Paper:

Role of Pre-Operation in Experiencing Differently Sized Hands

Kenji Terabayashi*, Natsuki Miyata, Kazunori Umeda*, and Jun Ota*****

*Department of Precision Mechanics, Faculty of Science and Engineering, Chuo University
1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan
E-mail: terabayashi@mech.chuo-u.ac.jp
**Digital Human Research Center, National Institute of Advanced Industrial Science and Technology (AIST)
2-3-26 Aomi, Koto-ku, Tokyo 135-0064, Japan
***Research into Artifacts, Center for Engineering (RACE), The University of Tokyo
5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8568, Japan
[Received April 1, 2010; accepted August 7, 2010]

In this paper, we investigate *pre-operations* intended to adapt one to hands of controlled sizes when experiencing differently sized hands. *Pre-operations* are categorized into four types based on the relationship between a hand and an object. To quantify the degree of adaptation to differently sized hands, an index, called "*Degree Of Immersion (DOI)*," is defined. The index indicates the appropriateness of the observed behavior to the presented hand size. The DOI was measured to compare *pre-operations* when changing hands in size variously. The experimental comparisons led to two main points: (i) no *pre-operation* is required with decreasing hand size due to easy adaptation, (ii) a *pre-operation*, touching and controlling an object in position, is sufficiently effective for adapting larger hands. These points are important for design aid applications to assess usability of designing products by various users.

Keywords: pre-operation, differently sized hands, adaptation, asymmetric, body schema

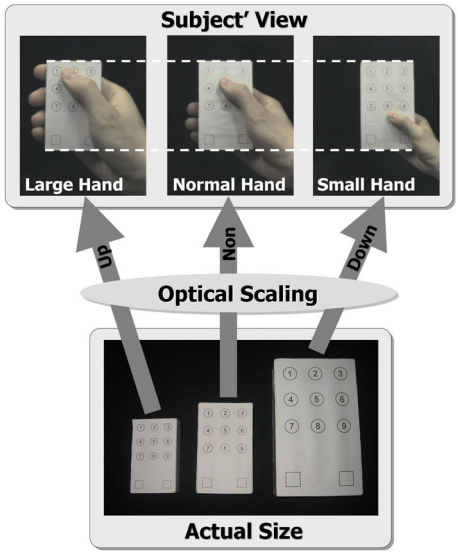


Fig. 1. Visual scaling of only hands to provide simulated experiences of differently sized hands by optical scaling with analogous objects.

1. Introduction

Early assessment of products is a very important step in product design and manufacture. There are two main approaches to support the evaluation of the usability of products: (i) computer simulation using a "digital human" [1–3], (ii) virtual/augmented prototyping [4–6]. A digital human is a human model to assess the usability of products in computer simulations; it replaces a real examination with a prototype of the product by sample users. The use of a digital human is useful to reduce assessment time and cost. Virtual/augmented prototyping provides physical experiences with a special mock-up having a part of product functions which can be controlled by designers. This leads to easy tuning of the functions in product design with a few test production.

In usability evaluations, especially for hand-held products, such as mobile phones, remote controls, and digital cameras, the following two points are essential: (i) the various sizes of user's hands have to be considered. (ii) products must be tested by hand touch and manipulation. These are because hands have many degrees of freedom of motion and highly sensitive sensors in small space. Digital human and virtual/augmented prototyping can aid with the first and the second points respectively.

To deal with these points simultaneously, a system to produce simulated experiences of differently sized hands has been proposed [7]. This system presents scaled hands in an environment which keeps its visual size by adjusting optical scaling and the actual sizes of analogous objects (**Fig. 1**). The simulated experience of differently sized hands allows designers to estimate other's usability by touching a designing product with various hand sizes, including two points which are useful as design aid. The first one is a subjective point, namely, that the hand size is recognized as different from one's own according to

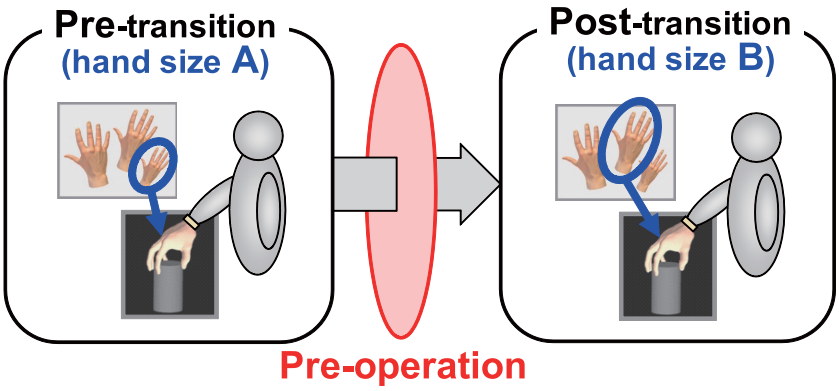


Fig. 2. Pre-operation when changing the experiencing hand size from A to B.

the presented hand size. This gives designers an opportunity to become aware of the difference in hand size between one's own and others'. The second one is a behavioral point, namely, that the grasping behavior is appropriate for the presented hand size. This is effective for designers to find the behavioral patterns of others. Through the experiences of differently sized hands, designers can find bad usability of a designing product and redesign the product as user-friendly.

