Lecture 2-2: Workplace Design

ENVD 5380 Human Factors/Ergonomics in Environmental Design
(ENVD 5311-001 Design & Ergonomics)
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Work Spaces (Sanders, Ch.13)

- Work space envelopes:
  - It means the 3 dimensional space within which an individual works. (e.g. the space within which the hands are used.)
  - This topic is related to physical space and arrangement.

- Related to the concept of work space envelopes:
  - Out-of-reach requirements
    - The distances required to prevent a person from reaching something (usually hazardous) over a barrier.
  - Clearance requirements
    - The minimum space needed to move through a tight space or perform work in a confined area.

Effects of direction of reach

- Effects of direction of reach and presence of restraints on work-space envelope.
  - Results based on the study (Roth, Ayoub, & Halcomb, 1977).
  - They measured the functional arm reach of subjects at various lateral angles from a dead-ahead seated position (from -45° left to +120° right) and at various levels (ranging from -60° to 90°) from a seat reference point (SRP).
  - Measurements were taken of the "grasp-center" reach point at 114 such locations, under both restrained and unrestrained conditions.
  - In the restrained conditions
    - The shoulders were held back against the seat back.
  - In the unrestrained conditions
    - The subjects could move their shoulders.
  - The type of restraint can influence the functional arm reach.
    - Based on study of comparing three types of vehicle seat restraint (Garg, Bakken, and Saxena, 1982).
    - The less the restriction, the further the reach.

- Effects of manual activity on work-space envelope.
  - Grip strength and the dynamic reach envelope (= kinetosphere)
  - Hand grasp: thumb tip measurement are about 2 in or more shorter than finger tip measurements (Bullock, 1974).
  - Different hand grasp actions influence the space envelope (Dempster, 1955).
    - Dempster’s (1955) study involved grasping a handlelike device with the hand in 1 of 8 fixed orientations (supine, prone, inverted, and all five spatial angles). Photographic traces of contours of the hand and the movement.
    - Kinetosphere is developed for each grasp, showing mean of three angles: top (transverse), front (coronal), and side (sagittal).
    - The shaded areas indicates the various types of hand grips could most adequately be executed by people.
Effects of apparel

- Effects of apparel on work-space envelope.
  - The apparel worn by people can restrict their movements and the distances they can reach, and can influence the size of the work space envelope.
  - Winter jackets restricted reach by 2 in (Sanders 1977).

Work-space envelopes for standing personnel

- Standing reach is a matter of body equilibrium
  - The reach envelop will be modified by any factor.
  - Reach is diminished if a weight is carried in the reaching hand or if an obstacle is placed behind a person that limits counterbalancing activities.
- The Zone of Convenient Reach (ZCR)
  - ZCR as the space in which an object may be reached within arm’s reach. (Pheasant, 1986).

Work-space envelopes

- Discussion of Work-space envelopes
  - The reasonable limits of such space are determined by "functional arm reach"
    - Functional arm reach is influenced by such variables as:
      • Direction of arm reach
      • The nature of the manual activity
      • The use of restraints
      • Apparel worn
      • The angle of the backrest
      • Personal variables such as age, sex, ethnic group, and handicaps.
    - Design such space for the 5th percentile of the using population, thus making it suitable for 95 percent of population.
    - Consider special populations the design of the work space requires particular attention.

Design: Out of reach

- Out of reach requirements
  - Things not to be touched (e.g. children play room)
  - Design space, a barrier of some height is place between the person and the object.
  - How far? It depends on:
    • 1) the height of the barrier
    • 2) the height of the object.
      - Example: Thompson (1989) using males of the 99th percentile in stature measured maximum reach for various combinations of these two variables (see Sanders, Figure 13-8, p. 436).
Design: Out of reach

Design: Clearance

• Clearance requirements
  – Move through, work in, or just fit into spaces.
  • Example: some unusual circumstances, such as the sleeping space needed by long haul truck drivers.
  • Sanders (1980) reports the dimensions of the preferred and prostrate (face-down) postures of the 95th percentile drivers.

