Applied Ergonomics 43 (2012) 271–276

Contents lists available at ScienceDirect

Applied Ergonomics

journal homepage: www.elsevier.com/locate/apergo

Editorial

Editorial: Comfort and discomfort studies demonstrate the need for a new model

Keywords:
Product comfort
Comfort model
End users
Discomfort

A B S T R A C T

The term comfort is often seen relating to the marketing of products like chairs, cars, clothing, hand tools and even airplane tickets, while in the scientific literature, the term discomfort shows up often, since it is used in research. Few papers explain the concept of a localized comfort experience in relation to product use, although people use these products daily. Therefore, in this special issue, the concept of product comfort is studied further. In this editorial an overview of comfort models has been made, evaluated with the papers from the special issue and a new comfort/discomfort model is proposed to increase our understanding of the factors influencing comfort and discomfort experiences.

1. The need for a special issue

Current bundling of the knowledge on comfort and discomfort has been limited, while the need for this knowledge is crucial, since people use products related to comfort every day, such as clothes, hand tools, kitchen appliances, computers and their workstations at the office and home as well as seats in cars, trains, airplanes and at the office. If we look at the trends like “attention to health”, “graying of the workforce (and population)”, “environmental awareness” and “attention to well-being”, (dis)comfort is closely related to these issues as well. Currently, the term comfort is also often seen related to the marketing of products like chairs, cars, clothing, hand tools and even airplane tickets. In the scientific literature the term discomfort shows up often, since it is used in research. A search of “Science Direct” using papers from 1980 through June 18, 2010 returned 104,794 papers including the term discomfort. Most of these studies refer to temperature as the source of the discomfort or patient comfort. There are also many application studies that use various systems to measure discomfort as a subjective phenomena to be related to musculoskeletal injuries. Galinsky et al. (2000), for example, examined the effects of supplementary rest breaks on musculoskeletal discomfort. They found that discomfort in several areas of the body were significantly lower under the supplementary than under the conventional rest break schedule. The assumption is that there is a relationship between self-reported discomfort and musculoskeletal injuries. This relationship was made clearer by Hamberg-van Reenen et al. in 2008, where local experienced musculoskeletal discomfort was measured in different body regions on a 10-point scale six times during a working day. She longitudinally tracked over 1700 participants and showed that those reporting higher discomfort in her measurements had an increased chance of back, neck and shoulder complaints three years later (the RR varied from 1.8 to 2.6). However, the theories relating comfort to products and product design characteristics are rather underdeveloped; the few papers explaining the concept of comfort are Helander and Zhang (1997), De Looze et al. (2003), Moes (2005) and Kuijt-Evers et al. (2004). Therefore, this special issue will focus on papers that contribute to knowledge concerning product comfort and this editorial will discuss the model(s) that these papers support and combine them into a new model that better ties comfort parameters to products.

2. The definition of comfort and the new knowledge in the papers

The definition of comfort in this special issue is: “comfort is seen as pleasant state or relaxed feeling of a human being in reaction to its environment” and “discomfort is seen as an unpleasant state of the human body in reaction to its physical environment”. The theory of Helander and Zhang (1997) convinced us that there was a division or discontinuity between comfort and discomfort scales while the model of De Looze et al. (2003) convinced us to add the physical dimension to the discomfort definition.

The ten papers in this special issue all refer to comfort and discomfort as defined above, but each has a specific addition to new knowledge in the field of comfort. Two papers highlight the channel of the **sensory input** (De Korte et al., this special issue and Vink et al., this special issue), which in the definition is the process from the environment towards the state or feeling, two other papers show that **activities** during the measurement influence comfort (Groenesteijn et al., this special issue and Ellegast et al., this special issue), referring to the characteristics of the environmental context part of the definition, two papers which stress the importance of the difference in how comfort is experienced in **different body regions** (Franz et al., this special issue and Kong et al., this special issue), which relate to the definition for the pleasant or relaxed feeling of the human being, two papers stress the effect of **contour** of the product for the comfort experience (Kamp, this special issue and Noro et al., this special issue), which is in the definition of characteristics relating to physical context, and two papers show that discomfort is related to **physical**

0003-6870/$ – see front matter © 2011 Elsevier Ltd and The Ergonomics Society. All rights reserved.
doi:10.1016/j.apergo.2011.06.001

loading (Lee et al., 2011 and Zenk et al., this special issue), demonstrating that discomfort also has value in connection to musculoskeletal loading.