In a previous study [7], a button-pushing operation, intended for adaptation to presented hand size by obtaining plentiful sensory information, is required every time before experiencing differently sized hands. This operation has some difficulties from the viewpoint of design aid. The operation requires a long time because its movement is complex, which makes the total time of usability evaluation too long because it is necessary every time due to the various sizes of user's hands. Additionally, this operation requires special objects which number increases in proportion to the number of hand sizes for the assessment. It would be ideal if this operation were not necessary or if a simple one were available. However, there is no knowledge whether the operation is inevitable for the simulated experience and no discussion for how to decide the operation.

In this paper, we investigate the role of the operation in terms of its category in experiencing differently sized hands when changing hand sizes, and label an operation, intended for adaptation to presented hand size, as *pre-operation*. **Fig. 2** illustrates the pre-operation for experiencing hand size B after experiencing hand size A. This investigation will be fundamental to the way to determine efficient pre-operation for design aid of usability evaluation, relating to adaptational characteristic of experiencing differently sized hands.

The rest of this paper is organized as follows. Section 2 reviews the method for providing experiences of differently sized hands and categorizes types of pre-operations based on the relationship between hands and objects. Section 3 contains a definition of an index for measuring the degree of adaptation to the experiences. In Sections 4 and 5, two experiments were examined to clarify whether pre-operations are inevitable before the experiences when changing hand sizes variously and which type of pre-operation is effective for the adaptation. Next, Section 6 is a discussion of the experimental results in the previous sections from the viewpoint of design aid and body schema [8]. Finally, Section 7 is the conclusion.

2. Method for Experiences of Differently Sized Hands

2.1. Method

This section reviews the method for providing simulated experiences of differently sized hands, according to a previous study [7].

The simulated experience includes the sensation of hand size as being different from one's actual hand size and change in behavior, 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 appropriate scaling. The top of **Fig. 1** labeled as "subject's view" is an example of the controlled view. To make this view, the scaling rate of the optical system is adjusted to present hands of the desired size, while the sizes of the objects used in this condition are varied inversely with the magnification of the optical system. In case of experiencing a small hand, a hand is presented through the scaled-down optical system with analogously large objects.

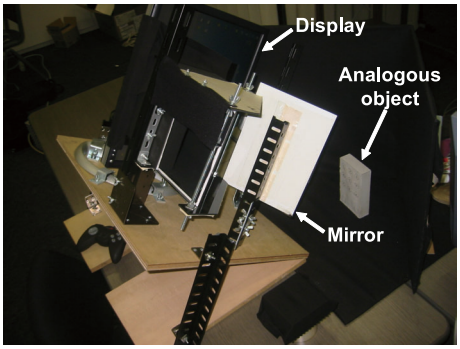
2.2. Implementation

Figure 3 shows the appearance of the experimental setup to provide the simulated experience of differently sized hands. The system consists of analogous objects, a camera with a zoom lens (Sony DFW-VL500), a computer, a display, and two mirrors; it realizes visual scaling only for the hands.

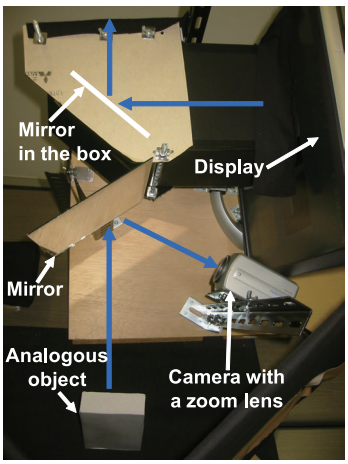
Consistency from the sensory viewpoint, especially regarding vision and somatic sensation [9–11], is essential

Table 1. Classification of pre-operations.

Classification criterion	Pre-operation category number			
	1	2	3	4
Touching on an object by hand movement	No	Yes	Yes	Yes
Object movement made by the hand	No	No	Yes	Yes
Change in contact state while controlling object pose	No	No	No	Yes



(a) Side view.



(b) Overhead view.

Fig. 3. Appearance of the experimental setup to provide simulated experiences of differently sized hands.

for the experience. The minimal visual delay of the system is 38 ms, which is due to hardware constraints. This delay is allowable regarding the consistency.

