Effective Adaptation to Experience of Different-Sized Hand

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Abstract. This paper reports the effect of pre-operation intended to familiarizing oneself with vicarious experiences of different-sized hands. To measure this effect, the index of degree of immersion (DOI) is proposed, which represents whether observed behavior is appropriate for the presented hand size. The DOI is measured for various sizes of hands when changing type of pre-operation which is classified based on relationship between hands and objects. The experimental results show that the pre-operation is effective for familiarizing the presented sized hand, especially in larger sized hands, and that behavior of touching and controlling an object in position is important for effective pre-operation.

1 Introduction

There are many hand-held products such as mobile phones, remote controllers, and digital cameras. The usability of these hand-held products is affected by the shapes of hands to operate them. It is difficult for designers to imagine the user's evaluation of these products in early assessment because of two reason: (1) difference of hand shape between a designer and users, (2) intangibility by nonexistence of actual products.

For experiencing a part of the functions of products, a number of studies have examined virtual prototyping and augmented prototyping. In these studies, the operating characteristics of a particular user interface [1][2] and the external appearance of products can be controlled [3]. However, few studies have addressed controlling the physical characteristics in the experience.

Computational models that assess the usability of products employing various hand shapes have been studied [4][5]. Using these models, designers can get the user's evaluation quantitatively in early assessment but cannot experience it intuitively.

In addition, as with "Through Other Eyes [6]", which is a system for experiencing physical characteristics caused by aging and disabilities, enabling designers to experience product manipulation with hands of various shapes can

G. Bebis et al. (Eds.): ISVC 2009, Part II, LNCS 5876, pp. 1002–1010, 2009.
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help designers to explore the usability of users having various hand shapes. In particular, experiencing behavior depending on the size of other people's hand is effective in such helping because behavior usually changes in proportion to hand size.

Thus, the authors have proposed a system that provides the experience of hands of various sizes, which presents hands of various sizes in an environment that appears not to change in size [7][8]. This is achieved in the proposed system by adjusting the optical zoom and actual object size (Fig. 1).

The system can provide two functions which are useful as design support. The first one is subjective aspect in which the hand size is recognized as different from one's own according to the presented hand size. This gives designers the opportunity to become aware of the difference in hand size between oneself and others. The second one is behavioral aspect in which grasping behavior is appropriate for the presented hand size. This is effective for designers to find behavioral patterns of others.

For changing the size of experiencing hand, a pre-operation is performed to familiarize with the presented hand size (Fig. 2). However, there is no knowledge

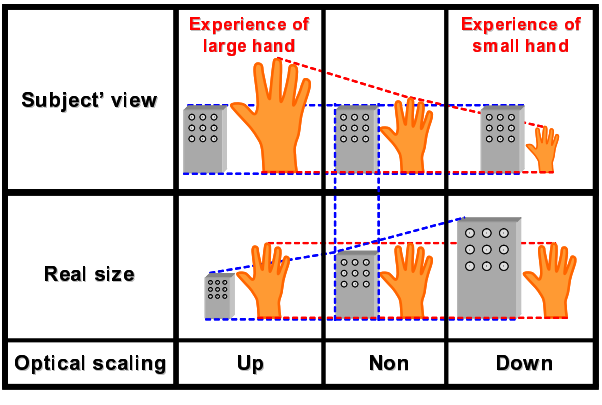


Fig. 1. Relationship among physical size, optical scaling, and the presented hand [8]

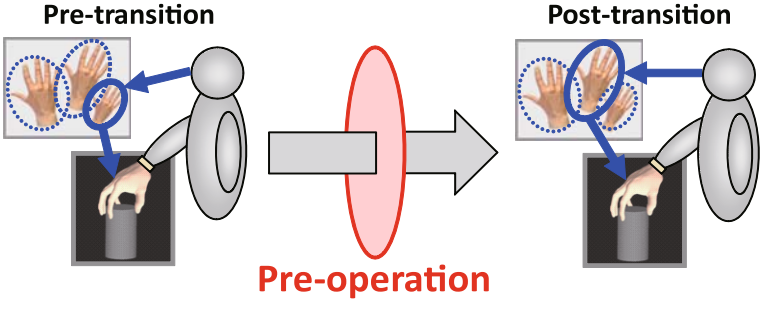


Fig. 2. Pre-operation when changing the size of experiencing hand

about that what kinds of pre-operation is adequate for what sizes of presented hands. It is important to design aid because in this case pre-operation should be simple and easy as much as possible.

