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Sitting Posture, Postural Discomfort, and Visual Performance: A Critical View on the Interdependence of Cognitive and Anthropometric Factors in the VDU Workplace

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The study focuses on individual and standard visual display unit (VDU) workplaces with respect to performance and muscular load. Three different work settings were realized: The workplace was either adjusted to individual preferences or to the European standard. The third condition mirrored exactly the individual setting, however participants were told that it was set according to another standard. Dependent variables were visual performance in a search task, the rated muscular load, and individual preferences. Results show that both individual work settings yielded a superior performance as compared to the standard. However, performance and muscular comfort improved when participants knew they had adjusted the workplace. Apparently, VDU users follow a intuitive rationale adjusting their work setting minimizing muscular load and optimizing performance.

sitting posture postural discomfort muscular load
VDU workplaces standard workplace adjustment
individual workplace adjustment anthropometric factors

1. INTRODUCTION

In today's societies, the nature of work has been fundamentally changed by the overarching spread of computers within our working lives. One of the

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most profound changes refers to the different postures people adopt while working. Whereas in former times work was mostly executed in standing (and thereby moving) body positions, nowadays the visual display unit (VDU) workplace is characterized by a rather rigid sitting posture over extended work periods, often resulting in sustained defective body positions. The homo erectus mutated to the homo sedens (Grieco, 1986).

The aftermaths of this development were not missing for long: Alarming numbers of an increasing incidence of muscular-related diseases give reason for severe concern (Sandsjö, Kadefors, & Lundberg, 2002). In a study (Eriksen, Svendsrod, Ursin, & Ursin, 1998) dealing with the prevalence of health complaints associated with VDU workplaces, 35% of employees indicated to be afflicted with severe back pains, 22% with pains in the lower back, and 32% with neck pains. Moreover, 25% of the employees reported suffering from pains in shoulders and arms, and further 7% indicated regularly suffering from migraine. In addition to the painful consequences for people, muscular-related disorders represent economically a losing deal: According to estimations of the European Agency for Safety and Health Care, 28.7% of the work failures in Germany are caused by the medical condition of the employees—the costs are estimated to amount to a considerable sum of €12 bn. The crucial question is twofold: Which factors account for the negative trend and which factors are able to stem against it?

Numerous studies were concerned with the influence of anthropometric and psychosocial VDU work-related factors on posture and postural discomfort (e.g., Bhatnager, Drury, & Schiro, 1985; Grandjean, Hünting, & Pidermann, 1983; Grandjean, Nishiyama, Hünting, & Pidermann, 1982; Hünting, Läubli, & Grandjean, 1981; Kroemer, 1997; Ong, 1993; Sauter, Schleifer, & Knutson, 1991; Zhang, Helander, & Drury, 1996; Ziefle, Dusch, & Wischniewski, 1999). Giving a very short overview of the studies' outcomes, the restrained body posture typically adopted in VDU work is assumed to be highly hazardous for the onset of muscular load, resulting in severe back and neck pains. However, the combination of conducive and aggravating circumstances vary individually: Users differ distinctly with regard to their anthropometry, visual abilities, age, and individual health state. This makes it rather difficult recommending one universal working position for a health-supporting workplace. In addition, psychosocial and cognitive factors can modulate the quality of the VDU work setting.

Grandjean et al. (1982, 1983) requested users to individually adjust the workplace according to their needs and compared the individual setting with a workplace adjusted according to the standard. Both work adjustments were

measured and examined by means of user preferences. It was found that the individual adjustments differed in fact from the adjustment according to the standard with respect to, for example, the viewing distance, the sitting height, and the inclination of the backrest. Moreover, users distinctly preferred the individual over the standard setting. The results suggest (a) that users adopt an individual rationale in workplace adjustment and (b) that the standard does not match the optimal setting properly. Unfortunately, as no performance measures were surveyed, it cannot be determined if a workplace that has been individually adjusted effectively increases performance. This, however, is of great ergonomic interest. Among many employers, faced with the costs for the purchase of modern ergonomic equipment, it is still common belief that a new chair does not increase, not necessarily increases, or not at all increases performance (Kuhlmann, 1999).