2.3. Pre-Operation

A pre-operation is performed before experiencing differently sized hands, which is intended to adapt one to the hands (**Fig. 2**). The study [7] employs a button-pushing task as a pre-operation. The task involves pushing numbered buttons on a handheld object, such as a remote control or a mobile phone. A four-digit number is entered five times by pushing a combination of buttons twenty times. This pre-operation gives plentiful sensory information to the operator, which is intended for adaption to experiences of differently sized hands; this pre-operation has some complexity and requires a long time to perform.

In the paper, pre-operations are classified into four categories based on the following three criteria:

- Touching an object with a hand movement
- Moving an object by the hand
- Change in the contact state while controlling the position of an object

These criteria are derived from relationships between hands and objects focusing on the motion and contact state. **Table 1** shows the relation between these criteria and the four following categories of pre-operations.

- **Category 1**: moving the hand only without an object.
- **Category 2**: touching an object while controlling the hand position (e.g., switch a light on by pushing the button).
- **Category 3**: controlling the position of an object in hand (e.g., holding and swinging a tennis racket).
- **Category 4**: moving the finger to operate an object while controlling its position in the hand (e.g., pressing buttons on a remote control).

The first category is characterized by hand movement alone, while the remaining categories are defined by the relationship of the hand and an object to touch. Categories 3 and 4 include controlling the position of an object in the hand, and the difference is the change in the contact state. In these categories, the amount and richness of sensory information obtained through pre-operations increases according to the category number and the complexity of the task. This indicates that a pre-operation in a category with a lower number will be simpler and easier.

The pre-operation of button-pushing described above belongs to category 4, which has the highest complexity. This pre-operation is known as sufficiently effective for the simulated experiences of differently sized hands. However, there is no information whether the pre-operation is inescapable for the experiences. From the viewpoint of design aid, the pre-operation is adjunctive operation relative to product assessment based on the experiences. Therefore, it would be ideal if this operation were not necessary or if a simple one were available.

In this paper, the effect of pre-operation on the simulated experience is investigated in the two following steps. As the first step, the necessity of pre-operations is examined in various transitions of hand sizes by comparing the conditions with or without the pre-operation of button-pushing task which is sufficiently effective for the experience and in the category 4. This examination is focused on explaining which transition of hand sizes does not require the pre-operation. Then, what types of pre-operations is necessary and enough for the experience is explored in the transitions of hand sizes in which the pre-operation is essential, which is perceived in the first step.

3. Measurement Index for the Degree of Adaptation to Differently Sized Hands

This section defines an index for measuring the degree of adaptation to differently sized hands, which is fundamental to the investigation of pre-operations and used in the following experimental sections.

The index is quantified on the basis of behavioral patterns determined by hand sizes because it is impossible to measure the adaptive strength directly. The size of actually experienced hand can be obtained indirectly from observed behavioral patterns if the probability of each behavioral pattern derived from hand sizes are given.

To specify the index, the behavior of grasping equilateral triangular prisms is evaluated. According to [12], grasp strategies are determined by the relationship between the hand size and the size of an equilateral triangular prism and are classified into four grasp patterns. The grasp strategy depending on hand size can be obtained appropriately using the method shown in Section 2 [7]. Additionally, the probability of observed grasp patterns has already known when adapting to the presented sized hand totally. Using this information, the probability of experiencing a specific hand size can be calculated from the observed grasp pattern and prism size.

When an equilateral triangular prism is v_j and the observed grasp pattern is g_k, the probability of experiencing the hand size h_i can be calculated based on the Bayes' theorem as the following equation.

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

where $p(g_k|v_j,h_i)$ is already known as discussed previously and $p(v_j,h_l)$ is determined by normalizing the frequency of pair of v_j and h_l, which is from the experimental condition.

In the paper, Eq. (1) is labeled as "*Degree Of Immersion (DOI)*," and the effect of the pre-operation is investigated on the basis of this index.

In the following two experiments, the numbers of h_i and v_j are both three, which are corresponding to hand sizes of Small, Normal, and Large, and the number of g_k is four, which are corresponding to grasp patterns reported in [12].

Table 2. Transitional conditions of hand size.

Condition index	Presented hand size	
	Pre-transition	Post-transition
(i) NS (**N**ormal **S**mall)	Normal	Small
(ii) SL (**S**mall **L**arge)	Small	Large
(iii) LN (**L**arge **N**ormal)	Large	Normal
(iv) NL (**N**ormal **L**arge)	Normal	Large
(v) LS (**L**arge **S**mall)	Large	Small
(vi) SN (**S**mall **N**ormal)	Small	Normal

4. Experiment on the Transition of the Presented Hand Size

This section examines the necessity of pre-operations, i.e., whether any pre-operation is inevitable for adaptation to the experience of differently sized hands in the case of various transitions of presented hand size.