Therefore, the purpose of the paper is to investigate the effect of pre-operation on the familiarization with different-sized hand. The effect is examined from the aspect of what kind of pre-operation is suitable for design aid.

In Section 2, the method for providing the experience of hands of various sizes is described. In Section 3, pre-operations are classified according to the relationship between hands and objects. In Section 4, the index of measuring the familiarization with this experience is defined. In Section 5, an effective pre-operation is explored comparing several kinds of pre-operations. In Section 6, this study is concluded.

2 Method for Presenting the Experience of Hands of Various Sizes

2.1 Method

We have developed a method for providing the experience of hands of various sizes [8]. This experience involves the sensation of hand size being different from one's actual hand size, which occurs when hands of various sizes are presented in an environment that appears to be of constant size. A controlled view of hands and objects is presented to subjects through an optical system with the appropriate scaling.

Fig. 1 shows the method employed to realize the desired view using an optical system and analogous objects. The top row shows the desired hand size to be presented. The middle row presents the actual sizes of the hands and the objects, and the bottom row shows the method used to scale the optical system. The scaling rate of the optical system is adjusted to present hands of desired size. The sizes of the objects used in this condition are varied inversely with the magnification of the optical system.

In this way, only the hand size, and not the object size, is changed visually. For instance, the right-hand column shows the method used to present smaller hands. The optical system is scaled down, and analogously large objects are used. In contrast, for presenting larger hands, the optical system is scaled up, and analogously small objects are used, as shown in the left column.

2.2 Implementation

According to studies suggesting the possibility of experiencing hands of various sizes [9][10][11], the consistency of senses, especially vision and somatic sensation, is essential for the experience. In the proposed system, employing an optical system and analogous objects achieves the required consistency.

The system consists of analogous objects, a camera with a zoom lens, a computer, a display, and two mirrors (Fig. 3). Images of the right hand and an object

captured by the camera are presented to a subject by rendering the images on the display. The camera is a Sony DFW-VL500 (VGA, 30[fps]). The minimal visual delay of the system is 38 [ms], which is due to hardware constraints.

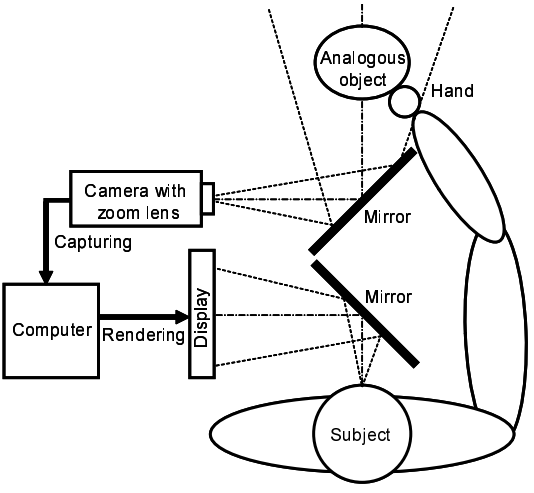


Fig. 3. Configuration of the system for providing the experience of hands of various sizes [8]

