Experimental Study on Discrimination Thresholds for Haptic Perception of Size in Manual Operation

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Abstract. Objective: This experimental study was designed to measure discrimination thresholds for haptic perception of size in manual operation. Methods: Common manual operation modes with finger pressing or pulling, three finger pinch or grip, and hand grip were used in this study. Taking the index finger pressing operation as an example, the distal phalanx finger length and the width of the index finger were measured in order to determine the size range of sample buttons. The assessment procedure along with the measurement data sheet of index finger regarding pressing operation was designed. Study subjects were recruited and discrimination thresholds for the size haptic perception of the index finger were measured and analyzed.

Results: The press operation assessment of index finger was performed on one-hundred subjects. By statistical analysis of valid data, the index finger size discrimination threshold of 1–2.5 mm was obtained. The discrimination threshold (2–2.5 mm) of male subjects was somewhat greater than that (1.5–2 mm) of female subjects. The size discrimination threshold in the elderly population was slightly larger than the young group.

Conclusion: The study results can provide basic data for the selection of sample size step of manual devices, thereby serving as the cornerstone of the effectiveness and accuracy in ergonomic design and assessment.

Keywords: Discrimination threshold · Size · Index finger pressing · Ergonomic design and assessment

1 Introduction

A lot of scholars have carried out the research on the haptic discrimination, which mainly includes the following: bimanual curvature discrimination of hand-sized surfaces [1], curvature affecting haptic length perception [2], haptic discrimination of

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bilateral symmetry in 2-dimensional and 3-dimensional unfamiliar displays [3], haptic curvature discrimination [4], haptic distal spatial perception mediated by strings [5], haptic perception of parallelity in the midsagittal plane [6], geographical slant perception [7], perception size and touch input behavior [8], peripheral neuropathy and object length perception by effortful (dynamic) touch [9], haptic two-dimensional angle categorization and discrimination [10], This study was designed to measure discrimination thresholds for haptic perception of size in manual operation.

During the study of human-machine adaptation for manual appliance, sample test or experimental method for simulating task scenario can be often used. The design of sample size step is usually given on the basis of experience while the number of samples is reduced by the limitation of the project cycle and research funding. Thus, the selection of sample step size will be adjusted and the validity and accuracy of the results can be eventually affected. The reasonable selection of sample size is the basis of ergonomics assessment research. Determining the step value of sample size based on discrimination thresholds is a necessary step in the assessment of ergonomics. Therefore, using the index finger pressing operation as an example, discrimination thresholds for haptic perception of size in the manual operation was performed to provide basic data for the evaluation of human-machine adaptation of manual appliance.

The main contents of this study were as follows:

1. The length and width of distal phalanx finger of the right index finger were measured;
2. Combined with the button size range and pressing force of manual ergonomics standards, the size range of the test buttons were determined; the button assembly was also developed and adjusted to the same displacement and the same pressing force; and
3. One-hundred healthy and non-dyskinesia subjects were recruited, and discrimination thresholds for size haptic perception concerning the right index finger was assessed, which resulted in a threshold value of 1–2.5 mm. The size discrimination threshold of the index finger was affected by gender and age. The size discrimination threshold of male subjects was mostly 2–2.5 mm, compared to the female size discrimination threshold of 1.5–2 mm. The size discrimination threshold in the elderly population was slightly larger than the younger group.

2 Experiment of Forefinger Discrimination Threshold for Size

The size range of button samples was determined based on the hand size and related standards of manual operation ergonomics. The button assembly was designed and manufactured; the test bench was built; the testing process and data record sheets were designed; study subjects were recruited; and assessment procedure was performed. By statistical analysis of valid data, the discrimination threshold of the right index finger for size was obtained. Specific contents were as follows:

2.1 Size Range of Button Samples

The main factors affecting the operation of the index finger pressing operation included: the abdominal width and length of the distal end of the index finger, shape and size of button, installation position, material for button, etc. In this study, samples were made of nylon material. A more common round button shape was selected although the shapes generally were either round, square, or rectangular. Pressing operation was usually divided into certain categories regarding the index finger, thumb, and palm. In this study, the index finger pressing action was used. Throughout the experiment, the width and length of the distal end of the index finger of 30 adult men and women were measured and analyzed. Referring to the dimension range of the circular button in the related ergonomics standards, the circular button sample size range was determined as 6–12 mm, and the step sizes were 0.5 and 1 mm.

2.2 Experiment Scheme

(1) **Assembly and Development of Button Sample.**

The circular pressing head of button samples were produced, and the ranges of the diameter were 6–12 mm. Specific diameters included: 6 mm, 7 mm, 7.5 mm, 8 mm, 9.5 mm, 10 mm, 9 mm, 9.5 mm,10 mm,11 mm, and 12 mm. The finished products are shown in Fig. 1.