In the various transitions, the DOI is compared between conditions with and without the pre-operation which is known to be sufficiently effective for the simulated experience [7]. If there is a difference in the comparison, the pre-operation is essential for the experience; otherwise, it is not needed.

In both cases of conditions with or without pre-operation, the patterns of grasping equilateral triangular prisms are measured when changing the presented hand size to quantify pre-operation's effect as DOI. These conditions are compared from the viewpoint of the DOI calculated using the observed grasp patterns.

4.1. Condition and Procedure

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 according to the hand lengths of actual subjects [13, 14] as all of the existing hand sizes is included in the range which is from Small to Large.

The transitional conditions of the presented hand size were determined as the couples of these scaling rates. Thus there are six transition conditions in total, as shown in **Table 2**. For example, the condition denoted by NS in this table means "to present a **S**mall hand after experiencing **N**ormal hand."

Ten right-handed male subjects participated in this experiment. To cancel the order effect of transitional conditions, five subjects were assigned the order "(i)-(ii)-(iii)-(iv)-(v)-(vi)" while the other five were assigned the order "(iv)-(v)-(vi)-(i)-(ii)-(iii)."

In each experimental condition, the subjects were asked to perform the following tasks.

- Perform the button-pushing task described in Section 2 by the hand size before the transition.

Table 3. Result of two-way repeated ANOVA ($*$: $p < 0.05$). The two arguments in the function F show degrees of freedom about conditions and residual errors respectively.

Dependent variables	Main effect		Interaction
	Pre-operation	Transition	Pre-operation × Transition
Degree of immersion	F(1.0,9.0) = 22.12 *	F(2.9,25.9) = 5.27 *	F(2.5,22.5) = 1.11

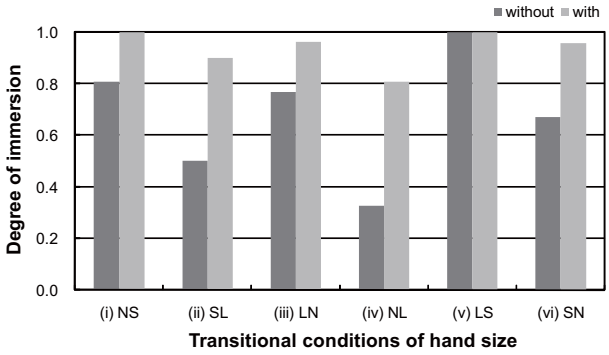


Fig. 4. Mean degree of immersion for all experimental conditions.

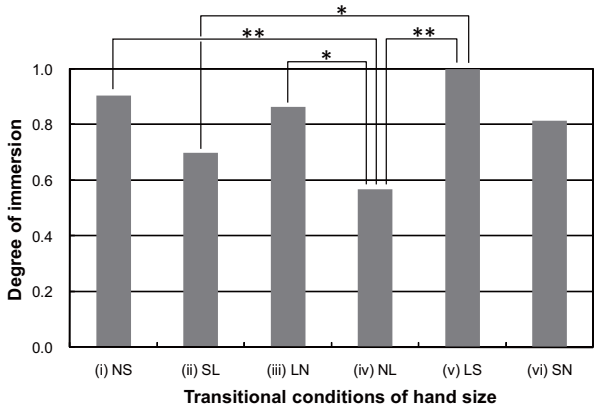


Fig. 5. Mean DOI for transitional conditions of hand size and result of multiple comparisons ($**$: $p < 0.05$, $*$: $p < 0.10$).

- Perform this task by the hand size after the transition 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.

4.2. Results

Figure 4 shows the mean DOI of post-transitional hand size for all experimental conditions. In this figure, the result shows a tendency for the DOI of the conditions with the pre-operation to be higher.

To prove the effects of the two factors, i.e., pre-operation and transition of the presented hand size, on the DOI, we used a two-way repeated measures ANOVA. The result, which is shown in **Table 3**, shows that the main effects of the two factors were confirmed but there was no interaction between them. According to this result, pre-operation is effective to become familiar with the presented sized hand.

To examine the main effect of the transition of hand size on DOI, multiple comparisons between the transitional conditions of the presented hand size were performed. The results are shown in **Fig. 5** along with the mean DOI. The significant differences observed among the transitional conditions show that there are various difficulties in becoming familiar with the presented hand in terms of the transition regardless of the use of the pre-operation.