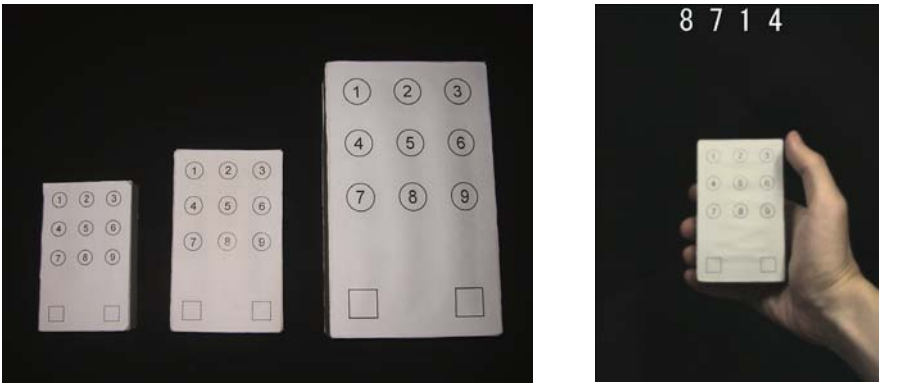
2.3 Pre-operation

Before the experience of various sized hands, a pre-operation is performed to familiarize with the presented hand size. In the previous work [8], the pre-operation is a button-pushing task. It involves pushing buttons on a object in hand, which correspond to a four-digit number five times. Fig. 4 (a) shows the analogous objects used in this task. In the developed system, the computer displays the numbers to push buttons, and controls the visual delay and the optical scaling of the camera. Fig. 4 (b) is an example of the subject's view.

3 Classification of Pre-operations

In terms of relationship between a hand and an object, pre-operations are classified into four categories.

- **Category 1:** Only hand motion without an object
- **Category 2:** Touching an object with controlling hand position (e.g. switch a light on by pushing the button)
- **Category 3:** Controlling position of an object in hand (e.g. hold and swing a tennis racket)
- **Category 4:** Finger movement to operate an object with controlling its position in hand (e.g. press buttons on a remote controller)



(a) Objects used for the button-pushing task (b) Example of the subject's view

Fig. 4. Pre-operation of button-pushing task. The sizes of objects in (a) are 83×50×17[mm] (left), 100×60×20[mm] (middle), 150×90×30[mm] (right).

The first category is about only hand motion, while the remaining categories are defined in relationship to an object. In these categories, the amount of senses through these kinds of pre-operations increases according to the category number. It indicates that a pre-operation in category of lower number can be simpler and easier.

The pre-operation employed in previous work belongs to Category 4. It is already known that this pre-operation is sufficiently effective for the experience of various sized hands in aspects of subjective and behavioral. But, it doesn't show that this pre-operation is inevitable for the experience in any case of presented hand size. From the viewpoint of design aid, pre-operation should be simple and easy as much as possible because it is adjunctive operation relative to product assessment through the vicarious experience. In this paper, the effect of pre-operation on the experience is investigated based on the categories.

4 Measurement of Familiarization with the Presented Hand

In this section, we define the index of measuring the familiarization with the presented hand. To judge whether the experience of different sized hand is successful, a task of grasping equilateral triangular prisms is employed.

According to [12], the grasp strategy are determined by the relationship between hand size and size of equilateral triangular prism and are classified into four grasp patterns. The grasp strategy depending on hand size can be obtained appropriately to the presented size of hand using our system.

Based on the previous work [8], the probability of observed grasp patterns has already known when familiarizing oneself with the presented sized hand

sufficiently, briefly experiencing different sized hand. Using this information,the probability of the experience of presented sized hand can be calculated.

In fact, when an equilateral triangular prism is v_j and the observed grasp pattern is g_k, the probability of which the experienced hand size is h_i can be calculated as the following equation.

$$p(h_i|v_j, g_k) = \frac{p(g_k|v_j, h_i)p(v_j, h_i)}{\sum_l p(g_k|v_j, h_l)p(v_j, h_l)} \tag{1}$$

where $p(g_k|v_j, h_i)$ has already known as discussed previously and $p(v_j, h_l)$ is determined by experimental setup.

The present paper labels Eq. (1) as "Degree Of Immersion (DOI)," and investigates the effect of pre-operation based on this index.

5 Experiment

In this section, we investigate what types of pre-operations are sufficiently effective for experience of different sized hand. This investigation is focused on the experience when increasing hand size because the previous work [13] shows that pre-operation is required for this case while it is not needed for the case of changing in hand size smaller. Some pre-operations based on the classification described in Section 3 are compared with the pre-operation known as sufficiently effective for familiarizing oneself with the experiences of different sized hands by using the index of DOI.

