Hand Requirements of the Interaction Performance in Older Adults Using Small Electronic Products

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Abstract: Increasingly the world is full of small, handheld, and complex electronic products with modern interfaces, e.g. digital cameras and personal organizers. Most small electronic products can be difficult for older adults to manage, particularly if they have difficulties with fine hand use. Age related changes in fine hand function appear to occur as a decrease in strength, dexterity and range. There is a decrease in hand grip strength and endurance with age, and the average 65 year old users having only 75% of maximal strength. Reduced fine hand use may affect older adults' abilities to press on tiny buttons, hold touch screen stylus, or assemble some accessories (e.g., battery, memory card, and SIM card exchange). Underlying causes of these restrictions may include manual dexterity and hand coordination ability.

While previous research on consumer products has mainly focused on graphic user interface issues, it is argued here that the impact of hand operation tasks represents a further important dimension for small electronic products design. To develop a better understanding of how small electronic products should be designed to facilitate their use by older adults, the study was conducted to explore what problems were encountered by older adult users via an observation of them operating small electronic products. Thirty older adults were selected to conduct a set of manual dexterity test. The researchers then examined two aspects of hand interaction tasks during the observation process in terms of performance, error consequences, and problems. There were three usability tasks: (1) Using the preferred or dominant hand to change/insert mobile phone battery and SIM ; (2) In the manual duration task, participants were required to use fingers to turn on the power at the side of a mobile phone.; (3) For the hand coordination tasks, users were required to insert and remove a memory card using both hands. The time spent for three tasks completion was recorded.

The empirical results, both objective and subjective, found out that current small electronic products still represented many design flaws that resulted in numerous errors and problems when they were used by older adults. The same results were also found when comparing the performance from the tasks, with the strongest correlation occurrred between user's manual ability and the time taken to complete the tasks. Based on elderly users' need revealed in this study, the researchers tried to retrieve small electronic product implications for hand requirements, which could be used easily by individuals across age and ability.

Key words: hand dexterity, older adults, small electronic product interaction.

1. Introduction

The human interface of most technologies, excluding special devices, has been designed for younger users. This trend continues today as human interface designs evolve in the manufacturing of electronic products. Unfortunately, small electronic products that are considered usable by younger adults may be difficult if not impossible to use by older adults primarily due to normal aging factors. Smaller screen, button sizes and assembly parts in particular, may pose as barriers if interfaces are not properly designed for aging vision, cognition, motor skills, and hearing, with such declines accelerating after individuals reach their old ages [5, 8]. Due to this trend, older people tend to have more difficulty using small electronic products, and exhibit poorer performance with these products compared to younger people. Older people also require longer time and made more errors in executing small electronic product work For example, older people show decreased speed and make more slip errors using input and assembly tasks, and encounter more frustration in the use of small electronic products.

Most small electronic products require physical manipulation of controls and manual handling. The hands are used to grasp, move and exert forces to operate various products. Assembly objects can be grasped, pushed and pulled. The human hand is composed of four fingers and an opposable thumb, which is a key to many dexterity tasks [3, 6]. Users can exert clamping forces between fingers to clamp and hold larger objects in the palm of the hand. Individual fingers can be used to exert pulling and pushing forces. Users often use both hands at the same time to manipulate objects. This coordinated movement requires strength and dexterity of the fingers together with sensory capability and motor control. There are many causes of pain that can limit dexterity. Arthritis is one example that is particularly prevalent for older adults, causing stiffness, swelling, and pain in the joints. The satisfaction level for using a small electronic product is seriously affected when it causes pain, even if the small electronic product is still usable. Many able bodied people will experience temporary bruising or breakages that can affect their fine-hand dexterity ability. This causes particular frustration when attempting to use small electronic products that require unusually high levels of strength or two-handed co-ordination.

In order to provide design guidelines for older adults with low hand operation ability, our research focused on the usability of small electronic products, specifically the popular mobile phones or digital cameras as research samples. The nature of the considered ‘‘fine manual operation’’ ability also changes with age [7, 10], especially among older adults. Challenges in the performance of tasks of small electronic product interface, especially in control settings (Depresses the power button of a mobile phonewith fingertips, for example), are considered far more complex than cellular or molecular mechanisms of aging due to complex body and environmental systems involved. Small electronic product performing related tasks, such as touching small and flat button, controlling continuous slider, adjusting knobs with discrete positions, grasping or turning, etc., have been found to be difficult for older adults. Older adults performing these tasks on small electronic products have been found to need assistance especially when performing highly dexterity demanded activities [4]. Given the steady increase in the aging of the technology force in Taiwan and other countries, and given the decline in muscle mass and other functional capacities such as force for task performance, speed, and endurance and dexterity with age, it is important to quantify upper manual dexterity of older adults not only for the design of work, but also for the design of small electronic products used daily by older adults. This paper revealed results from an experimental pilot study conducted to quantify manual dexterity skills and requirements on small electronic product interaction for older adults in Taiwan.