Sensory input (1): In the paper by De Korte et al. (this special issue) the focus is on comfortable VDU or computer work. They compare four types of feedback systems to remind users to attend to tasks besides their primary task like word processing. They come to the conclusion that users prefer a system that does not interfere with the primary task. Feedback via the screen interferes with the tasks as the screen is used for the primary task, but vibrational feedback in the hand uses another "sensory system" and is seen as most comfortable by the end users. This indicates that in designing comfortable products, all sensory systems should be considered and using different human sensory systems for different messages could be more comfortable and less disruptive.

Conclusion: Separating the sensory input to eyes (visual) and hands (vibration) has effects on comfort: be aware of the fact that using different sensory channels can influence the comfort experience.

Sensory input (2): In the study of Vink et al. (this special issue) airplane passengers' comfort is obviously related to knee space, where the physical constraints are clearly apparent. However, a relationship was also found with the positive attention of the crew, which shows that factors other than the physical load, form and firmness can also influence the seat comfort experience.

Conclusion: Often soft factors like personal attention influence comfort.

Activities influence comfort: In the papers by Ellegast et al. (this special issue) and Groenesteijn et al. (this special issue), five office chairs are compared with each other while performing office tasks in both a naturalistic office setting and in a laboratory. The measured effects on the human body (EMG, postures/joint angles and physical activity intensity) and discomfort did not show much difference (Ellegast et al., this special issue); however, if the chairs are compared by activity type, differences become visible. Positive comfort relationships were found for computer work while at a "swing system" chair, for telephoning while in a chair with active longitudinal seat rotation, and for desk work in a chair with a three-dimensionally moveable seat (Groenesteijn et al., this special issue). This shows how important it is to look for the correct context (in this case activity) to test effects of discomfort or comfort.

Conclusion: Be aware of the role of the context and specific activity when experiments regarding comfort are performed.

Different body regions: In the paper by Franz et al. (this special issue) various foam characteristics are tested to define the most comfortable headrest. A new concept for increasing comfort was to support not only the head, but also the neck, which was appreciated by most of the test subjects. Interestingly, the head (skull) needed different foam firmness than the neck, where the material supporting the neck needed to be much softer to create a comfortable head/neck rest. In the study by Kong et al. (this special issue) it appeared that comfort in the palm in of the hand was more related to the force levels than at the fingers, an interesting finding as it corresponds to the results of Franz et al. (this special issue). These results from the papers demonstrate that product design is more complex as the softness of materials may need to be different for various locations having contact with the human body, but if we strive for comfortable products it is a worthwhile endeavor.

Conclusion: In designing the material characteristics in the contact area be aware of differences by body region.

Contour: In the paper by Kamp (this special issue), the focus was on the tactile experience influencing comfort in seating. The visual aspect was reduced as a white sheet covered the car seats to prevent sensory input other than tactile. The hard seats with rather high side supports were rated sporty and appreciated by the sporty drivers and seats that were softer are rated better as for more luxurious cars; however, there is a large variability among subjects in their tactile preference. This means that contour and sporty or luxurious feel and appreciation influences comfort. In addition, Noro et al. (this special issue) found effects of contour affecting comfort for long-term static sitting. They describe a study in which they analyze the form of the cushions Zen priests were using which appears to follow the buttock form closely and is used in long-term static sitting. This inspired the designers to develop a new seat for surgeons. This new design was tested and surgeons reported an improved comfort, which again demonstrates the importance of following the form of the human body in product design for comfort.

Conclusion: Forms following the human body contour and individual preferences influence comfort.