These results present the possibility of the different effect of pre-operation about transitional directions. Based on the transitional directions, the conditions shown in **Table 2** can be divided into two categories, which are labeled Shrink and Enlarge. **Fig. 6** shows DOI for conditions with or without the pre-operation and transitional directions with the results of multiple comparisons. In the case without the pre-operation, there was a significant difference in the DOI for transitional direction, but there was no significant difference in the DOI in the case with the pre-operation. Therefore, these results show that the

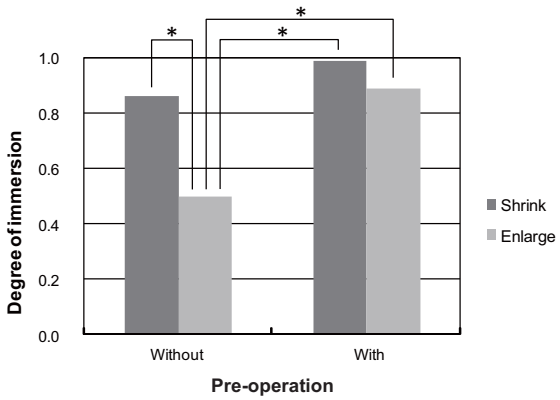


Fig. 6. Comparison of the mean DOI for pre-operation and transition direction ($*$: $p < 0.05$).

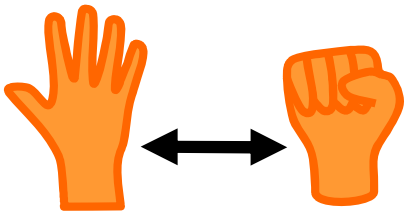


Fig. 7. C-1 pre-operation.

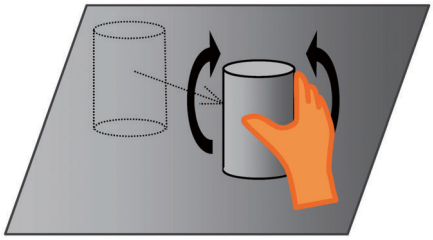


Fig. 9. C-3 pre-operation.

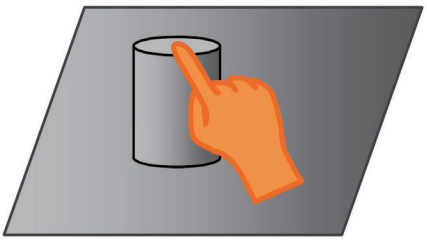


Fig. 8. C-2 pre-operation.

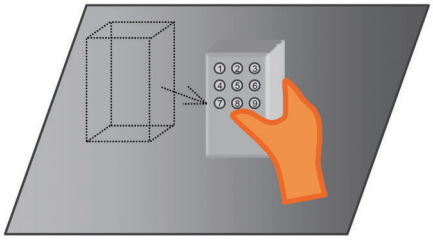


Fig. 10. C-4 pre-operation.

effect of pre-operation on the simulated experience of differently sized hands is asymmetric in terms of the transitional direction.

5. Experiment on the Category of Pre-Operation

In this section, we report the results of an investigation into the types of pre-operations that are effective for different-sized hands. This investigation focuses on the experience when increasing hand size because previous experimental results have shown that a pre-operation is required for this case but not for the case of a decreasing hand size. Four types of pre-operations based on the classification described in Section 2 are compared with the pre-operation known to be sufficiently effective for the adaptation to the simulated experiences by using the index of DOI. If there is a pre-operation having the same DOI as the effective pre-operation, it will be a substitution as a simpler pre-operation for the adaptation to a larger hand.

5.1. Condition and Procedure

DOI corresponding to the following five pre-operations are measured when increasing hand size.

The pre-operations employed in this experiment are determined by the classification shown in Section 2. Their details are reported below and shown in **Figs. 7–10**.

- **C-1**: Clasp and unclasp one's hands three times (**Fig. 7**).
- **C-2**: Touch the top of a cylinder only once without grasping (**Fig. 8**).
- **C-3**: Grasp and rotate a cylinder (**Fig. 9**).
- **C-4-1**: Pushing numbered buttons on an object in hand corresponding to a four-digit number one time (**Fig. 10**).
- **C-4-2**: Pushing numbered buttons on an object in hand corresponding to a four-digit number five times (**Fig. 10**).

The number attached to these indices indicates the relative complexity of the pre-operation in view of design aid applications. In this sense, a pre-operation should be simple and not time-consuming for the main purpose of assessing designed products. Regarding the sensory information related to adaptation to different-sized hands, the number attached represents the richness of the sensory experience. Therefore, there is a trade-off between simplicity and the sensory richness of pre-operation.

Pre-operation C-4-2 is known to be sufficiently effective for adaptation to larger hands. If the other pre-operation does not have different DOI from C-4-2, it will be regarded as a useful pre-operation from the viewpoint of design aid. This experiment investigates an effective pre-operation by comparing C-4-2 with other pre-operations.