2. Materials and Methods

2.1 Participants

Thirty older adults (ages between 56–66, average age 61.6 years) participated in this research. Twelve out of the thirty participants were female and eighteen were males. There were twenty-eighty right-handers and two left-handers. Older adult participants for the research were recruited from retired recreation centers in the City of Taichung. All older adult participants in the research were Taiwanese. Older adults who had history of arthritis or other muscle-related discomfort in hands or shoulders were excluded from this research. All older adult participants lived independently in their own homes, and led active lives (as evidenced by their participation in daily planned activities in retired recreation centers). All participants in the research were volunteers and were not paid any money or other compensation for their participation.

2.2 Tools, Equipment and Usability Tasks of Small Electronic Products

In this research, the researchers conducted one manual dexterity test and one user observation of small electronic products. Manual dexterity skills in this experiment were measured using a battery of test, the Purdue pegboard test. In user observation, the researchers observed the behaviors of older adults interacting with mobile phones with three usability tasks on related manual-controlled works. The equipments and procedures used were described in detail in the following sections.

2.2.1 The Purdue Pegboard

The Purdue pegboard is intended to measure two types of activities [1, 2, 9]: (1) gross movements of the hands, fingers and arms; and (2) finger dexterity, which can be considered the ability to integrate speed and precision with finely controlled discrete movements of fingers. The Purdue pegboard Model #32020, manufactured by Lafayette Instrument Company, was used in this experiment. This apparatus (Fig. 1) is a wooden pegboard with four cups for pins, collars and washers at the top of the board, and two columns of 25 holes each at the center of the board. The four tests conducted using this equipment included a test with the right hand, a test with the left hand, a test with both hands, and an assembly test.

In preparation for the Purdue pegboard test, participants were seated comfortably at a normal table height. The pegboard was placed directly in front of the participants, with cups containing pins, collars and washers at the far end of the pegboard. It was ensured that cups at the extreme right and extreme left of the center contained 25 pins each, and the cups immediately to the right and left of the center contained 50 collars and 100 washers each, respectively. Participants were then instructed that the goal of the experiment was to determine how many pegs, or assemblies for an assembly task, they could complete in 30 seconds. They were then instructed carefully, one step at a time, the tasks by the researchers, and were allowed time to practice each task until they felt comfortable. The participants were also reminded that, in the actual test, they should not worry about pins or other assembly components that drop, and should proceed with the experiment using components that were available on the pegboard. For tests using only one hand, depending upon which dominant hand of the participant, instructions were provided for both of the right-handed test and the left-handed test. For the right-hand test, participants were instructed to pick one pin at a time with their right hand from the right-hand cup. They were then asked to place each pin in holes along the right-hand column of the pegboard, beginning from the top hole. Participants were instructed that they had to place as many pins as they could, working as rapidly as possible, until the investigator requested them to stop at the end of 30 seconds. The number of pins placed in 30 seconds with the right hand, which was monitored with a stop watch, was recorded. For the left-hand test, participants were instructed to pick one pin at a time with their left hand from the left-hand cup. Participants were requested to place the pins in holes along the left-hand column of the pegboard beginning from the top hole, working as rapidly as possible. The number of pins placed in 30 seconds with the left hand was recorded. For the test requiring both hands, participants were instructed that they were to use both hands at the same time for the tasks. They were instructed to pick up a pin from the right-hand cup with their right hand, and at the same time pick up a pin from the left-hand cup with their left hand. They were to then place the pins down the right-hand and the left-hand column of the pegboard, respectively, beginning from the top of the board. The total number of pins placed with both hands in a 30s time interval was recorded. For the Purdue pegboard assembly task, participants were required to pick up one pin from the right-hand cup with their right hand, and while they were placing it in the top hole along the right-hand column of the board, to pick up a washer with their left hand. As soon as a pin was placed, they were directed to drop the washer over the pin. While the washer was being placed, participants were to pick up a collar with their right hand. While the collar was being dropped over the pin, they were to pick up another washer with their left hand and drop it over the collar. This series of tasks completed the first assembly consisting of a pin, a washer, a collar and a washer. Participants were instructed that when the final washer for the first assembly was being placed with their left hand, they were to begin the second assembly immediately by picking up another pin with their right hand, and continue placing it in the next hole. The total number of pieces assembled in 30s was recorded. Since each assembly consisted of four pieces, each piece placed in the pegboard was counted as a point, and each completed assembly was counted four points.