Discomfort is related to physical loading: Kee and Lee (this special issue) found several clear relationships between discomfort and posture holding time, maximal holding time, torque at joints, lifting index and compressive force at the L5/S1. Discomfort scales are typically less time consuming in their use than the objective measures that Kee and others have used. Thus, discomfort scales are very valuable in research or evaluation of products in development; however, Kong et al. (this special issue) found that the discomfort scale was better for high force levels (>65% MVC) than the comfort scale. For these low physical load levels Zenk et al. (this special issue) showed that if we measure for long enough time periods, subjects are able to feel differences which relate to an objective findings. Kyung and Nussbaum (2008) even discuss that discomfort measurements are more useful in long-term measurements than pressure recordings as it is related to fatigue. A previous study with experiments of longer than 2 h driving, comfort and pressure recordings gave input for a seat which adapts itself to the "ideal" pressure distribution by recording pressure and adapting the form, showing that for low physical loads, comfort may be a function of time. In the paper in this journal, Zenk et al. (this special issue) measured the pressure in the intervertebral disc and showed that also the pressure was lowest in the most comfortable ("ideal") situation.

Conclusion: Use of comfort and discomfort scales are useful to estimate the physical loading, especially above 65% MVC discomfort scales are more useful. In general, long testing periods may be useful when rating comfort or discomfort for lower forces.

The theories of dis(comfort) have been explored by others such as Helander and Zhang (1997), De Looze et al. (2003), Moes (2005) and Kuijt-Evers et al. (2004). These authors have all provided models and frameworks that influenced the content of the papers in this special issue and will be described.

3. Comfort and discomfort division of Helander and Zhang

Helander and Zhang (1997) influenced the comfort research field as they distinguished comfort and discomfort. In the late 1950s, Herzberg et al. (1959) interviewed employees to find out what made them satisfied and dissatisfied on the job. Physical factors, according to Herzberg, cannot motivate employees but can minimize dissatisfaction, if handled properly. In other words, they can only dissatisfy if they are not all right. Dissatisfaction is related to company policies and salary. Motivators, on the other hand, create satisfaction by fulfilling individuals' needs for meaning and personal growth. These are issues such as the work itself and advancement are related to satisfaction. According to Helander and Zhang (1997) in comfort a similar division can be made. Absence of discomfort does not automatically result in comfort. Comfort will be felt when more is experienced than expected. Based on questionnaires by Zhang et al. (1996) and Helander and Zhang (1997) discomfort was found to be related to physical characteristics of the environment, like posture, stiffness and fatigue

Table 1
Factors, influencing comfort or discomfort during sitting according to Zhang et al. (1996).

Discomfort related factors:	Comfort related factors:
Fatigue	Luxury
Pain	Safe
Posture	Refreshment
Stiffness	Well-being
Heavy legs	Relaxation

(see Table 1). In the case of absence of discomfort, nothing is experienced. To notice comfort, more should be experienced. Comfort is related to luxury, relaxation or being refreshed. This division is affirmed by the fact that the comfort scales did not appear to be useful for high physical load (>65% MVC).

4. An often cited comfort model by De Looze

A comfort model often cited with respect to product comfort is the model by De Looze et al. (2003), which shows a relationship between physical product feature experiences with respect to discomfort and comfort (see Fig. 1). The special issue papers are related to the relationships in this model. In the model shown in Fig. 1, different factors underlying sitting discomfort and comfort are described, as well as the relationships among these factors.

Following the discontinuity of discomfort and comfort, the left side of this theoretical model concerns discomfort. The physical processes that underlie discomfort incorporate model parameters on the aetiology of work-related physical complaints (Winkel and Westgaard, 1992; Armstrong et al., 1993), which consider exposure, dose, response and capacity. According to Armstrong, exposure refers to the external factors producing a disturbance of the internal state (dose) of an individual. The extent to which external exposure leads to an internal dose and response depends on the physical capacity of the individual. With regard to seating, it could be said that the physical characteristics of the office seat (product level, e.g., form, softness), the environment (context level, e.g., table height), and the task (context level, e.g., the performance of VDU activities) expose a seated person to loading factors that may involve forces, joint angles and pressure from the seat on the body. These external loads may yield an internal dose in terms of muscle activation, internal force, intradiscal pressure, nerve and circulation inclusion, and skin and body temperature, all provoking further chemical, physiological, and biomechanical responses. The perception of discomfort may be established by exterocepsis (stimuli from skin sensors), propriocepsis (stimuli from sensors in the muscle spindle, tendons, and joints), interocepsis (stimuli from internal organ systems), and nocicepsis (stimuli from pain sensors).

