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Seat Comfort: A Review of the Construct in the Office Environment

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A general overview of approaches to the assessment of comfort relevant to design of office furniture is presented. These approaches include physiological/anatomical, subjective, postural, and performance-based measures. Pertinent literature from other fields is included.

THE MEANING OF COMFORT

Frequent references to user comfort suggest that it represents a consensually held construct that can be manifested objectively. Yet there is no universally accepted operational definition of comfort, since published definitions have reflected the disciplines of the researchers who formulated them. In doing so, researchers have considered such issues as the relevance of a particular dimension under consideration, the sensitivity of the measures to reflect this dimension, desirable regions of response, and the statistical approach underlying the analysis, all of which have been described in greater detail by Sharit and Salvendy (1982).

There is little consensus on whether comfort and discomfort should be regarded as being a bipolar continuum or as composing two experiential dimensions. Hertzberg (1958) first operationally defined comfort as "the absence of discomfort." We have all experienced the positive state of comfort. However, whether office furnishings can induce this state is still open to debate. To a certain extent, the debate becomes entrenched in semantics since a relief from discomfort may be experienced as a positive state of comfort. Discomfort has also been addressed more frequently because its objective correlates are more tangible.

Richards (1980) has suggested that the fact that people do rate their subjective responses across the entire continuum indicates that positive comfort is part of a bipolar dimension that can be attributed to characteristics of design. *Comfort*, unless specified, will be considered in this paper as representing both positive comfort and discomfort. The term *discomfort* will be used when the research under discussion was confined to the assessment of that construct.

The primary definition of comfort in Webster's dictionary (1964) is "the provision of support and assistance." Comfort relevant to office furniture might be viewed as a function of the patterns of physical supports and constraints on the worker engaged in a specific task or tasks. As such, comfort may be represented physiologically, psychologically, behaviorally, and in performance. Consequently, comfort cannot be a meaningful design criterion unless referenced to its

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operational task requirements. For example, the desirable work-surface height for writing differs from the optimum typing work-surface height; the desirable seat-back angle frequently differs if the worker is engaged in conversation or writing. Adjustability is more relevant to certain contexts than to others.

This task referent becomes both more important and more elusive with the dramatic transitions occurring in the information age. There is a trend towards both multitask and task-specific workstations corresponding to developmental trends of information systems. Design of furniture for information centers must also be flexible enough to accommodate future needs due to the rapid change and shorter product life cycles of information systems than for the furniture that supports these systems. For example, flat panel displays may replace CRTs, voice interactive systems may replace keyboarding, electronic data handling may alter storage requirements, and artificial intelligence may transform the nature of white-collar work.

Office workers seldom use only one item of furniture to perform a task, underscoring the need for a systems analysis of interactive workstation design considerations. The seat height is effectively determined by the work-surface height (Burandt and Grandjean, 1963; Floyd and Ward, 1964, 1969; Langdon, 1965). Viewing angles and distances are each influenced by both VDT support heights and pull-out keyboard support distances. Interactions between tasks frequently indicate compromise solutions.

A designer might attempt to minimize the level of discomfort or maximize the level of positive comfort. These aims may conflict. For example, German DIN standards are moving away from workstation adjustments such as keyboard height, ostensibly because people do not use them. Although a fixed-level work surface in conjunction with an adjustable footrest may reduce the number of worst-case situations (assuming that the footrests are used), movement is restricted and the number of possible best-case situations is reduced. Another example is the evidence that keyboard operators experienced fewer physical impairments in the shoulders, neck, and back when the keyboard was much higher than has been traditionally considered acceptable (Hünting, Laubli, and Grandjean, 1980). In the case cited, document holders were not available or were not used, and operators were twisting their heads to read. Although the most desirable solution would be to ensure that document holders are available, that they suit task requirements, and that they are used, it can be seen that an excessive desk height might simultaneously reduce both the number of worst and best cases.

