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Movement times for a seated operator moving within and outside the Zone of Convenient Reach

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ABSTRACT

An experiment was aimed at determining the effect of the location of the movement on the movement time taken. The movements were made within the normal working area (NWA), zone of convenient reach (ZCR) and outside the zone of convenient reach. The latter movements required trunk movement to reach the movement zone. It was found that movement time (MT) was dependent only on Fitts' Index of Difficulty (ID) for movements within NWA and ZCR, but was also dependent on the amplitude of the movement when outside the ZCR, where trunk motion was required. Significant differences in MT occurred between each movement zone. Movements between NWA and ZCR zones were not significantly different in time to those within these zones. Times for movement between the NWA and outside the ZCR were not different to those made outside the ZCR.

Relevance to industry: Times for making movements are dependent on the region forward of the person in which the movements are made. When making movements outside the zone of convenient reach, where the arm is fully extended, trunk movement is required and movement times are increased.

1. Introduction

For a seated operator doing assembly work, there are several areas of the workbench that are of importance in design for location of trays and components for the assembly task. These important areas are the Zone of Convenient Reach (ZCR) and the Normal Work Area (NWA) (Pheasant, 1986). The two areas for working are defined with the trunk upright. For the NWA the arms are in a comfortable arrangement with no excessive extension or straightening and for the ZCR the arms are fully extended. Typical dimensions for the NWA and ZCR are given by Pheasant (1986) for 5th, 50th and 95th percentile males and females. When working within and between each of these areas, the body movements required of a person are different. Within the NWA, arm movements may be made with a 'natural' movement as there is a comfortable movement of the arm, with extension about the elbow and upper shoulder joint. Between the NWA and ZCR, the arm becomes more extended and arm comfort may be reduced. Reaches outside the ZCR require the arm to be fully extended and it becomes necessary to use trunk motion in order to move the hand to further distances.

Few studies of movement time have been reported where there is more than a single body component involved in making the movement as, for example, when reaching to an object that is out of normal reach, requiring both arm and trunk motion. An example is that of Bonnetblanc (2008) who studied reaching movements of participants when standing at a workbench. As far as we can determine, only the research of Bonnetblanc (2008) has reported movement times for reaching between the different zones of movement. Two reaching distance conditions were used: a 'control' condition where the target was 100 mm in front of the participant and a 'distance' condition where the starting point was 300 mm to the front. In all cases, the amplitude of movement was 300 mm. The control condition required only an arm movement, whereas the further distance required both an arm and trunk movement of the standing participant.

The results of movement time (MT) are shown in Fig. 1, plotted as dependent on Fitts' Index of Difficulty (ID), where $ID = \log_2(2A/W)$; A is the movement amplitude and W is the target width (Fitts, 1954; Fitts and Peterson, 1964). Bonnetblanc noted that the gradient of the relationship between MT and ID increased as the number of degrees of freedom introduced in the task (arm and trunk coordination) increased. Regressions of his data gave,

$$MT(arm) = -330 + 124\,ID$$

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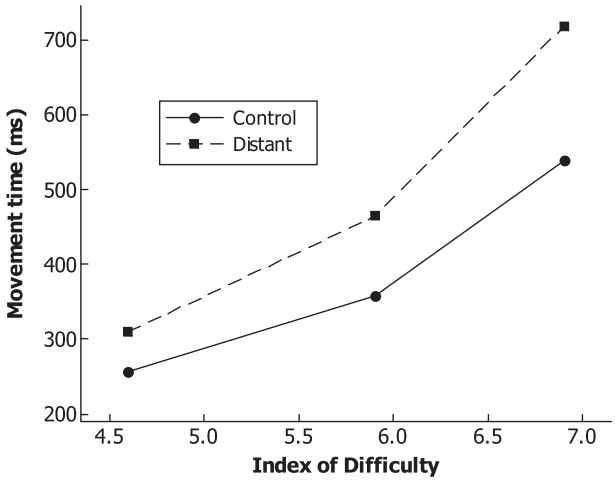

Fig. 1. Movement time data of Bonnetblanc (2008) with standing participants. The control movement was for an arm movement, whereas the distant movement required both arm and trunk movement.

$$MT(arm + trunk) = -499 + 172\ ID$$

In making reaching motions beyond the ZCR, and thus extending the usable workspace, it is necessary to use additional body motions apart from the arm motions. These may include hip flexion, trunk rotation and scapular rotation. It is the summation of these possible components that leads to the hand reaching an object outside the zone of normal reaching. Studies have been reported of the way in which these component motions are summed in order to produce the reach (Kaminski et al., 1995; Ma and Feldman, 1995; Saling et al., 1996; Pigeon et al., 2000; Rossi et al., 2002). The overall effect of the combination of body motions is to provide a hand motion path that is generally close to linear between the starting location and the required end position.

