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Movement strategy and performance in a high-volume order picking workstation

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Abstract. The design of a work station generally prescribes a global movement pattern of the operator, but also leaving some degrees of freedom regarding movement strategy. For a specific order picking work station, we studied the movement strategies, the underlying factors and its impact on performance. Eight subjects performed a task comprising, the picking and placing of an object and pressing a button in eight conditions varying in product weight, movement direction (left vs. right), and placing distance. Movements were analyzed and cycle times were obtained from video-recordings. We observed various types of strategy regarding hand use and global placing mode (reaching vs. placing). The different strategies did not show clear relationships with performance (in contrast to the various work place factors). Ergonomically spoken, the fact that the workstation allows movement variation without loss of performance, is favorable.

Keywords: movement strategy, physical load, body posture, order picking, human performance

1. Introduction

In many sectors of industry, the continuously increasing degree of mechanization and automation drastically affects the work content of operators on the shop floor. This holds true for the order picker in automatic warehouses. Instead of moving into the warehouse to pick products out of racks according to an order list, he (she) may now stand relatively still in a specifically designed stationary work station, picking products out of product bins and placing them into order bins.

These picking stations are typically designed to facilitate the handling of large quantities per hour. Ideally, materials and equipment are placed within reach in order to limit time-to-contact and prevent awkward body postures (Bosch *et al*. 2008).

Engineering and ergonomic guidelines and tools may give support to designers of such work stations. However, one factor potentially affecting both performance and health risk, may remain 'out of consideration, namely the human movement strategy. Any design of a work station prescribes a global movement pattern required to perform the task, but will also leave some degrees of freedom with regard to body kinematics. In the stage of work station design, the potential variation in movement strategy and its impact on performance and health risk often remains questionable. (Park *et al. 2005*)

In the present experimental study we examined movement strategy and its effect on performance in a high-volume order picking task. The research questions were: (1) which differences in movement strategy can be discerned, (2) how are these affected by product weight, distance and direction, and (3) how do these strategy differences relate to performance?

2. Methods

2.1. Subjects

Four males and four females participated in the experiment. They all were familiar with order picking but had no specific experience related to the picking station that was used in the present experiment. The average stature of the subjects was 1.74 m (sd, 0.11 m), ranging from 1.58 to 1.92 m. [*]All subjects were right handed.

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2.2. Task

The subjects performed a task on a high-volume order picking work station (Figure 1). Initially, the subject was standing in front of the product bins on a height adjustable platform which was ergonomically adjusted to the anthropometry of each individual.

The first step was to pick one product out of the right or left central product bin, depending on the location of the order bin (right or left).

The second step was to move to one of the order bins and place the product into it.

The third step was to press a button in order to confirm the placement of the product in the order bin. The buttons are located on the edge of the picking station near the order bins.

After standardized instructions and prior to the experiment, subjects practiced the work for 10 minutes. Subjects practiced picking, placing and pushing the button in 4 set ups, containing all experimental variables (product weight, order bin distance and order bin direction).

Each subject performed the same task under different conditions varying with respect to product weight (light (0.2kg) vs. heavy (3.0kg)), movement direction (order bin on the left or right location) and distance (order bin in inner or outer position).

In the condition with the light products 30 product cycles were performed and with the heavy products 20 product cycles, which implied that each task on average lasted between 90 and 150 seconds. After the ending of the task in each condition, 5 minutes of rest were applied before starting the task in the next condition. The order of the conditions was randomly varied across subjects

Subjects were asked to maintain a constant pace , which could be regarded as normal in case of an eight hours working day. Product must be placed in the order bin, not thrown. No further instructions with regard to movement technique were provided.

2.3. Measurements

To identify relevant characteristics of the movement strategy, movement recordings were made during the experiments. These recordings were visually inspected in order to find the typical movement patterns showing variation between or within subjects. After defining types of movement strategy, the prevalence of these were determined for each condition. Moreover, we determined the number of within-subject changes in movement strategy across the series of movement cycles, compared to the previous cycle, in each condition. The cycle time (as a performance indicator) was deduced from position data using the MVN inertial motion capture system by XSens (Roetenberg et al. 2009).

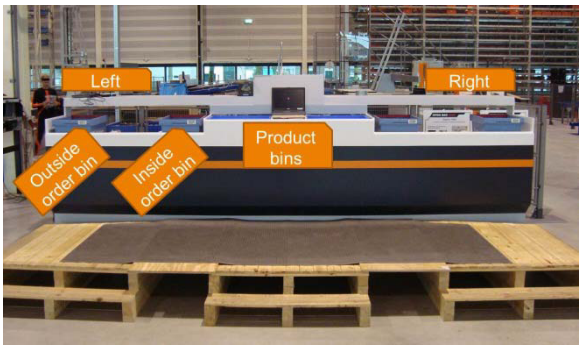

Figure 1. The high-volume picking stations (5 meter wide) showing the two product bins and the inner and outer order bins on the left and right side, and the confirmation button (in front of each order bin.