The dual aims of the provision of support and the accommodation for movement may also conflict. Schoberth (1978) attributes the following physiological benefits to movement:

(1) Muscle movement serves as a pump to improve blood circulation.
(2) Afferent nerves send impulses to the central nervous system to maintain alertness.
(3) The spine receives nutrients solely by passive diffusion occurring from changes in pressure caused by movement.
(4) Pressures acting on the spine and tissues are continually redistributed.

Accommodation for these movements frequently curtails the potential for support. Support of one dimension entails a corresponding constraint along another dimension. A contoured seat pan distributes pressures over the buttocks yet limits the ability to shift one's weight. As a desk supports certain postures so does it limit other postures. Decisions must hinge on the extent to which the overall movements are constrained, the task-related movements are supported, and the temporal context is applicable to the design.

In another context, Grandjean (1980b) analyzed automobile seating as a function of person-machine links. The driver's movements are restricted by the requisite hands on the wheel, feet on the pedals, eyes on the road. These postural constraints suggest that the driver should be provided greater physical support and contouring than the passengers. Support for office workers can also be analyzed by linkages. For example, VDT operation, characterized by hands on the keyboard and eyes alternating between the screen and the source document, requires greater support than many other tasks.

In the absence of acceptable comfort standards geared towards the provision for movement and support relevant to specified criteria and contexts, one could presume that as much comfort as possible should be provided regardless of costs. Such an extreme position is not tenable. The lack of an accepted measure of comfort and the formulation of the relevance of comfort to return on investments and cost-benefit criteria have frequently caused comfort to be relegated to a low priority in comfort decision making.

METHODS OF ASSESSMENT

The assessment of comfort may be approached from a number of perspectives. These include physiological/anatomical, subjective, postural, and performance-based approaches.

Physiological and Anatomical Recommendations

The primary impetus for this movement arose from the work of Akerblom (1948). Expert recommendations have been based on physiological measures of comfort, the etiology of pathologies such as back disorders, and the application of available anatomical and physiological knowledge.

Physiological measurement of comfort. Physiological measurement is desirable because it appears to provide an objective corollary of our subjective experience. Research is presently limited in its understanding of physiological parameters relevant to the positive state of comfort and of moderate levels of discomfort frequently characteristic of white-collar work. Physiological levels of comfort may also be a relative rather than an absolute phenomenon. Teichner (1967) has suggested in another context that comfort represents "no optimum or ideal fixed set of physiological conditions but rather . . . optimally varying physiological levels" (p. 502).

Theoretically, measures may pertain to physiological factors that induce the state of comfort (e.g., relative seated pressure distributions) or that represent that state (e.g., the presence of the stress response). Of these, discomfort is more amenable to measurement than is comfort. Schmidtke (cited in Rohmert and Luczak, 1978) has classified the phases of physical fatigue that appear to parallel sequential phases of discomfort. In the first phase, task-specific physiological disturbances can be detected, such as muscle activity (electromyograms), generally appearing prior to one's cognition. In the second phase, disturbances reach a level at which the worker perceives them. This indicates a reaction of arousal and activation (i.e., heart rate, arrhythmia, and EMG of trunk muscles not specifically related to the task). The third phase, characterized by central integration process disturbances, results in nonspecific physiological reactions.

One of the more widely used forms of physiological comfort measurement has been EMGs of large muscle groups relevant to the task. The most ready interpretation of EMGs is in the assessment of fatigue, manifested by an increased amplitude and slowing of the signal (Kadefors, 1978; Petrofsky, Glaser, and Phillips, 1982).

EMGs have also been used to evaluate seat design and postures (Andersson and Orten-

gren, 1974a, 1974b). However, interpretation of EMGs is not without ambiguity. A low level of activity in one muscle group may signal increased activity of other groups; as a consequence of the mechanism by which the human supports a given posture the EMG should measure all groups involved. Muscle activity must be considered in the context of muscle size and task activities. Although needle electrodes are only able to tap single motor units within muscles and are therefore relatively unreliable, surface electrodes that are able to sum over larger areas are located remotely and measure muscle activity of indeterminate volumes. Additionally, different EMG potentials do not necessarily quantify in equivalent manners; the electrical potentials of fibers within a given motor unit contribute linearly, but fiber potentials between motor units do not. Differences in muscle sizes or in force-length relationships of the same muscle in different postures may change the level of forces for a given EMG measure (Kadefors, 1978; Petrofsky et al., 1982). Relief of overall muscle activity may also signal increased pressure on the spine since the muscles appear to assume spinal stresses (Lundervold, 1958).