The right side of the model concerns comfort only, that is, feelings of relaxation and well-being. Again, using the seating example from above, the influential factors are presented on human, seat, and context levels. At the context level, not only the physical features are assumed to play a role, but also psychosocial factors such as job satisfaction and social support. At the seat level, the aesthetic design of a seat as well as the seat's physical features may affect the feelings of comfort. At the human level, the influential factors are assumed to be individual expectations and other individual feelings or emotions.

5. The relationship between the model and these special issue papers

Fig. 2, shows how the papers in this special issue are positioned within De Looze et al (2003) model. The key element from each paper has been noted and connected to the model.

5.1. Discomfort (left side) of the model

In the paper by Groenesteijn et al. (2010) it is clear that the activity influences comfort. They found that a combination of the task and specific physical seat features influence the comfort. Ellegast et al. (2010) used the same seats in a laboratory setting to measure the physical effects of the task and the seat. Muscle activation was not significantly influenced by the different chairs; however, posture, joint angles and physical movements showed

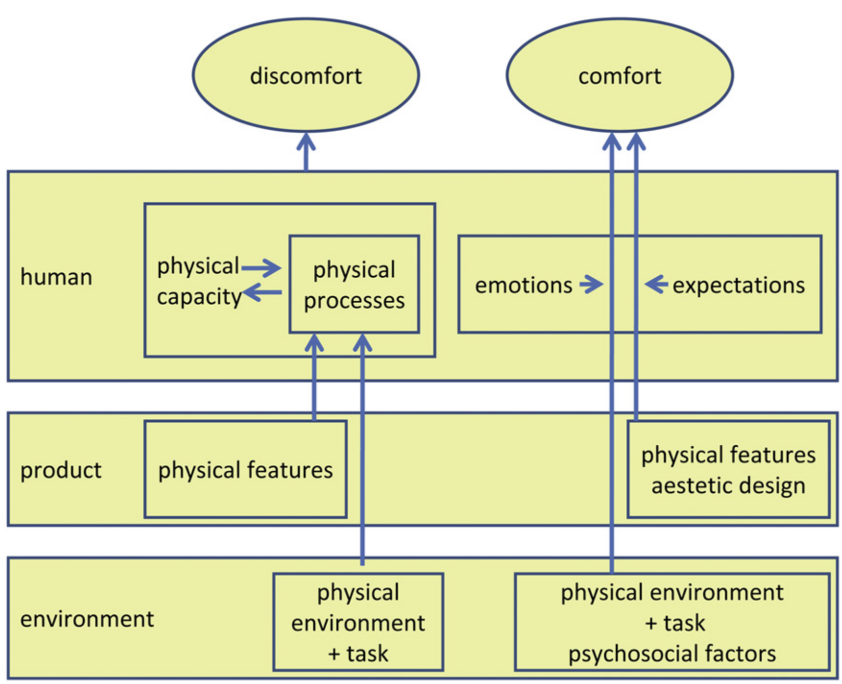

Fig. 1. The comfort model for sitting described by De Looze et al. (2003).