Design: Clearance

Design of work surfaces

• Work surfaces
  – Within the envelope of a workplace, specific design decisions need to be made about various features of the workplace, the location and design of work surfaces
    • e.g. surface involved benches, desks, tables, etc.
  • Examples of the work surfaces:
    – Horizontal work surface area
    – Work surface height: seated
    – Work surface height: standing

Design: Horizontal work surfaces

• Horizontal work surface area
  – To be used by seated and “sit stand” should provide for manual activities to be within convenient arm’s reach.
• Work surface area definition and dimensions
  – Normal area and maximum area (Barnes, 1963)
    • Normal area:
      – The area can be conveniently reached with a sweep of the forearm while the upper arm hangs in a natural position at the side.
    • Maximum area:
      – The area could be reached by extending the arm from the shoulder.
  – Work surface area with the dynamic interaction of the movement of the forearm as the elbow is moving (Squires, 1956).

Working Area (NWA or MWA)

• Normal working area (NWA)
  – NWA allows hand motion to be made in a convenient zone with normal energy expenditure.
  – Area described by the arms and hands with the elbows flexed at ~90 degree.
  – Typically, the comfortable limit of outward rotation is about 25 degree.
• Maximum working area (MWA)
  – MWA is the intersection of the ZCR with the horizontal surface such as table or bench.
Design: Horizontal work surfaces

- Slanted surfaces for visual tasks:
  - They found that subjects using slanted surfaces (12° and 24°) had better posture
  - reported less trunk movement, less fatigue, and less discomfort than when using horizontal surfaces.
  - Bridger (1988)
  - Slanted surfaces 15°
  - Less bending of the neck, more upright trunk

Seated work surface height and nature of the task

- Work surface height: seated
  - The surface height should be adjustable to fit individual physical dimensions and preferences.
  - The work surface should be at a level that places the working height at elbow height.
  - The work surface should provide adequate clearance for a person's thighs under the work surface.

Design: Work surface height

- Work surface height: standing
  - The surface height is related to the nature of task.
  - Heights for precision work, light work, and heavy work as related to elbow height (Grandjean, 1988)
    - For light and heavy work are below elbow height
    - For precision work is slightly above elbow height.
Design Ergonomic Chair

- Why an ergonomic chair?
  - The average office loses over $7300 per employee per year in poor productivity and medical and workers' compensation claims (the bureau of labor statistics).
  - Over 50% are low back injuries. Poor chair design contributes to poor seated posture which plays a major role in these injuries (e.g. secretary back syndrome).
  - Musculoskeletal discomfort (Ong et al., in work with computers, 330-337, 1989)
    - Survey of 672 full-time computer users complaints related to poor ergonomic furniture, including the chair.
  - Musculoskeletal discomfort (Ignatius et al., Journal of Human Ergology, 22, 83-93, 1993)
    - Survey of 170 women typists working at computers, Mismatch between chair height and desk height and poor furniture design related to symptoms.

Myths of ergonomic seating

- Ergonomic seating always requires a single, cubist (90 degree upright) postural orientation that is independent of the user's task (Dainoff, 1994).
- You can judge how ergonomic a chair is by briefly sitting in it.
- Users should be able to adjust everything.
- Users don't need training on how to sit in a chair (Dainoff, 1994).
- One chair design will provide the best fit for all users.

Principles of ergonomic seat design (Sanders, 1993)

- Promote Lumbar Lordosis
  - Definitions:
    - In standing, lodotic inward arch: the lumbar portion of the spine (the small of the back, just above the buttocks) is naturally curved inward (concave).
    - In sitting, Kyphotic outward bend (convex). Lumbar kyphosis results in increased pressure on the discs.
  - Reclined postures often are preferred (Grandjean, 1988).
  - In unsupported sitting or forward leaning the lumbar spine may be in kyphosis, which is undesirable.
  - During supported sitting the lumbar spine should be maintained in lordosis by an adjustable lumbar support.
    - The use of a 2 inch thick lumbar support had a impact on maintaining lumbar lordosis with a seat backrest angle of 90 degree. When the backrest angle was reclined to 110 degree, the lumbar spine resembled closely the lumbar curve of a person standing (Anderson et al. 1979).
    - A forward-tilting seat produce a more relaxed posture (Mandal, 1985).
  - Lordotic effect of forward-tilting seats was small and depended on other factors such as seat height and table top slant (Bendix, 1986).