For each pre-operation condition, the sampling number is fifteen, i.e., five subjects and three transitional conditions of hand size. These subjects are different from the subjects in the previous experiment.

This sampling number is decided on the basis of the facts that there is no significant difference between within-subjects variance and between-subjects variance in a differently sized hand experience and there is no significant difference between the transitional conditions regarding increasing the hand size, as shown in **Fig. 5**.

The scaling rates of the presented hand sizes are 0.67, 1.00, and 1.20, which are labeled Small, Normal, and

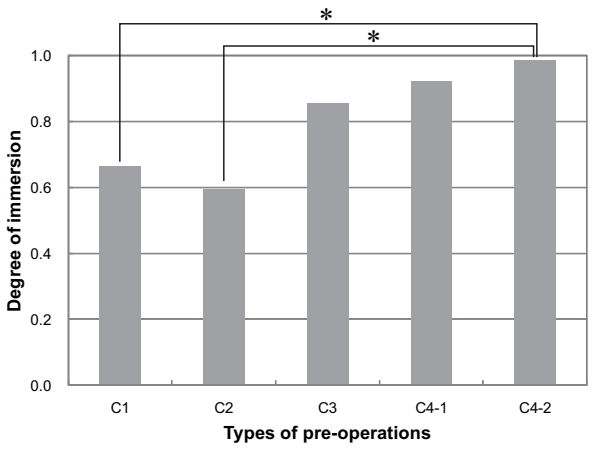


Fig. 11. Comparison of the mean DOI for types of pre-operations ($*$: $p < 0.05$).

Large, respectively. These rates were determined according to the hand lengths of actual subjects [13, 14].

The transitional conditions of the presented hand size were determined as the couples of these scaling rates:

- from Normal to Large,
- from Small to Normal,
- from Small to Large.

In each pre-operation condition, the subjects were asked to perform the following tasks.

- Perform the button-pushing task described in Section 2 by the hand size before the transition.
- Perform this task by the hand size after the transition 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.

The order of pre-operations is decided randomly for each subject.

5.2. Results

Figure 11 shows the experimental results of the mean DOI for conditions of pre-operations with multiple comparisons by the Wilcoxon signed-rank test which is employed to compare multiple means of DOI. In this figure, significant differences are confirmed between C-1 and C-4-2 and between C-2 and C-4-2. This means that pre-operations C-1 and C-2 are insufficient for adaptation to larger hands. Therefore, controlling the position of an object by grasping is essential in order to become familiar with the simulated experience of differently sized hands.

6. Discussion

The following are statistical summaries of the experimental results presented above.

- According to the results shown in Section 4, no pre-operation is needed when decreasing hand size.
- According to the results shown in Section 5, pre-operation C-3, which is the behavior of touching and controlling the position of an object, results in effective adaptation to a larger hand.

From the viewpoint of design aid applications, pre-operation can be skipped or simplified before the assessment of design products. This knowledge is very important for effective assessments for the following two reasons; (i) time savings for pre-operation, and (ii) no need to prepare complicated objects for pre-operation.

In general, the design process requires many assessments for iterative modification and various users. Since pre-operation is required before every assessment, saving time for pre-operation can influence the total assessment time. The number of objects for pre-operation is dependent on the number of hand sizes assessed. The number of hand sizes assessed can be easily increased because of (i) time savings and (ii) ease to prepare objects for pre-operation.

The above summaries about experimental results can be considered from other viewpoint of body schema [8]. In cognitive science, the body schema is defined as a model to control one's own body and to recognize its shape and pose. This body schema is deformable and flexible, and is updated in proportion as body change like growing and injury [15, 16], sensory illusion [10], and tool use [11].

Adaptation to differently sized hands can be regarded as updating of a body schema by performing a pre-operation in a scaling environment in the sense that the observed behavioral strategy is changed after it. Iriki et al. have reported that a body schema is updated by autokinesia with a tool use [11], and all pre-operation dealt with in this paper are autokinesia.

The experimental result that smaller hand size is easier to experience than larger hand size can be considered as that people had a body schema for smaller hand when they were young age.

A body schema is effectively updated by autokinesia [11, 15, 16] and tactile sense with synchronous visual sense [9, 10]. This knowledge is consistent with the experimental result in Section 5 except for pre-operation C-1 and C-2. Pre-operation C-1, closing and opening one's hand without holding an object, is similar to the movement described in other research [15, 16], but the movement time of pre-operation C-1 is much shorter than that noted in such research. Pre-operation C-2, touching the top of a cylinder only once without grasping, is different from that referred to in other research [9, 10] regarding the touch frequency.