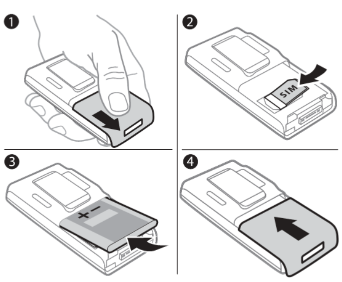
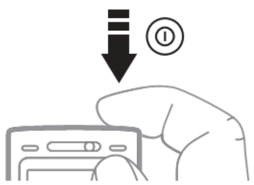
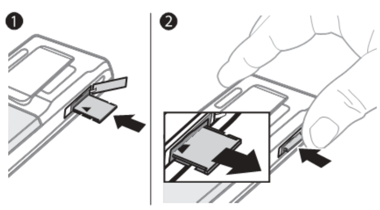
Figure.1 The Purdue pegboard test and experimental environment

2.2.2 Usability Tasks on Assembly Works of Small Electronic Products

Before observations started, the researchers explained the purpose of the experiment and the basic functions of the apparatus. The detailed operation methods of the small electronic product controls were not mentioned as the researchers intended to observe the natural behaviors and problems coming from the expectations and intentions of each participant. The participants performed 3 operating tasks in each observation (Table 1). No time limits were imposed; however, the participants were asked to perform the tasks as accurately and as quickly as possible. Interaction times and behaviors were recorded by the researchers during the observations, and the observations were recorded for later review. The researcher was a Ph.D. candidate majored in HCI, and had more than four years of experiences in projects involving product designs, user observations, usability evaluations, and interface designs.

After each task was completed, the participants were asked to provide a spoken protocol describing their performance and explaining their interpretation of their manipulated process during the task. The researchers remained silent during this stage but asked follow-up questions on anything that remained unclear. The participants were debriefed after the follow-up period and offered an opportunity to discuss the study. In user observations, the interaction spoken protocols of participants were examined after completion of all 3 tasks. Each three-task observation lasted for approximately 5 to 10 minutes.

Table 1. Task Description

Task		Description
Task 1 Insert SIM card and battery		Insert SIM card and battery using both hands. 1. Remove the battery cover. 2. Slide the SIM card into its holder with the contacts facing down. 3. Insert the battery with the label side up and the connectors facing each other. 4. Slide the battery cover into place.
Task 2 Turn on the phone		Press and hold to turn on the power button using the preferred hand. The first start-up may take a few minutes.
Task 3 To insert and remove a memory card		1. Open the cover and insert as shown (with the contacts facing down). 2. Press the edge to release and remove.

2.3 Data Analysis

Since this research was a pilot study, data from participants were combined. In the manual ability test on Purdue Pegboard, summary statistics including the means, standard deviations, and ranges were first obtained for older adults. In addition, to determine if and to what extent manual dexterity affected task performance on small electronic products, three sets of Pearson-product moment correlations were calculated to examine the relationship between fine-hand dexterity ability and task performance. All statistical analyses were computed using SPSS Version 13 statistical analysis software.

3. Results

Table 2 presented summary statistics based on the Purdue pegboard tests for older adults in Taiwan (men and women together). The results revealed that the preferred hand, as compared with the non-preferred hand, had better performance. Table 3 demonstrated the results of this research comparing to those quoted by other studies conducted in the same idea with the manual-hand dexterity test [2, 3, 9]. Results indicated that Taiwanese older adults placed fewer pins in fine dexterity and coordination than the subjects in other researches. The different age range and sample size of the subjects between the present research and other studies might be one of the reasons that contributed to different results.

Table 2. Summary Statistics for Manual Ability on Purdue Pegboard Test for Older Adults

Characteristics	Mean	SD	Minimum	Maximum
Age(years)	61.6	2.6	56	66
Purdue pegboard test (number of pegs (or assemblies)/30 s)				
Preferred hand	11.9	1.7	9	15
Non-preferred hand	10.5	1.1	8	12
Both hands	8.5	1.6	6	11
Assembly	17.4	2.1	14	21

Table 3. Comparison on Manual Ability Test's Scores with The Other Similar Studies

Characteristics	Age(years)	Sample size	Preferred hand	Non-preferred hand	Both hands	Assembly
The present research	61.6	30	11.9	10.5	8.5	17.4
Desrosiers, J.et al. (1999)	72	360	12.5	12.0	9.5	25.9
Pennathur, A. et al. (2003)	71.3	18	12.9	11.3	9.5	21.5
Desai, K. et al.(2005)	60.1	70	13.5	13	11.5	28.5