Another approach entails the comparison of relative stresses acting on the spine. Keegan (1953) and Andersson (1980) have used X rays to examine deviations from the normal spinal curvature with different standing and sitting positions. Corlett and Eklund (1983) devised an instrument that inferred spinal compression from measurements of spinal length while controlled postures were assumed. Using this device, they found significantly greater shrinkage of the spine when subjects sat without back-rest supports. Nachemson and Elfstrom (1970) have described the construction of a needle containing a pressure transducer that is inserted into the intervertebral disc to measure spinal pressures. Although this method has been used successfully (Andersson and Ortengren, 1974a; Hein-Sorenson, Elfstrom, and Nachemson, 1979), it is obtrusive and may be objectionable to subjects. Ridd and Davis (1981) have described a technique that may bypass these issues. A pressure-sensitive pill, swallowed by the subject, emits radio waves and is measured remotely. Spinal pressures are then inferred from these abdominal pressures because of their high intercorrelation. Although this approach has only been applied in an industrial context, it may become a useful design tool in the future.

Despite a long-term interest in seated pressure distributions (Hertzberg, 1958, 1972; Lay and Fisher, 1940) pressures have never been correlated with comfort. It is still not known what specific distributions of pressure are optimal, though general guidelines do exist. Measurements of seated pressure distributions have resulted in design alterations that increased the correspondence between the seat and body contours (Diebschlag and Muller-Limmroth, 1980). Attempts have been made to design manikins that record seat hardness from the seat (Thier, 1963) or with pressure pickups to predict pressures on the user (Kohara and Sugi, 1978). These approaches are problematic at best, if one wishes to account for the diversity of postures assumed by office workers.

Anatomical recommendations. Although there is no "ideal" posture, some postures are more desirable than others, and the incidence of particular positions has been associated with physical discomforts (Burandt and Grandjean, 1963; Duncan and Fergusen, 1974; Hunting et al., 1980), and permanent damage (Keegan, 1953, 1962; Schoberth, 1978). Recommendations are intended to support "healthy" postures, as these are most comfortable over the long term. However, Jones, Gray, Hanson, and Shoop (1961) have shown that subjects have clear concepts of their "best" and "most comfortable" pos-

tures, and that these do not correspond. A person may slump because a reduction of muscle stress is comfortable over the short term, but the increased spinal stresses signal long-term consequences.

The available literature has been fragmented and frequently reflects national orientations. Extensive reviews are, however, available (Ayoub and Halcomb, 1976; Floyd and Roberts, 1958; Kroemer and Robinette, 1968).

The consideration of different criteria for comfort has resulted in conflicting recommendations. Akerblom (1954) has suggested extreme seat depths to maximize support of the thighs, whereas Ridder (1959) has recommended shorter depths as being preferred by more users and also as being desirable for increasing freedom of leg movement and maximizing body leverage. Keegan (1962) has added that it is easier for tall users to adapt to short seats than the converse. A backward seat slope has been suggested to maintain posture (Keegan, 1962) and to increase use of the backrest (Akerblom, 1954), although Mandal (1982) has indicated that the increased thigh-to-torso angle resulting from a forward seat-pan slope improves the lumbar curvature of the spine. Schoberth (1978) has questioned the benefits of forward sloping seat pans because of the general tendency to slump and the inability on the part of more than half of the population to effect a lumbar curve. Floyd and Roberts have suggested that postures associated with sloping seats in either direction "are only comfortable for relatively short periods of time" (Floyd and Roberts, 1958, p. 5).

