Applied Ergonomics 74 (2019) 233–240

Contents lists available at ScienceDirect

Applied Ergonomics

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

A study of classroom seat (dis)comfort: Relationships between body movements, center of pressure on the seat, and lower limbs' sensations

Luisa Fasulo[a], Alessandro Naddeo[a,*], Nicola Cappetti[b]

[a] Dept of Industrial Engineering, University of Salerno, Italy
[b] Star Engineering Italia s,r,l., Italy

ARTICLE INFO

Keywords:
Comfort
Discomfort
Center of pressure
Pressure map
Body movements
Classroom seat
School furniture

ABSTRACT

The aim of this work is to define a new method that helps researchers to analyze perceptions of (dis)comfort in dynamic conditions. Recent studies pay considerable attention to body movements, mobility, and stability to measure comfort or discomfort when seated. Most of these discuss the relations between subjective comfort/discomfort and objective measurements (e.g. body pressure distribution, body movement and EMG) for short- and medium-term sitting. The present analysis took place in a classroom of the Industrial Engineering Department at the University of Salerno. The participants included 25 students (12 females and 13 males), who were observed during classroom hours. The students were invited to sit at a combo-desk and were free to perform different combinations of movements while writing and listening. These activities required that they adapt their body movements, as the combo-desk was fixed to the floor. A pressure pad was used to detect pressure at interface and center of pressure's changes, allowing for the bodies' motion data to be recorded. The aim was to identify the correct threshold to be used for movement detection and to investigate correlations between the number of movements and the perceived (dis)comfort. The study also identifies those body parts that have the greatest effect on (dis)comfort perception.

1. Introduction

Products are designed according to specific functions that benefit users. However, their successful function is dependent on people being able to use them correctly. In the past, the principles of user-centred design were defined as methods for creating products, environments and systems that are fit for human use (Pheasant and Haslegrave, 2006). Ergonomics, meanwhile, studies the interfaces between people, the activities they perform, the products they use, and the environments in which they work, travel or play. As stated in Mokdad and Al-Ansari (2009), ergonomics principles allow to develop guidelines for improving and redesigning both old and new products.

A wide range of research on physical comfort and discomfort in the workplace has been carried out. Most papers discuss the relationships between environmental factors that can affect perceived levels of comfort/discomfort, such as temperature, humidity, applied forces, and others (Galinsky et al., 2000).

Several papers follow the assumption that a relationship exists between self-reported discomfort and musculoskeletal injuries, with these injuries affecting perceived comfort (Hamberg-van Reenen et al., 2008; Naddeo and Memoli, 2009). Theories relating comfort to products and product design characteristics, however, are rather underdeveloped.

The last 15 years have seen only five "comprehensive models" that considered every aspect of human perception: the Helander model (Helander and Zhang, 1997), the Moes model (Moes, 2005), the Vink-Hallbeck model (Vink and Hallbeck, 2012), the Naddeo-Cappetti model (Naddeo et al., 2014) and the Vink model (Vink, 2014).

In the Naddeo-Cappetti model (see Fig. 1), the internal body and perceived effects play a fundamental role in comfort/discomfort perception and evaluation.

The purpose of this work was to define a method to evaluate (dis)comfort perceptions based on body movement by observing the behavior of university students during lectures. The classroom is a learning environment in which the furniture is an important physical element. The furniture's function is to facilitate learning and provide a comfortable, stress-free environment. Poor classroom sitting posture is one of the main negative effects of bad furniture design on students (Dianat et al., 2013).

Students spend a considerable portion of their day at school, and most of that time is spent doing schoolwork in the sitting position (Castellucci et al., 2010; Macedo et al., 2013). Fixed-type furniture is commonly used, and, while this should meet the students' requirements,

* Corresponding author.
E-mail address: anaddeo@unisa.it (A. Naddeo).

https://doi.org/10.1016/j.apergo.2018.08.021
Received 6 November 2017; Received in revised form 13 June 2018; Accepted 29 August 2018