Since 1996, the standards, beforehand in the domain of each country, have been merged to a universal European standard. The agreement aimed at providing a specific quality level with respect to the hardware, the software, and psychosocial work factors. Different from before, the European standard does not recommend a specific setting any more, the impact of the standard has been distinctly enhanced by depicting legal requirements. This has positive effects, as the awareness of the endangerment by suboptimal VDU work settings has been increased generally. But naturally there are problems associated with this generic approach: The demands are addressed to an average user profile, not able to satisfy different user needs, and therefore, the requirements are rather imprecisely couched in terms. The present study addresses this problem posing the following questions:

- How optimal is the standard compared to an individually adjusted workstation with regard to users' effectivity?
- Is the rationale of individual workplace adjustment rather arbitrary, reflecting moods and modes, or does it follow ergonomic factors?
- Does the standard differ from the individual adjustment regarding physical measures?
- Are cognitive factors able to modulate performance independently of the design of the workstation?

Three VDU workplaces were examined: (a) a workplace arranged according to the standard, (b) a workplace individually adjusted by participants, (c) the same workplace as in, (b) however, participants were told that this was a work setting arranged according to another industry standard. Proving effects of the different workplace designs, visual performance, muscular load, and user preferences were determined.

2. METHOD

2.1. Experimental Variables

2.1.1. Independent variable

The design of computer workstations was the independent variable. Three different types were varied: (a) the standard workplace (Council Directive 90/270/EEC; Standard No. DIN 66234, Deutsches Institut für Normung [DIN], 1998); (b) the individually adjusted workplace, in the following referred to as cognitive; and (c) the individual workplace, exactly the same setting as in (b), but without the participants' knowing that.

The standard workplace (Figure 1). The user is recommended to sit upright on a height-adjustable chair, the back should be firmed up by a back-rest, disposing of a lumbar support. The upper arms should be relaxed, hanging down vertically, and the elbow angle should be at 90° , with the forearms and hands held horizontally. The thigh should be horizontal, the lower leg vertical, and the feet should be on the floor (using a footrest, if necessary).

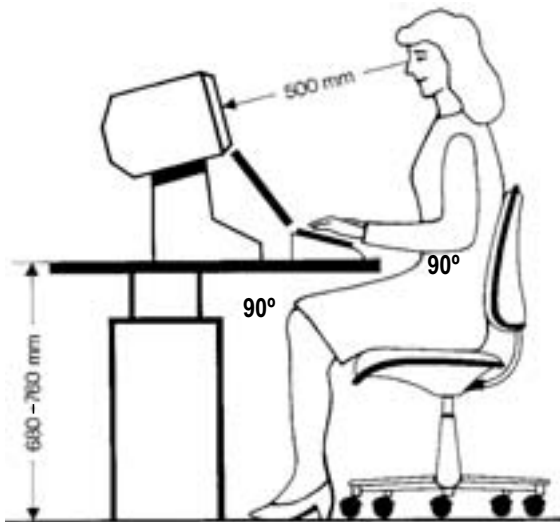


Figure 1. Example for a standard working place (Standard No. DIN 66234, Deutsches Institut für Normung, 1998).

The cognitively adjusted work setting. Participants were requested to adjust the workplace according to their needs and preferences. They were told that this condition was purely individual (“cognitive”). To avoid biases,

in the beginning the equipment was set in a default position (the screen was put in the rear, the chair was set to the lowest position possible, the backrest was set upright, and the footrest stood aside). The position participants adjusted was surveyed and physically measured.

The individually adjusted work setting. This work setting was exactly the same as in the cognitive condition, except participants were not informed. As it was pretended through a cover story that only one work setting was individually adjustable, participants expected this condition to comply with one of two different industry standards (and, as checked by post-experimental interviews, participants were in fact unaware this was not so).

2.1.2. *Dependent variables*

There were five dependent variables.

Performance measures. Speed (ms/line) and accuracy of visual search was measured. According to the signal detection theory, errors were defined as miss (target present was not detected) or as false alarms (target not present was reported to be present).

Ratings of sitting comfort. The sitting comfort due to the three work settings was rated on the category-partitioning scale (Heller, 1985), a 50-point scale, with verbal categories and numerical steps. Categories were *very slight* (1–10), *slight* (11–20), *medium* (21–30), *strong* (31–40), and *very strong* (41–50).

Ratings of muscular load. Before and after each working condition, participants reported their muscular load in their neck, shoulders and back as *relaxed*, *tensed*, or *painful*. When a muscular region was judged as *tensed* or *painful*, the extent was quantified by the category-partitioning scale, allocating an appropriate number. The ratings were finally weighted, determining the overall muscular load: *Relaxed* was taken as 0, *tensed* as 1, whereas ratings as *painful* were weighted by factor 2¹. The total score referred to the body complaint score.