An emphasis on the importance of movement has resulted in some recommendations that are no longer adhered to, such as the use of noncontoured seat pans. Other recommendations have become standard design criteria, such as lumbar back supports and seat-pan "waterfalls" that slope the seat front in order to reduce thigh compression and to avoid impacting nerves in the popliteal area.

Subjective Assessment

Methodology. Subjective measurements of comfort have been the most frequent form of comfort assessment due to the ease of use and apparent face validity. Typically, these measures are ordinal and have been resorted to in the absence of other measures to assess validity. Methods have usually assessed either the general or localized comfort states of the raters or their preferences among comparable items of furniture or features. Each approach has inherent strengths and weaknesses. Ratings of overall comfort are subject to many influences other than the furniture under investigation. Ratings of comfort in selected body parts may reduce response variability and may also implicate specific design solutions but obscure the overall experience of the user. When attention focuses on particular elements of the design, interactions between these elements and weightings for the relative components of the subjective experience become elusive. Occasionally, several subjective approaches have been used in conjunction to achieve an overall assessment of a group of chairs (Drury and Coury, 1982; Grandjean, Hunting, Wotzka, and Scharer, 1973; Habsburg and Mittendorf, 1980; Shackel, Chidsey, and Shipley, 1969).

It may be preferable to use a smaller number of pretrained testers than a larger sample of untrained subjects. In addition to giving more reliable results, pretrained testers are more sensitive to lower levels of discomfort (Jones, 1969). Hall (1972) indicated that back sufferers are particularly sensitive discriminators of seating comfort. Blindfolds have been used during comfort ratings to avoid confounding with aesthetic attributes (Shackel et al., 1969), but they preclude the use of a task referent. Habsburg and

Mittendorf (1978) reported that aesthetics had no influence on comfort ratings.

Comfort ratings of seats decrease with time, but the slope of this descent varies (Shackel et al., 1969). Jones (1969) found that time to experience the onset of discomfort was a reliable discriminator. The use of subjective methods as reliable discriminators for a given population has already been established. However, just what these assessments represent is not clearly understood. Neither British standards (which are based on anthropometric data) nor expert opinion on projected seating comfort for the general public has been found to predict the actual ratings of lay persons (Shackel et al., 1969). Are the standards and experts incorrect or are users unable to relay their own experiences? Habsburg and Mittendorf (1980) found that raters judged seats more stringently in the personal suitability judgment (for me/not for me) than in their ratings on overall seat comfort, suggesting that their comfort judgment hinged upon the projected comfort of an independent and objective user. Shackel et al. (1969) found that users appear to rate chair features as a set of intellectual concepts rather than as personal comfort factors.

The duration of each test trial required to reliably establish comfort assessments is not known. Wachsler and Learner (1960) found that absolute comfort ratings of seats resulted in the same rank ordering with 5-min trials and 4-h trials. Barkla (1964) found that 5-min ratings of absolute seating comfort were unstable, showed an order effect, and did not correspond with 30-min ratings. The discrepancy between these studies may have been caused by the greater range of seating used in the former study.

The experience of comfort appears to be determined by one's selective filtering of sensory inputs. Comfort is, therefore, a weighted function corresponding to the attendant inputs. Corlett and Bishop (1976), in an industrial context, found that ratings of overall comfort were a function of the number of body parts experiencing discomfort rather than the intensity of these discomforts. Wachsler and Learner (1960) found that ratings of seating comfort were heavily loaded by back and buttock comfort, were somewhat influenced by neck and shoulder comfort, and were independent of thigh and leg comfort.

Assumptions. The use of subjective responses regarding comfort frequently entail four assumptions described by Branton (1969).

First, it is assumed that the respondents are aware of their feelings of comfort. Certainly, individuals differ widely in such awareness.

The second assumption is that feelings of comfort can be verbalized. Branton (1969, p. 210) indicated that postural analysis suggests that comfort is "very primitive and deeply ingrained . . . (and) not readily accessible to introspection and verbalizations." He described an unsuccessful attempt to use a hand dynamometer in a cross-modal attempt to eliminate the need for verbal responses.