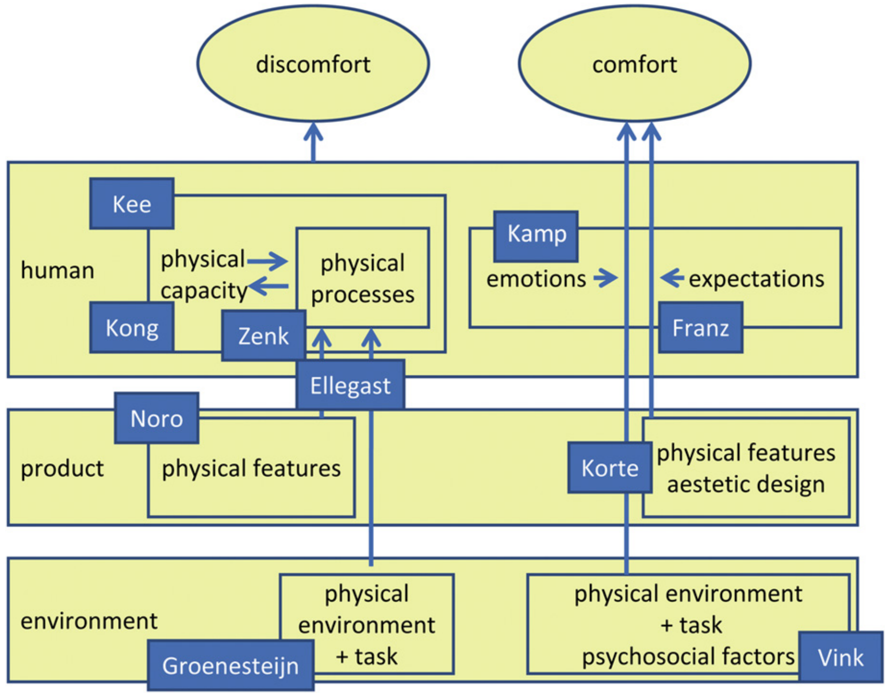

Fig. 2. The different papers of this special issue positioned in the comfort model of De Looze et al. (2003).

some differences between the chairs, while the tasks performed strongly affected the measured muscle activation, postures and kinematics since the users moved frequently due to the task switch. Therefore, the seats did differ slightly. Noro et al. (2010) evaluated seating comfort for the static task of micro-surgery, showing clear effects of a newly design of a surgical seat. Zenk et al. (2010) demonstrated the effect of adapting the physical seat features to the individual end user. The pressure was recorded while driving in a seat and the seat adapted itself automatically to the ideal pressure distribution. This represents the connection between human and product in the model for comfort, on the right side of the model as well. He also recorded the physical processes as he was able to measure the effect of posture on the pressure between the intervertebral discs. These studies all consider sitting, but the model also has value for hand tools, as well as the whole body. Kong et al. (2010) shows that discomfort is influenced by physical processes within the "human" while using hand tools. A higher %MVC resulted in more discomfort and is also related to the physical capacity. Hand (dis) comfort was more correlated with the palm than the fingers as the contact area with palm had more influence. Kee et al. (2010) also show that clear relationships exist between physical load and discomfort for the whole body. For instance, postural discomfort linearly increases with increasing holding time and holding force.

5.1.1. *Comfort (right side) of the model*

The paper by Vink et al. (2010) demonstrates the relationship between psychosocial factors and comfort. Comfort has a clear relationship with positive attention from the crew for airline passengers. The results of the paper of De Korte et al. (2010) show that additional visual information inserted on the screen to instruct the user while performing a visual task is not appreciated by the user. They found comfort is higher if another "sensory channel" is used such as vibration within the hand. This implies that the features of the information system influence comfort in some other way than by just its physical characteristics. Franz et al. (2010) show in their results that just asking whether a foam material is comfortable does not give enough input for creating a comfortable neck and headrest. By having participants test various foams with a variety of characteristics, the participants were able to differentiate and find an optimum comfort feel. Relationships with previous foam feel (a form of expectation, as it is named in the model) was needed to define the ideal for design. The left side of the model is also very applicable to this study as the physical support required for the neck and head differed: softer foam, was needed for comfort in the neck and more firm foam was needed for the head to prevent discomfort. Kamp et al. (2010) measured the emotional reaction to a tactile experience. They demonstrated that it is possible to increase the comfort experience further by rating current (reference) and designing new seats which have the ability to elicit the same emotion as a reference seat for a specific use (e.g. sports car vs. a van).

6. Model by Moes (2005)

Another model that could be utilized to explain the process of discomfort experience is the model of Moes (2005). Moes (2005) has established five phases in the process before discomfort is experienced (see Fig. 3). I – interaction, E – effect in the internal body, P - perceived effects, A - appreciation of the effects and D – discomfort. Moes (2005) also describes that this process is dependent on the person, the seat, the purpose and why the seat is used. Moes (2005) describes that if a person uses a seat with a specific purpose, the interaction (I) arises. For example, this interaction can consist of the pressure distribution of the contact area between the subject and seat. An interaction results in internal body effects (E), such as tissue deformation or the compression of nerves and

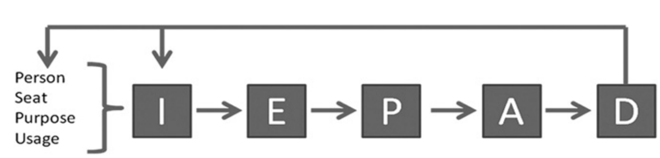

Fig. 3. A part of the comfort model of Moes (2005).

blood vessels. These effects can be perceived (P) and interpreted, for instance as pain. The next phase is the appreciation (A) of the perception. If these factors are not appreciated, it can lead to feelings of discomfort (D).