Preference ratings. Participants indicated which of the three working adjustments they preferred most, second, and last.

Physical measures. Desk height, seat height and width, viewing distance, inclination of backrest and usage of a footrest was measured.

¹ Example: A user reported to have a *painful* neck, rated by 33 points. His shoulders were *tensed*, rated by 40 points. The back was *relaxed*. The ratings were now weighted. Neck: 33 (×2) = 66; shoulders: 40 (×1) = 40; back: *relaxed*: 0 (×0) = 0. Total score: 106.

2.2. Procedure

As the factor *workplace* was a between-subject variable, all 30 participants completed all work settings lasting 30 min each. The order of conditions was semi-counterbalanced as the individual setting could only be applied after participants had adjusted their own setting (cognitive). Realizing the cognitive condition, it was told that the study aimed at showing if the sitting posture on a VDU-workplace affected effectivity. Participants were informed that three workplaces were under study: Two referred to industry standards, imposed by the experimenter, and one referred to an individual adjustment. Thus, participants knew only one setting to be individual. In the beginning, body measures were determined. Before and after each condition, muscular load and sitting comfort were rated. Finally, preference due to different workplaces was indicated.

2.3. Experimental Task

A visual search task was used. Participants scanned through lists of letters, arranged as a matrix, and searched for the target letters D and Z (Figure 2). Each matrix consisted of 30 lines of 22 letters each. Both targets were equally frequent. Either one or no target was in the list. For training purposes, six lists were completed in the beginning².

01	L T V M F N X M F W V K M X W V F L W N M K	01
02	X H M K F N V M L K T F H L X F M W V L N M	02
03	X W L F M H L W V T F N W H K L W F T L H N	03
04	W H M N L T X K N M H T N V F L N V X T K N	04
05	N L F M V T X W N M V H X T W M X L H K T M	05
06	H F N K V W L F T X L F H X L K W M N K H F	06
07	T W K L H T W K L N F H L X M W F V L W K T	07
08	M H L V T K N H X T N F M H X V L T W X M F	08
09	W V X M K N V M K F W L H V K V L T F H T V	09
10	H T N X L W M V T L H K M Z X F H N T M H F	10

Figure 2. Example of a search list. The height of the list subtended 18 cm, the width 12 cm, presented in the center of the display.

² As experimental display, a 17" CRT screen (Sony, Japan, Multiscan 200 PS, 1024 × 768, 90 Hz) was used. Presentation times and reaction times (RTs) were controlled with a timer-board (National Instruments, Germany, AT-MIO-16 F-5).

2.4. Participants

Thirty participants (15 male, 15 female) between 21 and 39 years ($M = 27$ years) took part. Determining the ex-ante muscular load, a pre-experimental screening was carried out. Participants were found not to be bothered by strong muscular discomfort. Visual acuity was at least normal (checked by a TITMUS, USA, tester). As taken from post-experimental interviews, all participants were frequent computer users. Asked if they had adjusted their home computer workplace, they only partly affirmed, however, for different reasons: The judged comfort as the deciding criterion was reported by only one participant. Others stressed aesthetic reasons (“It’s nicer”) or practical ones (desk too small, room lighting makes it necessary). Others denied, indicating that an individual adjustment was too bothersome or cumbersome.

3. RESULTS

Results were analyzed by analyses of variances for repeated measurements. The level of significance was set at $p < .05$.

Muscular load and sitting comfort. Figure 3 (right) shows that muscular load with respect to the three workplaces differed significantly, ($F(2, 58) = 3.2$, $p < .05$, from each other.