2.4. Statistics

GLM repeated measures with a Bonferoni correction was used to test for main effects. P-values < 0.10 are discussed as trends and $p<0.05$ as significant differences.

3. Results

3.1. Types of movement strategy

Two main strategy characteristics were defined, namely ‘hand use’ and ‘global place mode’.

With regard to hand use the following parameters were defined for further analysis;

- hand use during picking: left (L), right (R) or both (B)
- hand use during placing: left (L), right (R) or both (B)
- hand use during whole process of picking, placing and pressing the button; e.g. RRR, RRL, RLL, and so on (Overall strategy)

During placing, we observed two typical strategies. One strategy concerned moving all the way to the order bin (until ‘standing in front of it’) before placing the product into the bin (moving strategy). The other strategy was to move not until the bin and placing the product into the bin by reaching (reaching strategy).

3.2 Hand use in picking and placing

During picking participants used the right hand in 63% of the cycles, the left hand in 32% and both hands were used in 5% of the cycles. Heavy products were picked with both hands for 10% of the cycles while light products were almost never picked with both hands. For left and right hand picking there was a small interaction trend between product weight and direction (p = 0.099 and p = 0.090, respectively) (see figure 2).

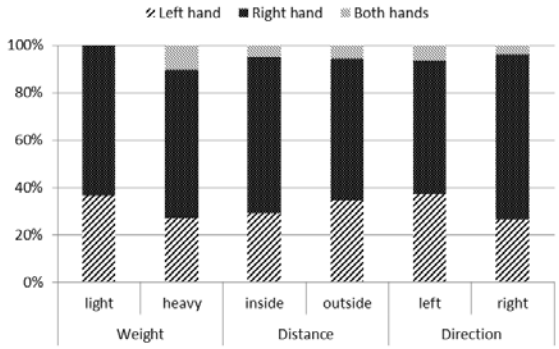

Figure 2. Picking, distribution of hand use. Percentage of product cycles.

Placing the products in the order bin was primarily done with the right hand (80%) and almost never with both hands. The right hand was used in 86% of cycles to the left direction and 75% to the right direction. A tendency for an interaction was observed between the direction and distance (p=0.054 (right) and p=0.060 (left)) (figure 3).

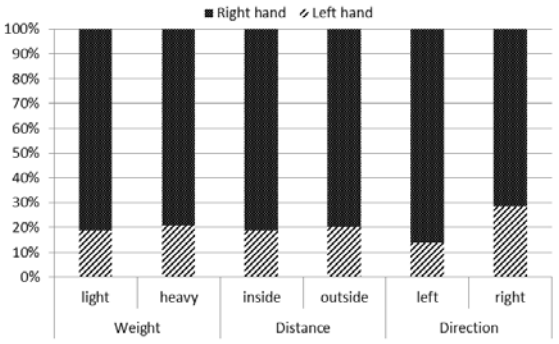

Figure 3. Placing, distribution of hand use. Percentage of product cycles.

The button was pushed almost equaly by the left and right hand (resp. 54% & 46%). Direction had a strong effect on hand choice for pushing the button (p=0.002), in the left direction the left hand is used in 85% of the cycles and to the right only in 19% (figure 4).

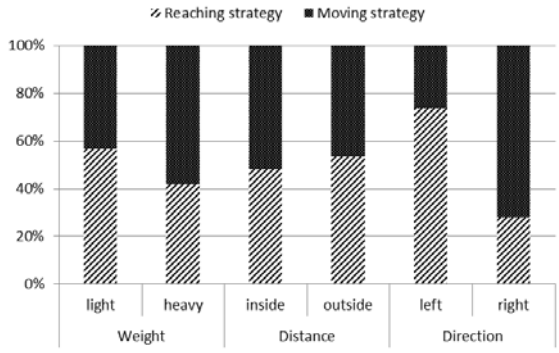

Figure 4. Reaching or moving strategy distribution. Percentage of product cycles.

3.3 Overall strategy in hand use

In figure 5 the proportional prevalences of the six most prevalent strategies are presented. These six stategies represent 94% of all cycles of all subjects.

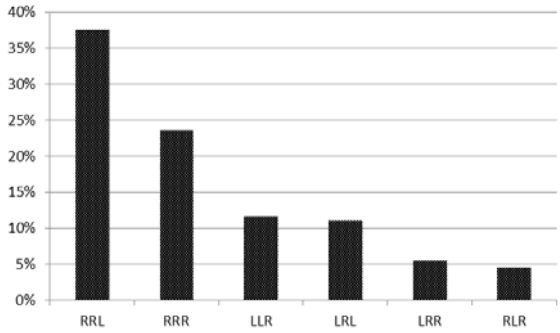

Figure 5. Distribution of overall strategies. Percentage of product cycles.

