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The effect of age on the hand movement time during machine paced assembly tasks for female workers

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ABSTRACT

The share of older adults in the workforce is increasing in many countries. In the manufacturing industry a high proportion of assembly tasks are machine paced. Previous studies have shown that older adults tend to have longer movement times than younger adults when working at a self-selected pace. However, it is unclear whether older adults can obtain the same hand movement time as a younger group when performing machine paced work at the assembly line. In the current study, 10 older and 10 younger female participants performed simulated light-duty assembly tasks during which the hand movement times were recorded. The results showed that the older participants were capable of working at the set pace and there was no significant difference between age groups in hand movement times (989.9 msec vs. 986.6 msec, $p = 0.5647$). A likely explanation to the results is that the older participant had to work closer to their physical limits or capacity in order to compensate for the age effect on movement time.
Relevance to industry: This study provided some preliminary quantitative data describing the hand movement time for younger and older female adults during machine paced assembly work. The results showed that age did not have a significant effect on hand movement time. Such results may help in adapting workplaces and work tasks to accommodate the needs of an aging workforce.

1. Introduction

Workforce aging is an important labor market trend in many countries. In the U.S. in 2000, 9.9% of the workforce was age 55 or older and this number is projected to grow to 15.3% by 2020 (Toossi, 2002). In Europe, when all the other workforce age groups have a decreasing trend, the age group 55–64 is expected to increase by 16.2% between 2010 and 2030 (Ilmarinen, 2012). In Germany, the percent of people who still work in the age group of 55–64 increased from 41.4% in 2004 to 51.5% in 2007 (BPB, 2008). In general, movement control declines in older adults (Ketcham and Stelmach, 2004). As people age, the physical body strength gradually decreases (Gall and Parkhouse, 2004; Garg, 1991; Roos et al., 1999), peak movement velocity is reduced (Bellgrove et al., 1998; Cooke et al., 1989), and the variability of the end-of-point position for the same movement and the variability of the kinematics parameters increases (Cooke et al., 1989; Walker et al., 1997). In terms of the movement time, the older adults require on average a 30%–60% longer time than younger adults for the same task (Welford, 1977). The time difference between young and old, however, varies greatly from one task to another. Ketcham et al. (2002) found that the movement time was 76% and 98% more for point-to-point movement with moving distances of 9.6 cm and 19.2 cm, respectively, for the older adults (mean age = 68), compared with the younger group (mean age = 23). In a grip task (Bennett and Castiello, 1994), the movement times of older participants (mean age = 65) were 17% longer than those of the younger participants (mean age = 22). For drawing pictures and writing words, the older adults (mean age = 71) were 30% slower than the younger adults (mean age = 21) (Amrhein and Theios, 1993). It should be noted, however, that all these movements were either made as fast as possible or at a self-selected pace.

Despite increased automation in manufacturing industries, manipulative manual tasks are still common in many job settings. Among these manual tasks, some need to be performed at a certain pace, such as jobs on machine-paced assembly lines. In general, however, time standards for machine pace work does not incorporate special allowances for elderly workers, but are based on average workforce. Given the results of the studies mentioned in the previous paragraph, it seems that older adults need longer

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movement time when they perform the manual tasks on assembly lines without external time pressure. However, it remains unclear whether older adults can keep the movement time the same as the younger group under time pressure.

The goal of the current study was to examine age effects on hand movement times under machine paced assembly work for female workers. It was hypothesized that adults older than 55 years would require a longer time to perform manual tasks compared with younger adults due to their impairing performance capability and ability to follow the work pace.

2. Method

2.1. Participants

Twenty female participants with no history of or current upper extremity musculoskeletal disorders participated in the study. Participants were divided in two age groups in this study. The younger group consisted of ten participants whose age ranged from 18 to 28 years (mean age = 25.2, S.D. 3.9), while the ten participants assigned to the older group had an age range from 55 to 65 years of age (mean age = 61.7, S.D. 4.3). The experimental protocol was approved by the local Institutional Review Board.