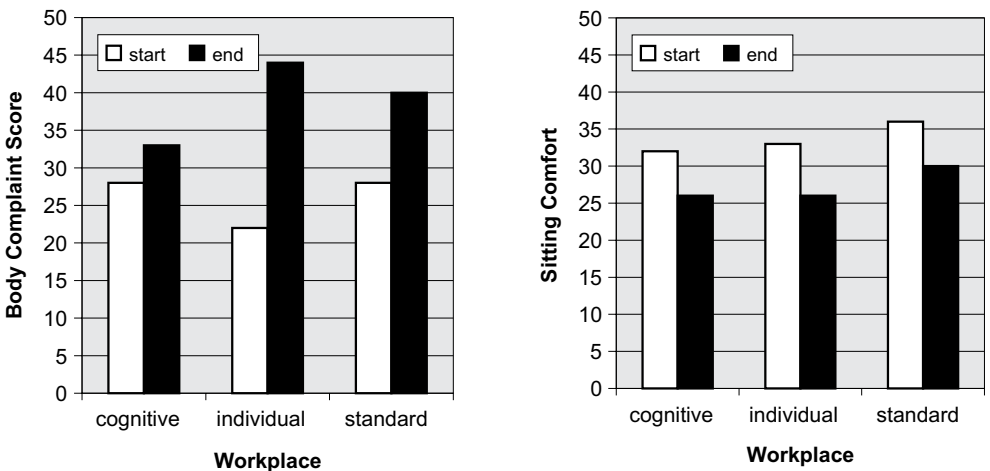


Figure 3. Left: Body complaint score regarding neck, shoulders, and back (maximum 300 points); Right: rated sitting comfort (maximum 50 points).

Muscular load was lowest in the cognitively adjusted workplace (the one participants knew to be individual), whereas “both” standard workplaces (in fact, only one was standard, the other was also individual) induced higher muscular complaints.

As shown by a two-way analysis of variance, there was an effect of time on task, $F(2, 58) = 15.9, p < .05$, indicating that muscular load increased from the beginning to the end of each condition. The significant interaction, $F(2, 58) = 4.09, p < .05$, of work setting and time on task showed that the increase of muscular complaints was smaller in the cognitive condition. On the left side of Figure 2, the rated sitting comfort is visualized, differing significantly, $F(2, 58) = 6.0, p < .05$, due to the different work settings. Again, a significant effect of time on task, $F(2, 58) = 25.4, p < .05$, showed sitting comfort to decrease from the start to the end in each condition.

What were the outcomes within performance measures?

Searching speed. It was found that the workplaces significantly affected the searching speed, $F(2, 58) = 5.4, p < .05$. In the cognitive condition, it took on average 3,797 ms to scan one line (Figure 4, left). In the identical condition (individual), search time was increased by 6% (230 ms/line). However, the longest search time was found in the standard condition, with 4,443.3 ms per line (increase by nearly 17% compared to the cognitive condition). Both individually adjusted workplaces, if taken together, showed to outperform the standard condition by after all almost 12%, though.

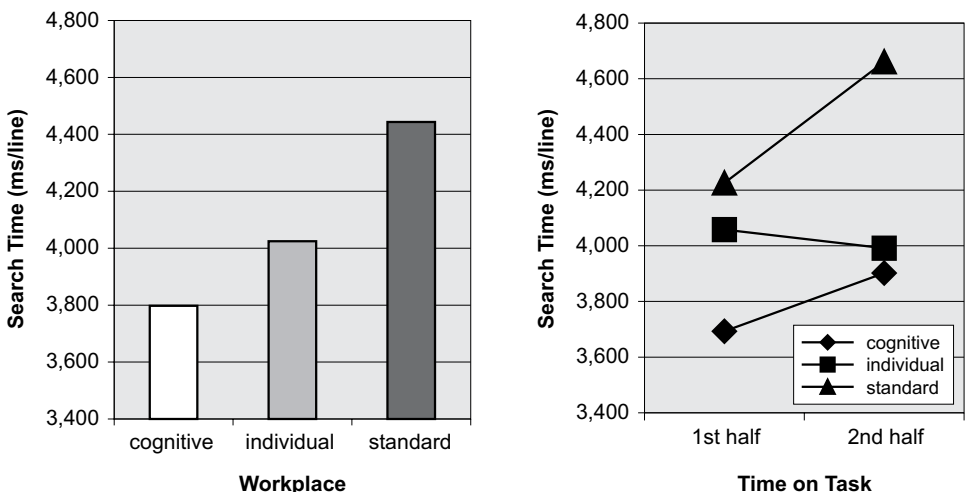


Figure 4. Left: search time (ms/line); Right: search time (ms/line) due to time on task.

The effect of time on task (the first 15 min versus the second 15 min of the search period, Figure 4 right) was also significant, $F(2, 58) = 10.9, p < .05$, as well as the interaction of both factors, $F(2, 58) = 4.2, p < .05$. The most distinct increase of search time from the first to the second half of the search period (over 400 ms per line) was found in the standard condition.