7. Conclusion

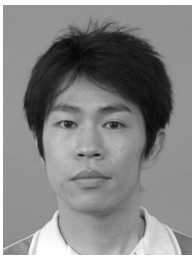
This paper investigated the effect of *pre-operation* on the experience of differently sized hands by classifying *pre-operations* on the basis of the relationship between a hand and an object. To measure this effect, the index of the *degree of immersion* into this experience was defined as the probability of observing behavior appropriate to a controlled size of the hand. The experimental comparison of the conditions with or without *pre-operation* shows that the *pre-operation* is important for adaptation to the presented hands, especially larger-sized hands. The experimental result shows that behavior of touching and controlling the position of an object is an effective *pre-operation* for design aid applications. Our future work is to find optimal pre-operations for specific hand-held products.

Acknowledgements

This work was supported by KAKENHI (21700147).

References:

[1] D. B. Chaffin, "Improving digital human modelling for proactive ergonomics in design," Ergonomics, Vol.48, No.5, pp. 478-491, 2005.
[2] M. Kouchi, N. Miyata, and M. Mochimaru, "An analysis of hand measurements for obtaining representative Japanese hand models," In Proc. of SAE 2005 Digital Human Modeling for Design and Engineering Conf., 2005-01-2734, 2005.
[3] N. Miyata, M. Kouchi, T. Kurihara, and M. Mochimaru, "Modeling of Human Hand Link Structure from Optical Motion Capture Data," In Proc. of IEEE/RSJ Int. Conf. on Intelligent Robots and Systems, pp. 2129-2135, 2004.
[4] M. Bordegoni, G. Colomboa, and L. Formentinia, "Haptic technologies for the conceptual and validation phases of product design," Computers & Graphics, Vol.30, No.3, pp. 377-390, 2006.
[5] M. Tideman, M. C. v. d. Voort, and F. J. A. M. v. Houten, "Design and Evaluation of Virtual Gearshift Application," In Proc. of IEEE Intelligent Vehicles Symposium, pp. 465-470, 2004.
[6] J. C. Verlinden, A. d. Smit, A. W. J. Peeters, and M. H. v. Gelderen, "Development of a Flexible Augmented Prototyping System," J. of WSCG, Vol.11, No.3, pp. 496-503, 2003.
[7] K. Terabayashi, N. Miyata, and J. Ota, "Grasp Strategy when Experiencing Hands of Various Sizes," eMinds: Int. J. on Human-Computer Interaction, Vol.1, No.4, pp. 55-74, 2008.
[8] M. Costantini and P. Haggard, "The rubber hand illusion: Sensitivity and reference frame for body ownership," Consciousness and Cognition, Vol.16, No.2, pp. 229-240, 2007.
[9] K. C. Armel and V. S. Ramachandran, "Projecting sensations to external objects: evidence from skin conductance response," Proc. of the Royal Society of London-B, Vol.270, No.1523, pp 1499-1506, 2003.
[10] M. Botvinick and J. Cohen, "Rubber hands 'feel' touch that eyes see," Nature, Vol.391, p. 756, 1998.
[11] A. Iriki, M. Tanaka, and Y. Iwamura, "Coding of modified body schema during tool use by macaque postcentral neurones," Neuroreport, Vol.7, Vol.14, pp. 2325-2326, 1996.
[12] T. Shirai, M. Kaneko, K. Harada, and T. Tsuji, "Scale-Dependent Grasps," In Proc. of the 3rd Int. Conf. on Advanced Mechatronics (ICAM'98), pp. 197-202, 1998.
[13] Japanese body size data 1992-1994, Research Institute of Human Engineering for Quality Life (HQL), 1997. (in Japanese)
[14] L. Peebles and B. Norris, ADULTDATA The Handbook of Adult Anthropometric and Strength Measurements – Data for Design Safety, Department of Trade and Industry, 1998.
[15] V. S. Ramachandran and D. R. Ramachandran, "Phantom Limbs and Neural Plasticity," Archives Neurology, Vol.57, No.3, pp. 317-320, 2000.
[16] V. S. Ramachandran, D. R. Ramachandran, and S. Cobb, "Touch the phantom limb," Nature, Vol.377, pp. 489-490, 2005.



Name:
Kenji Terabayashi

Affiliation:
Assistant Professor, Department of Precision Mechanics, Chuo University

Address:
1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan

Brief Biographical History:

2004 Received M.S. Eng. degree in systems and information engineering from Hokkaido University
2008 Received Ph.D. degree in precision engineering from the University of Tokyo
2008- Assistant Professor at Chuo University

Main Works:

• K. Terabayashi, N. Miyata, and J. Ota, "Grasp Strategy when Experiencing Hands of Various Sizes," eMinds, Int. J. on Human-Computer Interaction, Vol.1, No.4, pp. 55-74, 2008.
• K. Terabayashi, H. Mitsumoto, T. Morita, Y. Aragaki, N. Shimomura, and K. Umeda, "Measurement of Three Dimensional Environment with a Fish-eye Camera Based on Structure From Motion – Error Analysis," J. of Robotics and Mechatronics, Vol.21, No.6, pp. 680-688, 2009.