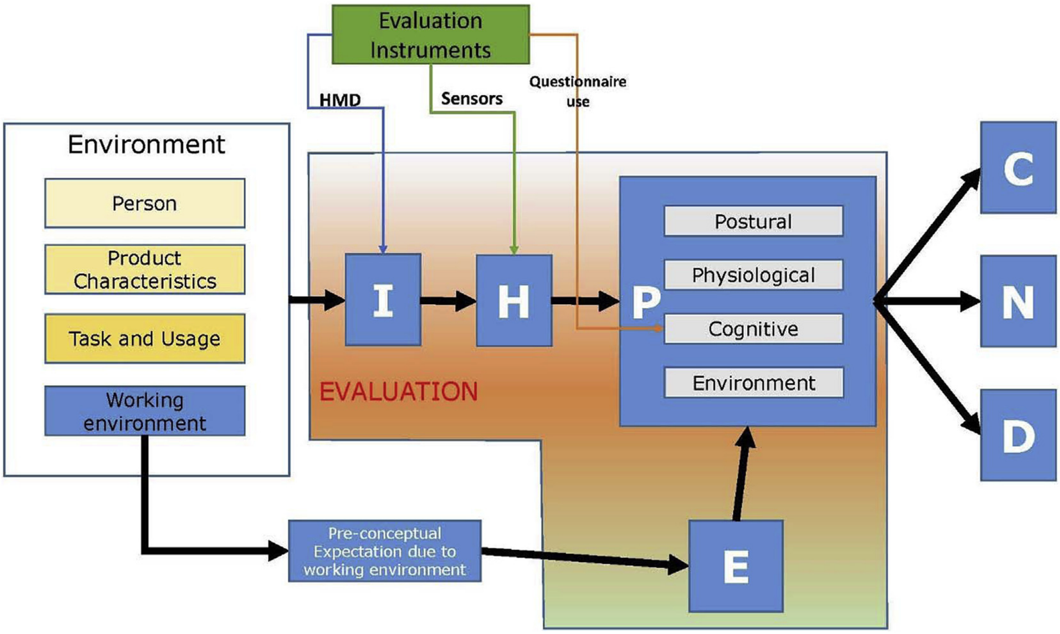

Fig. 1. Naddeo-Cappetti model of comfort/discomfort perception.

it may induce constrained postures (Gouvali and Boudolos, 2006; Parcells et al., 1999). Given that people differ in size and postural preferences, workstations with adjustable seats are preferred, as these have a significant positive effect on muscle tension and sitting posture. As well as promoting health and comfort (Koskelo et al., 2007; Thariq et al., 2010), they may also be related to better academic grades (Koskelo et al., 2007).

In the past, schools and universities often chose fixed-type chairs and tables due to the higher price and maintenance costs of adjustable alternatives (Straker et al., 2006). Side-mounted desktop chairs are often used in university classrooms. However, their correct design has been neglected. A study by Thariq et al. (2010) shows that side-mounted chairs do not meet the postural and comfort requirements of university students. Further to this, Naddeo et al. (2015a,b,c) identified a custom seat that had a positive influence on students' perceived comfort.

To investigate student's perceived (dis)comfort, a pressure pad was used to measure the pressure at the interface between the chair and the buttocks. Previous studies have developed the ideal pressure distribution for a car seat, whereby minimal pressure is applied to the intervertebral discs (Zenk, 2008). Furthermore, it is generally accepted that continuous static muscle activity results in discomfort (e.g. Falla et al., 2007). Regarding the number of movements, Graf et al. (1995) suggest that natural movements are desirable and necessary as long as they are within an acceptable range. Leuder (2004) stresses the importance of variation between several stable and healthy body postures. General seating studies describe the relation between seating time, discomfort, and body movement. Telfer et al. (2009) found that subjective discomfort and movement increases over time, with the amount of movement greater in chairs rated most uncomfortable. Vergara and Page (2002) proposed that macro-movements are a good indicator of discomfort. Fujimaki and Noro (2005) also found that discomfort increases over time, although they argued that macro-movements occur in a repeating pattern during prolonged sitting as a means to decrease discomfort. Similarly, Graf et al. (1995) found that work tasks which resulted in more muscular-skeletal disorders allowed for less frequent and less distinctive postural change. Finally, Callaghan and McGill (2001) suggested that humans redistribute their muscular loads using posture adjustments according to their comfort level.

The aim of this study is to understand if it is possible to use the analysis of pressure map data to describe the movements of a seated student, and to examine how these movements (number, description and frequency) can be used as indicators of perceived (dis)comfort. To this end, the output of the pressure pad was recorded to monitor the center of pressure and to evaluate the number of movements. This methodology was implemented to analyze (dis)comfort perceived by students during classroom hours. Results were validated via a consolidated methodology based on a manual count of the number of movements.

2. Method

Interactions can be recorded by many sensors (Vink, 2005). Most studies investigated the effects of pressure variables, such as mean and peak pressure (Hostens et al., 2001; Moes, 2007), contact area (Paul et al., 2012; Kyung and Nussbaum, 2008; Vos et al., 2006) and pressure distribution (Mergl, 2006; Zenk, 2008). Mergl (2006) and Zenk (2008, 2012), for example, defined the ideal pressure distribution for a car driver. Even though pressure distribution seems to be the best objective measure for discomfort (De Looze et al., 2003), it is influenced by other variables such as posture (Tessendorf et al., 2009; Oyama et al., 2003; Zhiping and Jian, 2011; Naddeo et al., 2015b), movement (Wang et al., 2011; Ciaccia and Sznelwar, 2012), expectations (Naddeo et al., 2015a) and first sight (Vink, 2014). Helander and Zhang (1997) and De Looze et al. (2003) stated that discomfort is more related to physical factors, while comfort is more related to luxury and feelings of refreshment.

In this study, data from a pressure mat mounted on the seat-pan of the combo-desk was used to detect and classify movements. Specifically, we used the amplitude of the center of pressure's shift to analyze changes in (dis)comfort perception for seated students during a one-hour lesson.

2.1. Subjects

Twenty-five students (12 females, 13 males), all volunteers, participated in the experiment. None had a history of musculoskeletal diseases. The main characteristics of the subjects are summarized in Table 1. All subjects were informed of the nature of the tests, and written consent was obtained. The subjects' selection method and the experimental setup and tests were approved by the university's ethical