Searching accuracy. A comparable result was found for searching accuracy. The three different workplaces differed significantly from each other, $F(2, 58) = 5.7, p < .05$. Search accuracy was worst in the standard setting, reaching only 79%. However, both individual workplaces were distinctly superior, yielding 85% for the cognitive and 86% for the individual workplace.

Preference ratings. Further, it was analyzed which of the three workplaces was ranked first and which last (Table 1).

TABLE 1. Preference Ratings of the Different Work Settings

Preference	Cognitive	Individual	Standard
First place	12	10	8
Second place	15	9	6
Third place	3	11	16

Overall, the cognitive work setting was ranked best (it was set 12 times in the first and 15 times in the second place, and only 3 times last). The individual condition was ranked in second position. Again, it was the standard condition that took the last position. Only 8 out of 30 participants preferred this setting, whereas more than 50% ranked it last.

To understand why the standard setting is so far behind, it is of central interest to analyze the physical dimensions and users' body measures as well as the rated complaints.

Physical settings and anthropometric measures. The individually adjusted settings differed physically from the standard setting. First, the adjusted viewing distance was smaller than the standard ($t = 2.2, p < .05$) and the seat height differed from the standard setting ($t = 3.1, p < .01$). The seat height was negatively correlated with the length of the upper part of the body, significant only for the female subgroup ($r = -.573, p < .05$), hinting at the individual workplace adjustment to follow a rationale meeting individual body measures.

Judgments of muscular load and correlation to anthropometric measures. Moreover, it could be shown that the judgments regarding muscular

load were negatively correlated with body height ($r = -.57, p < .01$, the length of the upper part of the body ($r = -.56; p < .01$) and body weight ($r = -.38, p < .05$). In other words, the shorter participants were, the higher were the complaints with respect to the judged muscular load.

4. DISCUSSION

The present study focused on the influence of different VDU work adjustments on ratings of muscular load, visual performance, and preference measures. The basic idea was to experimentally separate cognitive, and anthropometric and ergonomic factors. One work setting followed the adjustment according to the European standard. The other two settings were individually adjusted by participants. To prove that cognitive factors play a crucial role, participants knew only in one of two (identical) conditions that this was their individual setting. The other individual setting was pretended to be imposed due to another industry standard.

The outcomes were remarkable, as both cognitive and ergonomic factors could be in fact separated and proven to distinctly affect performance as well as ratings of muscular load. As taken from performance results, two identical work settings produced different performance levels, with an increment of 6% in the setting the participants knew they had adjusted themselves. This difference must therefore be cognitive by nature. Performance results were confirmed by preference ratings and ratings of muscular load. The cognitive condition was not only preferred, but lead to the smallest increment of muscular load over the 30-min working period.

However, the present data reveal a strong ergonomic factor as well. If both individual conditions were comprised and compared to the standard setting, a strong disadvantage of the standard was found (speed: 12%; accuracy: 8%). This disadvantage was found to be related to ergonomic factors. Correlations of body measures with physical dimensions of work settings and with ratings of muscular load yielded body height and the length of the upper part of the body as the main criteria of the adopted ergonomic rationale. Thus, it can be assumed that the standard matches the needs of middle-sized users, but disregards participants shorter and taller than the average. The validity of this assumption could not be statistically confirmed, though, as the examined participants were taller than the population average (Kroemer, 1997). Therefore, a post-hoc segregation into a larger and a smaller user group could not be accomplished.

What can be learnt from the study? Answering the initially raised questions, the key results can be outlined as follows: The standard setting, rather disadvantageous with respect to performance and muscular load, does not represent optimal workplace adjustment. In fact, individual adjustment optimizes performance. The rationale users adopt within their own adjustments follows individual body measures. Though ergonomic factors were shown to be weightier for performance, a distinct cognitive factor was also verifiable modulating users' effectiveness.

However, and this accentuates the significance, the findings here might be a substantial underestimation of the situation given in real work environments. The user group examined here does not at all represent the average VDU user in the work force. Participants were young, highly motivated, and healthy with no ex-ante muscular load. Moreover, only short term effects (30 min per condition) of working on-screen were under study. It is thus of high ergonomic interest to validate these findings within a broader user group. Current experiments focus on the adequacy of the standard workplace for VDU users shorter and taller than the average. Moreover, it will have to be examined how users, confronted with acute pains in the back, shoulders, and neck adjust their workplace. Here, it will be very instructive to determine if and to what extent ergonomic and cognitive factors possibly modulate performance and comfort ratings.

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