2.2. Apparatus

A simulated workstation of a low intensity assembly task with repetitive motion was built in the laboratory. Low-intensity tasks were defined as those with an intensity level less than 20% of the maximum voluntary contraction for the trapezius muscle activation level (de Looze et al., 2009). A wooden board with 15 vertical dowels was placed on the table in front of the participants. The dowels were coded in five different colors. Five bins containing same color-coded washers were placed on the table with varying distances from the wooden board. The assembly task included retrieving a washer from a bin and slipping it on a dowel of the same color (Fig. 1).

According to Fitts' law (Fitts, 1954), movement time is proportional to the index of difficulty (ID) of a task defining as 2D/W, where D is the distance from the starting point to the center of the target, and W is the width of the target. In the current study, the inner diameter of the washers was 18 mm and the outer diameter of the dowels was 10 mm. Therefore, the width of the target area was 8 mm (the difference between the inner diameter of the washers and the outer diameter of the dowels). The distances between the bins and the dowels were set in a way so that the ID approximately ranged from 5 to 7. In order to represent the machine paced work at an assembly line, a metronome was used to control the upper boundary of the time of the assembly task cycle.

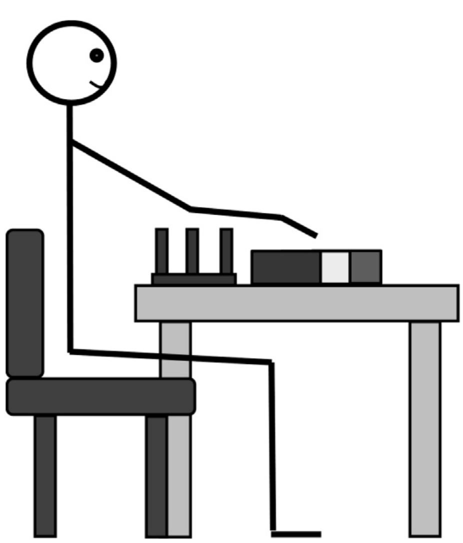

Fig. 1. An illustration of the experiment setup.

An active motion tracking system (Optotrak Certus System, Northern Digital, Ontario, Canada) was used to capture the movement of the participant's right hand during the assembly task. The position of the metacarpophalangeal joint of the middle finger (MCP3) of the right hand was reconstructed from a marker cluster placed on the right hand with a 100 Hz sampling rate.

2.3. Experimental design

The independent variables in this study included AGE (between-participants variable) and ID (within-participants variable). There were two levels of AGE – younger and older, and five levels of ID ranging from 5 to 7 with 0.5 increment intervals. The dependent variable was the movement time from picking a washer to slipping it on a dowel.

2.4. Procedure

Before the experiment, each participant was given instructions for the assembly task. After the participant sat on the chair, the table height was adjusted to the elbow height of the participant and the marker cluster was attached on the right hand of the participants. The participant was given 5 min to become familiar with the assembly task. During the experiment, the metronome was set to 2 s per beat, which was determined using the methods-time measurement (MTM) based on movement distance, load on the hand, and task nature (Chaffin, 1999). In the pilot test, it was confirmed that the 2-s cycle time derived from MTM was sufficient to complete an entire assembly cycle without substantial extra time for resting. Each participant performed eight 10-min trials, taking a one-minute break between trials. In each 10-min trial, participants picked a color-coded washer from a bin in turn and slipped it on a matching-color dowel using the rhythm of the metronome.

2.5. Data processing and analysis

The movement time of the right hand from bin to dowel in each cycle of the assembly task was extracted for each trial from the kinematics data. The ID of each movement was grouped by a 0.5 interval from 5 to 7. The mean movement time was calculated for each trial and each ID. Preliminary statistical analysis did not show a significant trend for the movement time in time sequence. Therefore, the effect of fatigue was not further analyzed. Analysis of variance (ANOVA) was used to examine the effect of AGE, ID and their two-way interaction on the movement time and its intra-participant variability. A balanced two-stage nested model with participant nested within AGE was employed in SAS 9.1 (SAS, Cary, USA). A p-value of 0.05 was used as the criterion for the significance.

3. Results

The results showed that the average movement time from the bins to the dowels during the assembly task was 989.9 (96.7) *msec* for the older group and 986.6 (111.6) *msec* for the younger group. In accordance with Fitts' law, the movement time increased from 853.3 (197.1) *msec* to 1059.0 (95.7) *msec* when the ID (index of difficulty) increased from 5 to 7 (Fig. 2). ANOVA showed that only ID