Somewhat surprisingly, there has been no information published on the differences in movement time between the various zones of reach with which a worker has to move in a seated manual assembly task. Thus, the aim of the present experiment was to investigate the movement times within and between several of the movement zones. The zones considered were (i) within the NWA, (ii) the region between the NWA and the ZCR, (iii) outside of the ZCR but within reach capability of arm plus trunk movement, (iv) starting within the NWA and moving to the region between the NWA and ZCR and (v) starting within the NWA and moving outside of the ZCR. It is considered that these movements will cover the range of movements likely to be made in manual assembly tasks with a seated worker. On the basis of previous research it is hypothesized that when trunk motions are required to reach outside the ZCR, the movement times will be longer than within zones where trunk motion is not required.

2. Method

2.1. Participants

There were 22 males and 14 females in the experimental group. Ages ranged from 18 to 25. All were right-handed and had no self-reported musculoskeletal or visual problems. Participants were fully informed of the purpose of the experiments and took part under the ethical guidelines of the City University of Hong Kong.

2.2. Design

Participants were seated comfortably on an adjustable chair at a fixed bench and the chair height was adjusted so that the elbow was about 15 cm above the bench height. To determine the Normal Work Area (NWA), the participant, with trunk held vertically and the elbow flexed to about 90°, made a sweeping movement marking with a hand-held pen a region on paper attached to the bench. This was done with the two arms moving symmetrically outwards as outlined in Pheasant (1986). The Zone of Convenient Reach (ZCR) was then determined in the same manner, but with the arm outstretched, scribing a circle on the paper attached to the bench. The NWAs and ZCRs thus obtained for each individual participant then allowed for the different arm lengths and statures of the participants. As noted in the following, the target locations for each participant were made relative to their individual marked areas of NWA and ZCR. A diagram of NWA and ZCR and typical target locations is shown in Fig. 2.

The experiments, and the corresponding analyses, are described separately due to the differences that exist between the ID and amplitude conditions when the movements were made within a given zone (NWA, ZCR, Outside the ZCR). The same set of experimental conditions of ID and amplitude were able to be used when moving within a given zone, but movements between different zones (such as from the NWA to outside the ZCR) required different amplitudes of movement, although the same ID values were used. In the case of movements outside the ZCR, trunk movements were required to reach the extended distance of the movement. The different experimental conditions were performed by participants in a different random order for each participant. The whole study took about two hours. Each experiment took approximately one hour to complete, with participants allowed rest when requested.

2.3. Experimental Condition 1: movements within zones - NWA, ZCR and outside of the ZCR

2.3.1. Target locations

Typical target locations relative to the participant-defined movement zones are shown in Fig. 2. The nearest target was

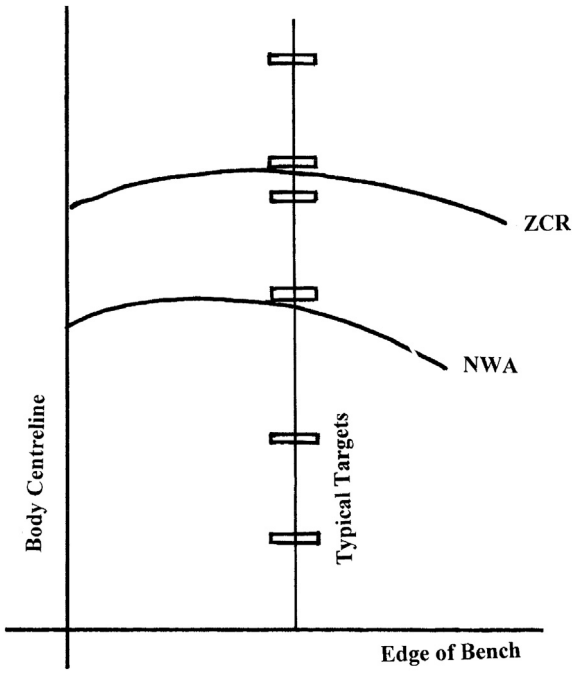

Fig. 2. Target locations within the NWA and ZCR zones and outside the ZCR zone. Targets were located so that movements were approximately in the line of the shoulder point. Typical target locations are shown.