The third assumption is that the respondents are able to identify the attribute of the physical environment that is the source of their (dis)comfort. Branton (1969, p. 208) states that the "aim is to find the comfort of the design characteristic rather than the comfort feelings of the person, and the experimenter uses persons as channels of information." The lack of validity of this assumption may widen the gap between the felt sensation and its projection onto a design solution.

Of course, ratings of overall comfort may be subject to multivariate analysis. These methods determine the proportion of the variance in the responses correlated with states of each variable while bypassing the issues. A multifactorial approach may also enable the formulation of cost trade-offs for achieving a given level of physical comfort

(Myers and Marshall, 1980). Although this technique has been used to establish comfort of seating design characteristics (Wachsler and Learner, 1960), the present review of the literature failed to reveal instances of its application to a larger context, such as the office. The rating trial duration should correspond to the expected temporal context in which workers will operate, since the relative weightings of comfort criteria appear to be time dependent (Branton, 1972).

The fourth assumption is that one's sensation of comfort can be maintained in memory sufficiently long to compare it with the comfort sensations resulting from other settings or furniture items. The correspondence between absolute comfort ratings of seats after each 30-min trial and direct rankings of these seats after all eight 30-min trials supports this tenet (Shackel et al., 1969).

Finally, Oborne and Clarke (1973) include the additional assumption that similar verbal expressions represent similar states of experience. They suggest using statements about specific experiences rather than general feelings. For example, ratings of the experience of "sitting in a soundproof room" may be more reliable than ratings of "pleasantness." Descriptions of body parts or body diagrams that localize the ratings of comfort at various body segments have been widely used (Corlett and Bishop, 1976) (Hunting et al., 1980) and may improve the consonance of interpretation.

Postural Measures

An analysis of postures assumed by users may serve as an analytical tool for design. Branton (1969) suggested that the potential sources of bias in eliciting valid verbal judgments indicate that postural analysis is at least as good an index of comfort as are subjective estimates.

One such approach is the determination of "habitual restlessness." These movements may be viewed as falling somewhere between involuntary motor reactions such as heartbeat and breathing and intentional movements, such as those dictated by the task (Jurgens, 1980). Restless movements are presumably associated with attempts to compensate for uncomfortable conditions. Jurgens (1980) also found that directional tendencies of movements can indicate particular design constraints. Branton and Grayson (1967) achieved corresponding results with long-term filming of a few subjects and short-term observation of a larger sample.

However, postural variation does not provide an unambiguous interpretation. Furniture may constrain movements and, as such, represent a poor design solution (Karvonen, Koskela, and Noro, 1962). Postural analysis has been assessed in terms of postural immobilization (intraindividual variations) and homogeneity of postures (interindividual variations) that are a function of the task as well as of the furniture (Laville, 1980). Behavior also tends to enact continuous postural cycles that may occur in 10- to 20-min sequences over a period of several hours (Branton and Grayson, 1967). Postural restlessness varies within and between individuals and is a function of numerous variables other than comfort, such as age, diurnal cycles, time of day, and genetic influences on behavior (Jurgens, 1980).

An alternative approach is the evaluation of those postures that are assumed most frequently with different furniture. Furniture does exert an influence on postures (Floyd and Ward, 1964). Branton (1969) suggested analysis of the intrinsic stability of body postures as a measure of comfort. Postures may also be compared with orthopedic recommendations (e.g., the probability of slump) (Branton and Grayson, 1967; Mandal, 1982).

This form of evaluation may be problematic since the physiological desirability of many positions is either not known or not agreed upon.