We observed frequent within-subjects changes in overall strategy during the performance of the tasks. Generally, In 14% of the cycles a different overall strategy was chosen than in the previous cycle. The weight had a significant effect here: with heavy products 23% of the cycles showed a change in strategy versus 6% with light products (p=0.003) (see figure 6).

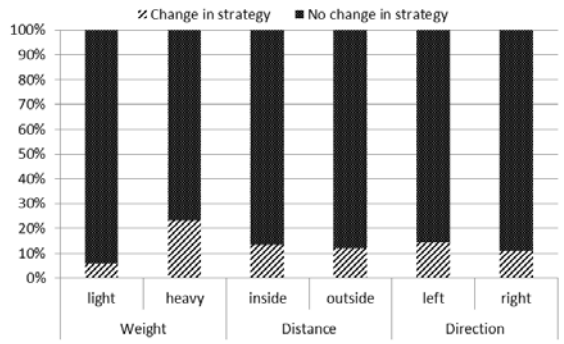

Figure 6. Percentage of product cycles in which the overall strategy was changed compared to the previous cycle strategy.

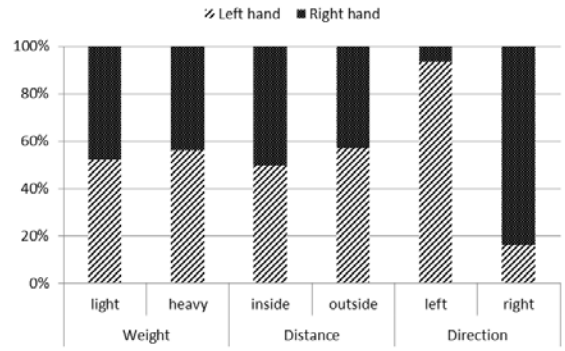

Figure 7. Pushing button, distribution of hand use. Percentage of product cycles.

3.4 Reaching vs. moving

Reaching occurred in 50% of all cycles. Direction and weight had a significant effect here. In the left direction, 74% of the cycles showed a reaching strategy vs. 28% in the right direction ($p = 0.030$). These percentages were 57% for light products vs. 42% for heavy product ($p = 0.030$) (see figure 7).

3.5 Performance

The average cycle time was 4.2 seconds. There was no performance difference between the two global placing modes. The reaching strategy had an average cycle time of 4.1 seconds and the moving strategy 4.3 seconds ($p = 0.212$). In addition, no significant effect of hand use was observed

4. Discussion

Picking, placing and pushing a button are quite simple operations which require no specific skills. It could therefore be expected that choice of movement strategy would be optimized for efficiency (time and effort). It is striking that picking and even more so placing is performed primarily with the preference hand (respectively 62% and 80%). The option to use both hands is only used during picking and at the higher weight (5%). Preference hand seems not to influence the use of hand for pushing the button (left hand 46% and right hand 54%).

Picking and placing of heavier products place a larger strain on the body. Choice of movement strategy is more constraint compared to handling light products. On the other hand, the body may also be fatigued sooner which could lead to change of strategy to unload fatigued body parts. The product weight influences the picking strategy, typical placing strategy and the number of overall strategy changes. Heavy products are picked with both hands in 10% of the cycles, whereas light products are almost never picked with both hands. It seems that picks with both hands with heavy products are left hand picks are supported by the right hand. The reaching strategy while placing is used less often with heavy products (42%) and changes in overall strategy are more common (every 4 cycles). These extra strategy and less reaching changes might not reflect the effect of actual fatigue, because of the short trial duration, but subject might anticipate on future fatigue.

More distance creates more time to do picking placing and pushing operations within the movement to cover the distance compared to a stationary position in which operations are performed. However,, in this experimental set-up distance has no effect on movement strategies.

Movement direction changes the orientation of the body to the workstation. The preference hand might not always be on the most efficient side compared to the workstation. Direction has effects on movement strategies. For placing products a small difference exists between the right and left direction. In the right direction the left hand is used more often (25%).

Though for pushing the button there is a large difference. In the right direction the right hand is used primarily (81%) and for the left direction the left hand is used primarily (85%). Efficiency seems to have a great influence on hand choice for pushing the button, because the chosen hands are closest to the button in these directions. Optimum efficiency (based on time and distance) would be achieved if a different hand would be used for placing an pushing the button. But this is not the case, because with placing subject primarily use their preference hand. Placing with the preference hand (in this case right) has an additional effect on the typical placing strategy. When placing in the left direction the reaching strategy occurred much more often (71%). Probably as an compensating strategy to make up for the larger distance that the right hand had to travel to place products in the left order bins.

No effects of strategy on performance (cycle times) were found. One could have expected that the typical placing strategy influenced performance. While during reaching to the order bin, less distance had to be traveled. This was not confirmed in this experiment. It can be stated however, that, ergonomically, the fact that the workstation allows movement variation without loss of performance, is favorable.

Acknowledgement

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