7. Both models reflected

The advantage of having ten experiments clustered on (dis) comfort in one issue of *Applied Ergonomics* is that the outcomes of the studies can be related to these models. The model of Moes (2005) is simple and linear and explains the process more clearly as the step between interaction and internal effects and weighting the internal to check whether it is appreciated are explicitly shown. It fits well with the findings in the paper by Franz et al. (2010) in this special issue, where subjects compare the various comfort experiences to each other, which is the weighing process and the paper by Kamp et al. (2010), where the tactile experience of the seats is also compared. The advantage of the model of De Looze et al. (2003) over Moes' (2005) is that the environment is explicitly shown. Comparing the paper of Noro et al. (2010), where sitting in a static posture shows large effects for seat characteristics and the paper of Ellegast et al. (2010), where a dynamic situation shows little difference between chairs, the importance of the environment and its influence on comfort is highlighted. The model of De Looze et al. (2003) has also the advantage that the connection to expectations can be made, which is important in the mental process of deciding whether or not a product is comfortable, as shown in the paper by Vink et al. (2010) where a business class seat received the same comfort score as an economy seat, because business class passengers have higher expectations. Another advantage of the model by De Looze et al. (2003) is that it can end with "comfort" as an outcome. The model by De Looze et al. (2003) has two separate processes, one on comfort (right) and one on discomfort (left), reflecting the prevailing concept of two distinct scales, one for discomfort and one for comfort (not just lack of discomfort), as shown by Kong et al. (2010). In reality, the physical contact can also lead to comfort, having the same process. Often "more comfort than expected" is reflected in a comfort experience, which is a valuable outcome of the De Looze et al. (2003) model. Interestingly, in the model by Moes (2005) discomfort in the usage or interaction parameters could be changed by, for instance, shifting in the seat. Both descriptions of the models discuss the probability of a relationship between discomfort and musculoskeletal complaints, but Hamberg-van Reenen et al. (2008) confirms that discomfort may influence the chance of having musculoskeletal complaints in the long-term.

8. New comfort model

Based on these reflections we propose a new model (see Fig. 4), which is heavily inspired by the models of Moes and De Looze.

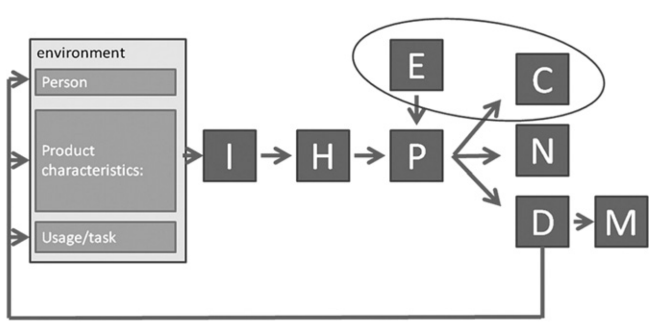

Fig. 4. The new proposed comfort model based on the findings of the 10 papers in this special issue.

The interaction (I) with an environment is caused by the contact (could also be a non-physical contact, like a signal in the study of De Korte et al. (2010)) between the human and the product and its usage. This can result in internal human body effects (H), such as tactile sensations, body posture change and muscle activation. The perceived effects (P) are influenced by the human body effects, but also by expectations (E). These are interpreted as comfortable (C) or you feel nothing (N) or it can lead to feelings of discomfort (D). There is not one form of comfort or discomfort experience, but it can vary from almost uncomfortable to extremely comfortable and from no discomfort to extremely high discomfort. It could even be 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 (M). There is a circle around E-C as we believe expectations (E) are often linked to comfort (C). If discomfort is too high or the comfort not good enough there is a feedback loop to the person who could do something like shifting in the seat, adapt the product or to change the task/usage.