Again, this measure is subject to considerable interindividual variation. For example, females appear to assume more erect postures than males (Branton and Grayson, 1967; Floyd and Ward, 1964; LeCarpentier, 1969; Ridder, 1959). The kind of posture is also a function of the task. There appear to be two postures characteristic of office work. During such traditional office tasks as reading and writing, the trunk is supported by leaning the arms on the desk most of the time (Floyd and Ward, 1964) and the backrest is used infrequently (Burandt and Grandjean, 1963; Floyd and Ward, 1964; Langdon, 1965). This posture is evident from a very young age (Floyd and Ward, 1964, 1969; Karvonen et al., 1962). During VDT operation, only 10 to 20% of workers sit in the upright position (Chisvin, 1983; Grandjean, Hunting, and Piderman, 1982). The posture relevant to VDT operation, measured in two separate studies by Grandjean et al. (1982) is characterized as follows: "the trunk is leaning backward, and the neck is bent forwards, the shoulders are held high, the arms are extended forwards and forearms and hands are often high . . .", similar to a car-driver's stance (Grandjean, 1980a, p. 7).

Comparisons of somatic problems associated with different postures and furniture may provide easier design evaluations. Harmon (1951), using the data of Finnegan (1945) claimed to have established relationships between poor school seating and postural, visual, and dental abnormalities in children. Burandt and Grandjean (1963) compared the incidence of physical complaints with postures that office workers select using different furniture and found a correspondence between discomfort and workstation deficiencies.

A simpler criterion is the probability that the operator will use such support devices as the backrest (Branton and Grayson, 1967; Floyd and Ward, 1969). However, Branton and Grayson note that this measure does not indicate whether the supports are not used because of improper design or because they are not needed.

Performance

The societal shift towards white-collar work has resulted in a renewed interest in the relationship between comfort and performance. Although there may be a positive relationship between physical comfort and improved performance in the industrial context its relevance to the office environment is still subject to debate. Can comfort increase performance? Can performance be considered an index of comfort? Magazines replete with advertisements convey an implicit message that comfort is cost-effective. Union activity and pending legislation within the U.S. are underscoring this interest.

Certainly the association appears to underlie an intuitive logic: when we feel comfortable, it is easier to work. Office workers consider comfort of primary importance (Springer, 1982), and an office survey (Louis Harris and Associates, 1980) found that the majority of office workers feel that increased comfort would enhance their productivity. It appears likely that increased comfort enhances performance along a continuum corresponding to situational factors. However, these variables are not well understood.

VDT operation may represent one extreme along this continuum in that it appears to be more stressful than other work (at least at the clerical level). However, interpretation of research in an actual work setting is problematic because of numerous factors other than furniture design that influence comfort in this context (Canadian Labour Congress, 1982; Smith, Cohen, and Stammerjohn,

1981). Substantial improvements in VDT performance have been achieved with ergonomically designed workstations in experimental settings (Dainoff, Fraser, and Taylor, 1982; Springer, 1982), although performance differences from the latter might have resulted from factors other than the furniture.

The elusive relationship between performance and comfort is partially due to complexities inherent in the measurement of office performance. Office workers are information handlers who create symbolic end-products. The farther up the organizational hierarchy one ascends, the more abstract this end-product becomes. Professionals and managers incur the greatest cost investment of the office, but the performance of these individuals is the most difficult to measure. The literature on productivity differences among various categories of furniture users has been locally defined and generally has focused on evaluations of the open-plan, the traditional office, and the so-called bull pen, which contains many workers in one space. Performance differences between these settings are related to their flexibility, support of communication, and distractability, rather than physical comfort.

Performance appears to be a relatively insensitive index of comfort. Performance variability and error rate may be somewhat more sensitive than mean level of performance (Schmitdke, cited in Rohmert and Luczak, 1978).

Organizational productivity involves more than a strict interpretation of output per unit of work time. Absenteeism, turnover, and medical costs associated with health problems exact substantial costs. Hunting et al. (1980) found a relationship between the incidence of doctor visits and constrained postures, which suggested a need for improved workstation design. However, these indices are often problematic because of the many variables impinging on results. A large sample size would not necessarily separate these factors. Employee turnover could be more relevant to management style, for example, than to any furniture acquisition that was a manifestation of that style.

CONCLUSION

Although there exists substantial research in the field of comfort, these investigations have generally occurred in a microcosm. Little insight is available into the meaning of comfort, whether it represents an accessible construct with universally held connotations, the translation of the construct into design criteria, or the relevance of comfort to such contexts as performance.

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