Fig. 1. Button head samples

The press body assembly consisted of press head, supporting rod, fixing sleeve, spring, pre tightening sleeve, shell, nut and adjusting rod as shown in Fig. 2. The three regulation functions of this mechanism were the pressing force adjustment, the pressing displacement adjustment, and the replacement function of pressing head.

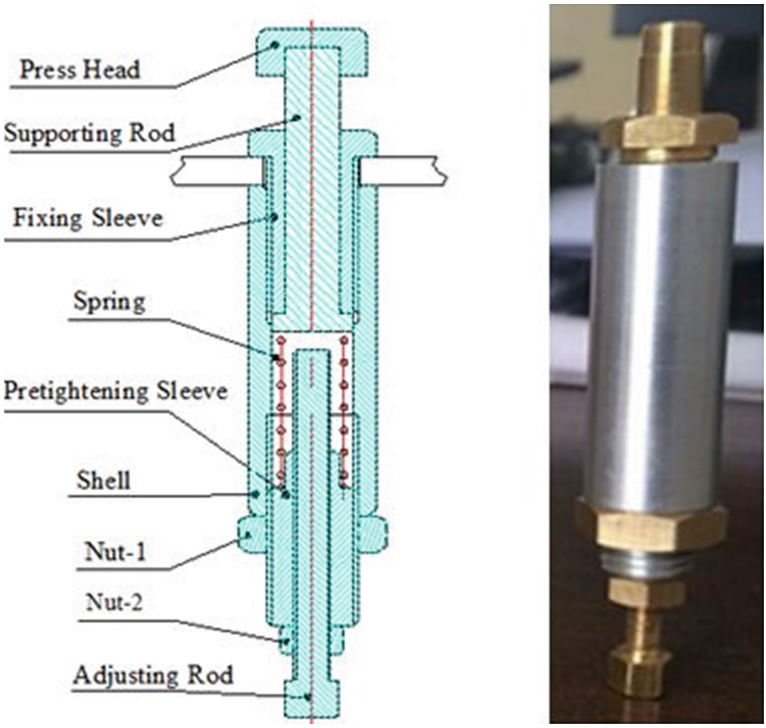

Fig. 2. The button body assembly (the left shows the design chart, the right shows the button sample)

(2) **Test procedure and specification.**

In a comfortable standing position, the subjects pushed the button at a normal rate with the right hand index finger. (Note: The distance between the subjects and the test bench was adjusted by the subjects themselves with the experiment table height taken below 5 cm of the standing elbow height of the people in the 50th percentile). The subjects made judgments about the diameter of the circular button head, which were either the same or different.

Thus, all data were recorded in the corresponding table featuring the three symbols as follows:

1. The tick symbol √, which showed the subject accurately distinguishing the size;
2. X symbol, which displayed subjects incapable of distinguishing the size or error; and
3. ? Symbol, which indicated subject being in the middle of the other two symbols, which was equivalent to the fuzzy perception. Test scenarios were shown in Fig. 3.

The experimental specification consisted of three points:

4. The subject's eyes needed to be occluded when the test was performed;
5. The step size was determined randomly when the test was performed;
6. Each test should be repeated two times to eliminate the process error.

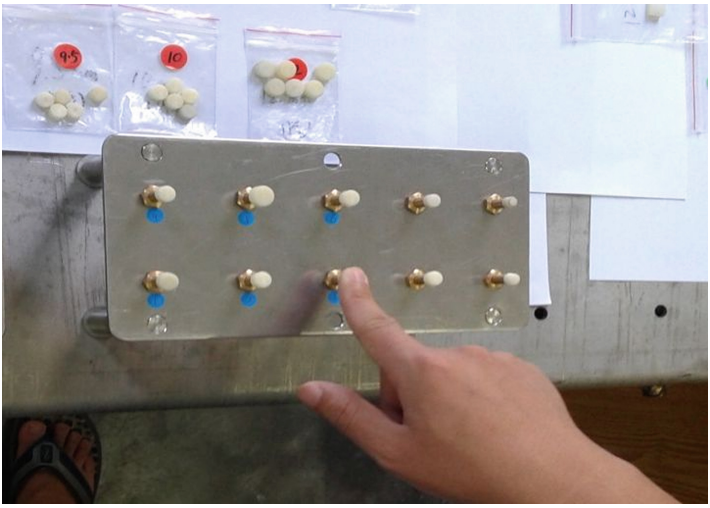

Fig. 3. Testscenarios

3 Results

The height and weight of the study subjects (50 females and 50 males) were measured, so was the hand size (hand thickness, hand length, hand width, index finger length, finger distal phalanx length and width). All data were used to analyze the relationship between hand discrimination threshold for size and related anthropometric dimensions.