9. New research

The work of Moes (2005) and De Looze et al. (2003) was useful as it has brought knowledge on products and (dis)comfort a step further toward conceptualization. However, in the future, definition the usage/tasks (see the paper of Groenesteijn et al., 2010) and the characteristics of the people performing those tasks is needed first and only then should the design of the products and testing the effects occur. The last element, performing experiments or tests is often missing. These outcomes of these experiments and tests should be fed back into the iterative design process. There are an incredible number of products being designed and becoming available every year, but these are rarely tested and iteratively refined/redesigned for comfort. Sometimes user tests are undertaken but the explanation for the comfort experienced is missing. Data on the internal human body effects are essential to understand the process towards experiencing comfort or discomfort. Additionally, more studies on long-term effects are needed, such as the study by Hamberg-van Reenen et al. (2008), which showed that a higher discomfort level increased the reporting of neck, back and shoulder complaints over a three year period.

Additionally, as environmental and sustainability issues become more important, we need to reduce the weight of products like cars, train and airplane seats like in the paper of Kamp (2010) or make smaller offices or hand tools that are lightweight and consume less energy. For this reason it is important to know what the minimum requirements are for user feelings of comfort and what makes a product comfortable, which is another new area of research. The first studies in this field have already started (e.g. Franz, 2010) in defining the minimal support needed to design a comfortable lightweight car seat.

10. Conclusion

As is mentioned above more research is needed in the field of product comfort and the model described in Fig. 4 could be helpful in understanding the comfort issues. However, some conclusions from the studies in this special issues can be drawn for designers, which need to be studied further as well as these are based on a limited number of studies:

- Be aware of the fact that using different sensory channels (e.g. separating visual and tactile input) can influence the comfort experience.
- Often soft factors like personal attention influence comfort.

- Be aware of the role of soft factors like personal attention, the context and specific activities when effects of products on comfort are studied.
- Be aware of differences in comfort experience by body region in designing the material characteristics in the contact area.
- Forms following the human body contour do influence comfort.
- Use of comfort and discomfort scales are useful to estimate the physical loading, especially above 65% MVC discomfort scales are more useful for low forces long testing periods may be useful to see differences in discomfort.

Acknowledgement

The editors would like to thank Pascale Carayon, John Wilson and Henny Knijnenburg for their wonderful support in making this special issue. The editors also would like to thank the authors of all the papers submitted to this special issue and the reviewers that supported us in selecting ten papers and improving the ten selected: C. Bazley, Jimconna, USA; R. Bubb, TU Munchen, Germany; Ching-Fu Chen, National University Taiwan; A.M. de Jong, Delft University of Technology, the Netherlands; E. de Korte, TNO, the Netherlands; M.P. de Looze, VU Amsterdam, the Netherlands; J. Durkin, University of Waterloo, Canada; R. Ellegast, Institute for Occupational Safety and Health of the German Social Accident Insurance (IFA), Germany; A. Gasparotti, Embraer, Brasil; R.H.M Goossens, Delft University of Technology, the Netherlands; L. Groenesteijn, TNO, the Netherlands; Shigekazu Ishihara, Heroshima International University, Japan; M.C. Jung, Ajou University, South Korea; I. Kamp, BMW, Germany; L. Kuijt-Evers, TNO, the Netherlands; Inseok Lee, Keimyung University, South Korea; R. Lueder, Humanics, USA; D. McMullin, Boeing, USA; K. Noro, Ergoseating, Japan; S. Openshaw, Allsteel, USA; L. O'Sullivan, University of Limerick, Ireland; J. van Dieen, VU Amsterdam, the Netherlands.

References

Armstrong, T.J., Buckle, P., Fine, L.J., Hagberg, M., Jonsson, B., Kilbom, A., Kuorinka, I. A.A., Silverstein, B.A., Sjogaard, G., Viikari-Juntira, E.R.A., 1993. A conceptual model for work-related neck and upper limb disorders. Scandinavian Journal of Work, Environment and Health 19, 73–84.

De Korte, E.M., Huysmans, M.A., De Jong, A.M., Van de Vene, J.G.M., Ruijsendaal M., Effects of four types of non-obtrusive feedback on computer behaviour, task performance and comfort. Applied ergonomics, 43(2), 344–353.

De Looze, M.P., Kuijt-Evers, L.F.M., Van Dieën, J.H., 2003. Sitting comfort and discomfort and the relationships with objective measures. Ergonomics 46, 985–997.