5.1 Condition and Procedure

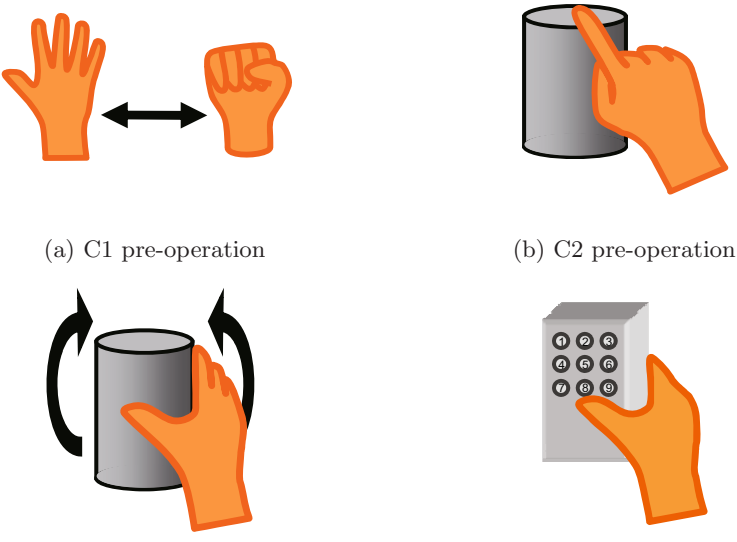
DOIs corresponding to the following five pre-operations are measured when changing in hand size larger.

The pre-operations employed in this experiment are decided by the classification shown in Section 2. The details of them are as stated below and shown in Fig. 5.

- **C-1:** Clasp and unclasp one's hands three times (Fig. 5 (a))
- **C-2:** Touch the top of a cylinder without grasping (Fig. 5 (b))
- **C-3:** Grasp and rotate a cylinder (Fig. 5 (c))
- **C-4-1:** Pushing buttons on a object in hand with corresponding to a four-digit number one time (Fig. 5 (d))
- **C-4-2:** Pushing buttons on a object in hand with corresponding to a four-digit number five times (Fig. 5 (d))

The scaling rates of the presented hand sizes are 0.67, 1.00, and 1.20, which are labeled Small, Normal, and Large, respectively. These rates were determined by data of the hand length of actual subjects [14][15].

The transitional conditions of presented hand size were determined by couples of these scaling rates.



(a) C1 pre-operation

(b) C2 pre-operation

(c) C3 pre-operation

(d) C4 pre-operation

Fig. 5. Pre-operations

– from Normal to Large
– from Small to Normal
– from Small to Large

The number of subjects is five. In each experimental condition, the subjects were asked to perform the following tasks.

– Perform the button-pushing task described in Section 2 in pre-transition sized hand.
– Perform this task in post-transition sized hand if the experimental condition has a pre-operation.
– Grasp equilateral triangular prisms. This grasp was recorded using a video camera to calculate the DOI in this experimental condition.

5.2 Result

Fig. 6 shows the experimental result of the mean DOI about conditions of pre-operations with multiple comparisons. In this figure, significant differences are confirmed between C-1 and C-4-2, and between C-2 and C-4-2 respectively. Therefore, controlling a object in position with grasping is essential for familiarizing oneself with the experience of different-sized hands.

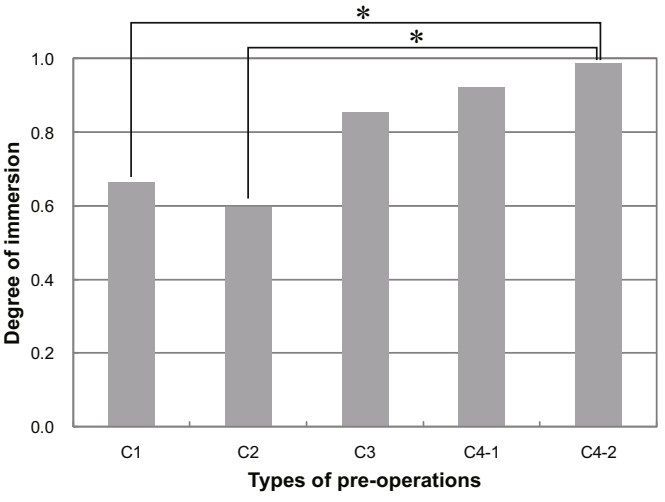


Fig. 6. Comparison of mean degree of immersion about types of pre-operations (*: $p<0.05$)

6 Conclusion

The effect of pre-operation on the experience of different-sized hand was investigated. To measure this effect, the index of degree of immersion into this experience was proposed. The experimental result shows that behavior of touching and controlling an object in position is important for effective pre-operation.

Acknowledgment

This work was supported by KAKENHI(21700147).

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