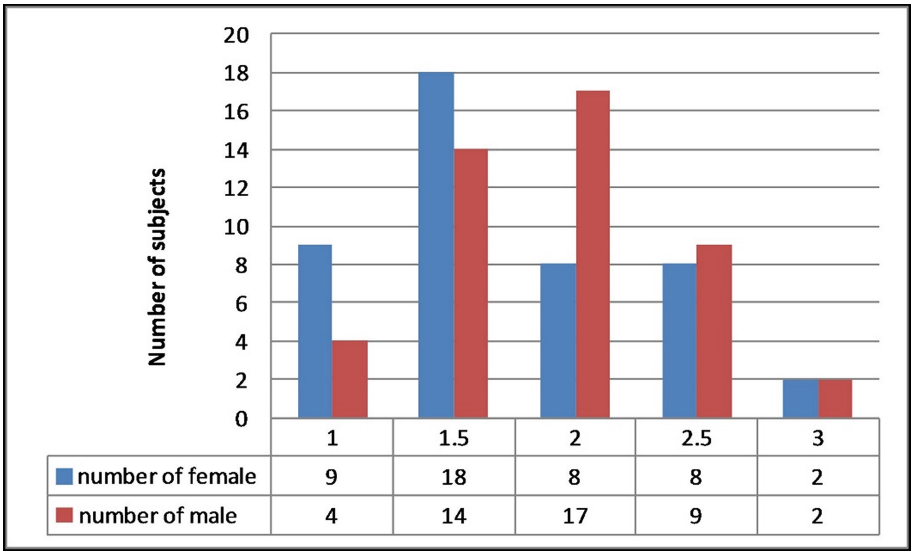

Fig. 4. Male and female finger size discrimination threshold distributions (Color figure online)

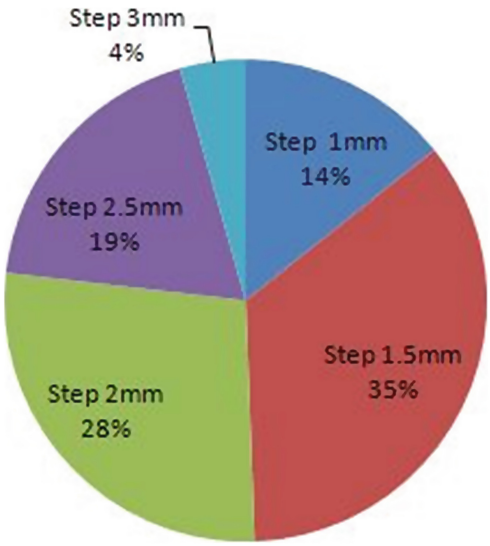

Fig. 5. The proportional distribution of various sensing steps of the index finger

Of the one-hundred subjects used in this study, 91 (46 males and 45 females) provided the most valid data (as shown in Figs. 4 and 5). The size discrimination threshold of the right hand index finger was about 1–2.5 mm, about 96 % of the total subjects chose this range, and the number of people who selected 1.5–2 mm was about 63 %.

For male subjects, 17 selected the maximum of 2 mm as step size, and 14 picked 1.5 mm (67.4 %). For female subjects, 18 adopted the maximum steps size of 1.5 mm while 9 chose 1 mm and 8 selected 2 mm. Overall, 78 % of the female subjects selected 1–2 mm as a step size.

4 Conclusions

(1) The experimental study was conducted to measure discrimination thresholds for haptic perception of size in manual operation. The press operation assessment of index finger was performed on one-hundred subjects. Forty percent (40 %) of the female subjects chose a maximum of 1.5 mm as a step size while 37 % of the male subjects selected a maximum of 2 mm as a step size. The size discrimination threshold values of female group regarding the right hand index finger were slightly lower than those of male group, indicating that females were more sensitive to touch than males.

(2) As indicated in the assessment results, the number of people who chose 3 mm as a step size was only 4 % of the total number of study subjects, indicating that the size discrimination threshold value of index finger size category was less than 3 mm for ordinary people.

(3) The weakness of this study included a low sample size in which only 27 % were an older age. Because of the sensitivity of the young man and the small size of their hands, the study results regarding the size discrimination threshold might be smaller. However, the size discrimination threshold value might be slightly larger when used in practice. Therefore, the increment of the number of study subjects was highly recommended in order to obtain more accurate results of the index finger discrimination threshold for size.

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