Membership in Academic Societies:

• The Virtual Reality Society of Japan (VRSJ)
• The Robotics Society of Japan (RSJ)
• The Japan Society for Precision Engineering (JSPE)
• The Japan Society of Mechanical Engineers (JSME)
• The Institute of Image Electronics Engineers of Japan (IIEEJ)
• The Institute of Electrical Engineers of Japan (IEEJ)
• The Institute of Electrical and Electronics Engineers (IEEE)

Name:
Natsuki Miyata

Affiliation:
Researcher, Digital Human Research Center, National Institute of Advanced Industrial Science and Technology (AIST)

Address:
2-3-26 Aomi, Koto-ku, Tokyo 135-0064, Japan

Brief Biographical History:

2000 Received Ph.D. from The University of Tokyo
2000- Joined Mechanical Engineering Laboratory, Agency of Industrial Science and Technology, MITI
2001- Joined Digital Human Laboratory, National Institute of Advanced Industrial Science and Technology (AIST)
2003- Digital Human Research Center, AIST

Main Works:

• N. Miyata, M. Kouchi, and M. Mochimaru, "Generation and Validation of 3D Links for Representative Hand Models," SAE 2007 Trans. J. of Passenger Cars – Electronic and Electrical Systems, SAE, pp. 888-894, 2008.

Membership in Academic Societies:

• The Robotics Society of Japan (RSJ)
• The Japan Society of Mechanical Engineers (JSME)
• The IEEE Robotics and Automation Society

Name:
Kazunori Umeda

Affiliation:
Professor, Department of Precision Mechanics, Chuo University

Address:
1-13-27 Kasuga, Bunkyo-ku, Tokyo 112-8551, Japan

Brief Biographical History:
1994 Received Ph.D. degree in precision machinery engineering from The University of Tokyo
1994- Lecturer at Chuo University
2003-2004 Visiting Worker at National Research Council of Canada
2006- Professor at Chuo University

Main Works:
• N. Hikosaka, K. Watanabe, and K. Umeda, "Development of Obstacle Recognition System of Humanoids Using Relative Disparity Maps from Small Range Image Sensors," J. Robotics and Mechatronics, Vol.19, No.3 pp. 290-297, 2007.
• M. Tateishi, H. Ishiyama, and K. Umeda, "A 200Hz Small Range Image Sensor Using a Multi-Spot Laser Projector," Proc. of IEEE Int. Conf. on Robotics and Automation, pp. 3022-3027, 2008.

Membership in Academic Societies:
• The Robotics Society of Japan (RSJ)
• The Japan Society for Precision Engineering (JSPE)
• The Japan Society of Mechanical Engineers (JSME)
• The Horological Institute of Japan (HIJ)
• The Institute of Electronics, Information and Communication Engineers (IEICE)
• Information Processing Society of Japan (IPSJ)
• The Institute of Electrical and Electronics Engineers (IEEE)

Name:
Jun Ota

Affiliation:
Professor, Research into Artifacts, Center for Engineering (RACE), The University of Tokyo

Address:
5-1-5 Kashiwanoha, Kashiwa, Chiba 277-8568, Japan

Brief Biographical History:
1989-1991 Nippon Steel Corporation, Kanagawa, Japan
1991- The University of Tokyo
1996-1997 Visiting Scholar at Stanford University, Stanford, CA, USA

Main Works:
• J. Ota, "Goal State Optimization Algorithm Considering Computational Resource Constraints and Uncertainty in Task Execution Time," Robotics and Autonomous Systems, Vol.57, No.4, pp. 403-410, 2009.
• N. Fujii and J. Ota, "Rearrangement Task by Multiple Mobile Robots with Efficient Calculation of Task Constraints," Advanced Robotics, Vol.22, No.2, pp. 191-213, 2008.
• S. Hoshino, J. Ota, A. Shinozaki, and H. Hashimoto, "Improved Design Methodology for an Existing Automated Transportation System with Automated Guided Vehicles in a Seaport Container Terminal," Advanced Robotics, Vol.21, No.3, pp. 371-394, 2007.

Membership in Academic Societies:
• The Robotics Society of Japan (RSJ)
• The Society of Instrument and Control Engineers (SICE)
• The Japan Society for Precision Engineers (JSPE)
• The Japan Society of Mechanical Engineers (JSME)
• The Institute of Electrical and Electronics Engineers (IEEE)