a new armrest to support working with a smart phone or a tablet Veen et al. (2014) tested the comfort and discomfort of different positions of the arm rest, which could be applied in vehicles. Also, a version for a chair in a lounge area was made. Based on those experiments a final prototype was made for the lounge (called the 'tablet chair') and tested again. It was compared with a traditional luxury chair (see fig. 5). This discomfort using LPD was lower in neck and arms for the prototype compared with the traditional chair and the comfort (using the scale from 1-10) was improved as well (Veen et al. (2014).

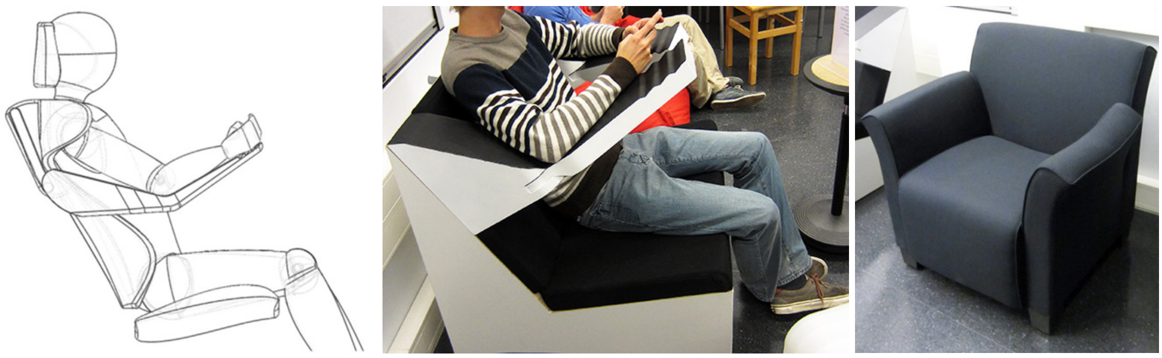

Figure 5. A design of a chair supporting the smart phone work. In the middle the prototype and at the right the benchmark chair.

In designing a light weight massage system (=LWMS) EMG recordings (recordings of muscle activities) were performed to check if the system has a relaxing effect (Franz et al., 2011). A light weight massage system (see figure 6) was developed for the BMW 7-series, but is was made in such a way that it could be applied later in electrical cars (light weight means more range). The LWMS are air bubbles than can be inflated by letting air in. It has specific movement patterns which reduce muscle tension and varies the pressure in the spinal disc. Two experiments were performed during driving with and without the prototype of the active LWMS in the seat. Subjective measurements were taken, in which the comfort experience was recorded for 20 participants driving a prescribed path around Munich for 120 minutes. Then objective (surface EMG above the rhomboideus and trapezius muscles) measurements and subjective measurements of the comfort experience were recorded over 7 laps on a test track for 24 participants. The results showed that the comfort was higher, and the EMG was significantly lower in the trapezius area while driving with the LWMS. So, even with light weight massage systems these effects can be produced. The massage system is since 2016 available and can be ordered by BMW 7 series customers.

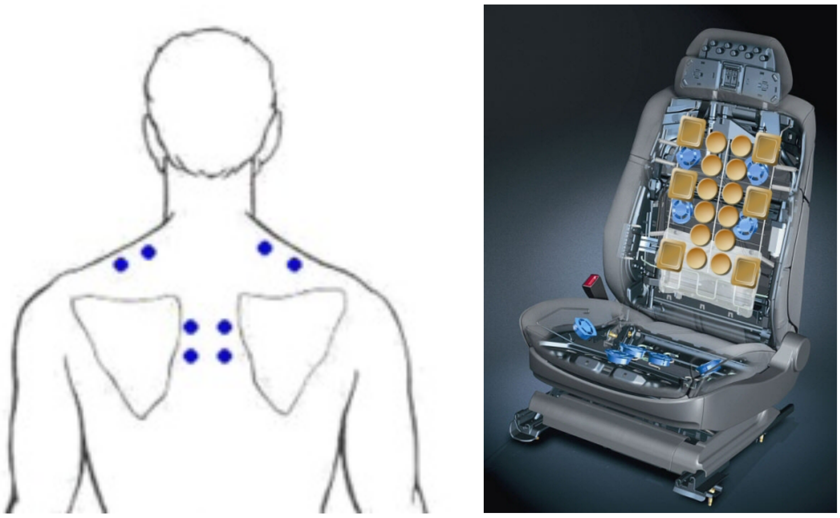

Figure 6. EMG recordings were made of the m. trapezius (upper four dots) and m. rhomboideus (lower four dots) to test the effect of the light weight massage system (right).

Conclusion

There are many definitions for comfort, but they have in common that it is a subjective experience. The majority of the literature makes a distinction between comfort and discomfort. Comfort is more related to luxury and discomfort more to physical aspects. The fact that it is a subjective experience means that it can be measure by questionnaires. In addition to using questionnaires, it is wise to add a measurement which is not influenced by experiences. Examples of these include pressure distribution, EMG, recordings of large fidgeting movements, and near-infrared spectroscopy to study blood flow. EMG is applied in one of the two applications of designing for comfort. EMG was significantly lower in the trapezius area with a massage system.

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