- Minimize disc pressure
  - Lumbar disc pressure varies with back posture and the load in the hands (Nachemson, 1974).
  - Unsupported sitting in an upright, erect posture (forced lordosis) resulted in a 40 % increase in pressure compared to standing (Nachemson& Elfstrom, 1970).
  - Unsupported sitting in a forward slumped posture increased pressure 90% compared to standing (Nachemson& Elfstrom, 1970).
  - Use of a reclined backrest has an effect with reductions in pressure by reclining backrests from vertical (90°) to 100 to 110 ° . Use of a lumbar support reduces disc pressure as does the use of arm rests. (Anderson, 1987)

Principles of ergonomic seat design (Sanders, 1993)

- Minimize static loading of the back muscles
  - Back muscle pain
  - Backrest angle and muscle activity:
    - Muscular activity as measured by electromyography (EMG) is similar when standing or sitting. EMG activity decreases when sitting in a forward slumped posture, even though maximum pressure on the discs (Anderson, 1987).
  - A reduction in muscular activity in the back when the backrest was reclines up to 110 degree (Anderson, 1987).
### Principles of ergonomic seat design (Sanders, 1993)

- **Reduce postural fixity**
  - The problems of postural fixity, sitting in one position for long periods without postural movement were found (Grieco, 1986).
  - Postural fixity promotes static loading of the back and shoulder muscles, restriction in blood flow to the legs, discomfort.
  - Chair design can reduce postural fixity some by allowing the user to rock in the chair and assume a variety of postures.

- **Adjustment features for an ergonomic chair**
  - Seat height
  - Backrest height
  - Ability to turn while seated
  - Back tilt adjustment
  - Adjustable arms
  - Seat tilt adjustment
  - Ability to lean back
  - Ability to track posture changes
  - Carpet casters/hard floor casters
  - Intuitive, easy to use control

### Ergonomic chair recommendations

- **Seat height and slope**
  - Minimum range of 16 to 20.5 in based on a compressed seat (ANSI)
  - 5 to 15° forward tilt to 5° backward tilt (Lueder, 1986)

- **Seat depth and width**
  - Chairs depth should not exceed 16.8" and the width of the seat surface be not less than 15.7" (Grandjean et al, 1973).
  - Seat depth: 15 to 17 in (ANSI)
  - Seat width: 18.2 in (ANSI)

- **Contouring and cushioning**
  - Seat cushion thickness range from 11.5 to 2" (Lueder, 1986).

- **Seat back parameters**
  - Seat back angle: a minimum range of 90° to 105° with the seat pan, up to 120° (ANSI)
  - Seat back width: at least 12" in the lumbar region.
  - Seat back height: a minimum of 19.5" (Lueder, 1986). As a backrest reclines, the lumbar support moves upward relative to the lumbar spine (Anderson, 1987).
Dynamic vs. static sitting

- Dynamic vs. static sitting study (Van Dieen et al., *ergonomics*, June, 2001)
  - They tested 3 chairs (fixed angle, dynamic angle A, and dynamic angle B). Subjects worked for 3 hours on CAD, word processing, and reading tasks. Measured spinal elongation, neck posture, back EMG.
  - Spinal elongation significantly greater for dynamic chairs.
  - Neck posture unaffected by dynamic sitting.
  - Back EMG depends on the task.

Effects of a chair headrest

- Effects of a chair headrest study (Monroe et al., 2001, proc. HFES, 1, 1082-6).
  - Studied effects of a reclined posture with headrest on typing.
  - Found significantly less muscle activity with this posture for:
    - Neck (>35% reduction)
    - Back (>34% reduction)
  - Found no differences in typing accuracy.

Workstation evaluation

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Assignment # 2 due (7/20 Tue)

- Assignment # 2 (Anthropometry for ENVD)
  - Write about “relation of anthropometric theory and data application (interior design) or ENVD reference standards”.
  - Format:
    - a single space, 5-6 pages, 12 fonts,
    - Include text citations and references (APA style).
    - Should incorporate at least 1–2 references from professional journals.

Discussion

- The design of work space includes:
  - The work envelope
  - Work surfaces such as desks, tables, etc.
  - Task lighting as well as layout/work area
  - Spatial configuration of the physical work area
- Bias thoughts in environmental design (i.e., built environment, interior design, etc.)
- Related to the subject of the design work places, what are the examples of work situations for environmental design were not well designed?
- Related to the subject, what are the good examples of environmental design applications in environmental design (i.e., interior design)?

Assignment # 2 due (7/20 Tue)

- Contents
  - Title and your name
  - Introduction
  - Objectives
  - Method
  - Findings
  - Conclusions/Discussions
  - References
- Presentation in Power point (Tuesday)
Reading

- Reading assignments:
  - Sanders (1993), Ch. 14