Ellegast, R.P., Keller, K., Groenesteijn, L., Krause, F., Berger, H., Vink, P. Comparison of four specific dynamic office chairs with a conventional office chair: impact upon muscle activation, physical activity and posture. Applied ergonomics, 43(2), 296–307.

Franz, M.M., Durta, A., Zenk, R., Desmet, P.M.A., Comfort effects of a new car headrest with neck support Applied ergonomics, 43(2), 336–343.

Galinsky, T.L., Swanson, N.G., Sauter, S.L., Hurrell, J.J., Schleifer, L.M., 2000. A field study of supplementary rest breaks for data entry operators. Ergonomics 43, 622–638.

Groenesteijn, L., Ellegast, R.P., Keller, K., Krause, F., Berger, H., De Looze, M.P., Office task effects on comfort and body dynamics in five dynamic office chairs. Applied ergonomics, 43(2), 320–328.

Helander, M.G., Zhang, L., 1997. Field studies of comfort and discomfort in sitting. Ergonomics 40, 895–915.

Kamp I, The influence of car seat design on its character experience. Applied Ergonomics, 43(2), 329–335.

Kee, D., Lee, I., Relationships between subjective and objective measures in assessing postural stresses. Applied Ergonomics, this special issue.

Kong, Y.U., Kim, D.M., Lee, K.S., Jung, M.C., Comparison of comfort, discomfort, and continuum ratings of force levels and hand regions during gripping exertions, Applied Ergonomics, 43(2), 283–289.

Kuijt-Evers, L.F.M., Groenesteijn, L., De Looze, M.P., Vink, P., 2004. Identifying factors of comfort in using hand tools. Applied Ergonomics 35, 453–458.

Kyung, G., Nussbaum, M.A., 2008. Driver sitting comfort and discomfort (part II): relationships with and prediction from interface pressure. International Journal of Industrial Ergonomics 38, 526–538.

Moes, N.C.C.M., 2005. Analysis of sitting discomfort, a review. In: Bust, P.D., McCabe, P.T. (Eds.), Contemporary Ergonomics 2005. Taylor & Francis, London, pp. 200–204.

Noro, K., Naruse, T., Lueder, R., Nao, N., Kozawa, M., Application of Zen sitting principles to microscopic surgery seating. Applied Ergonomics, 43(2), 308–319.

Hamberg-van Reenen, H.H., Van der Beek, A.J., Blatter, B.M., Van der Grinten, M.P., Van Mechelen, W., Bongers, P.M., 2008. Does musculoskeletal discomfort at work predict future musculoskeletal pain? Ergonomics 51, 637–648.

Herzberg, F., Mausner, B., Snyderman, B.B., 1959. The Motivation to Work. Transaction Publishers, Somerset, NJ.

Vink, P., Bazley, C., Kamp, I., Blok, M., Possibilities to improve the aircraft interior comfort experience. Applied Ergonomics, 43(2), 354–359.

Winkel, J., Westgaard, R., 1992. Occupational and individual risk factors for shoulder neck complaints: Part II – The scientific basis (literature review) for the guide. International Journal of Industrial Ergonomics 10, 85–104.

Zenk, R., Franz, M., Bubb, H., Vink, P., Spine loading in automotive seating. Applied Ergonomics, 43(2), 290–295.

Zhang, L., Helander, M., Drury, C., 1996. Identifying factors of comfort and discomfort. Human Factors 38, 377–389.

P. Vink*
Faculty of Industrial Design Engineering, Delft University of Technology, Landbergstraat 15, 2628 CE Delft, The Netherlands

TNO, P.O. Box 718, 2130 AS Hoofddorp, The Netherlands

S. Hallbeck
Department of Industrial and Management Systems Engineering, University of Nebraska–Lincoln, Lincoln, NE 68588-0518, USA
E-mail address: shallbeck1@unl.edu

* Corresponding author. Delft University of Technology, Faculty of Industrial Design Engineering, Landbergstraat 15, 2628 CE Delft, The Netherlands. Tel.: +31 15 2781438; fax: +31 15 2787179.
E-mail address: p.vink@tudelft.nl

8 August 2010