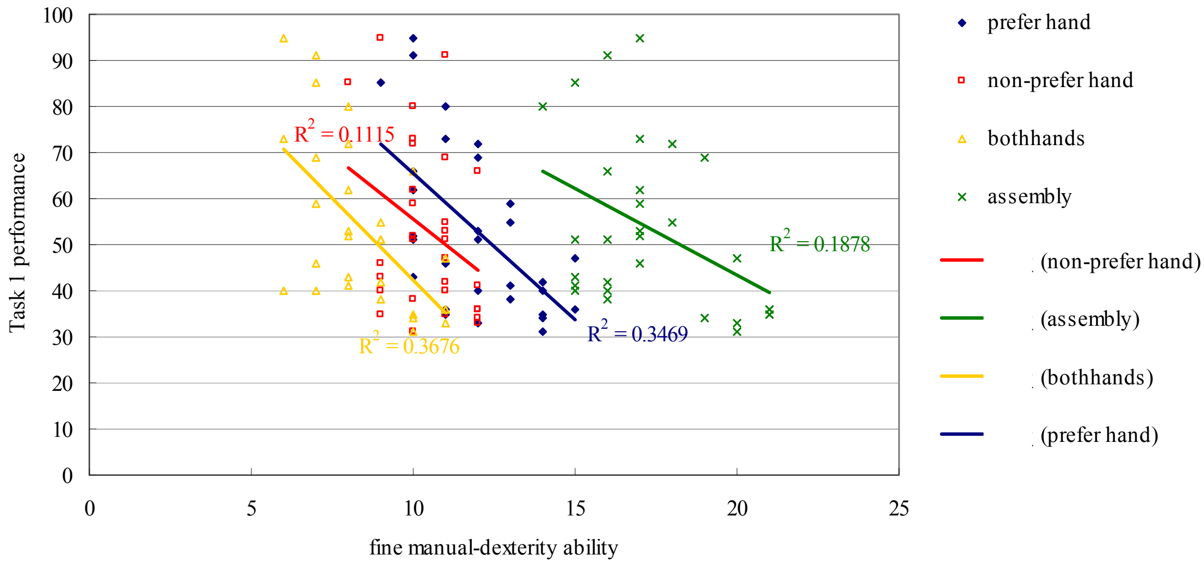
Table 4. Coefficient of Correlation between Fine-Hand Dexterity Ability and Task Performance

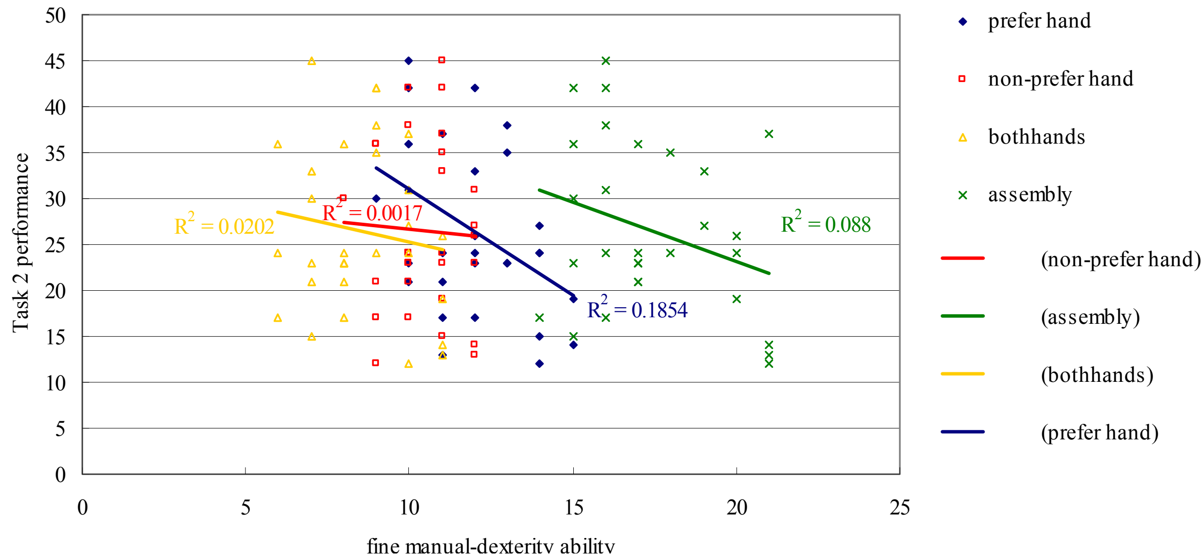
Correlations		Task 1	Task 2	Task 3
Preferred hand	Pearson Correlation	-.589**	-.431*	-.249
	Sig. (2-tailed)	.001	.018	.184
	N	30	30	30
Non-preferred hand	Pearson Correlation	-.334	-.041	-.448*
	Sig. (2-tailed)	.071	.831	.013
	N	30	30	30
Both hands	Pearson Correlation	-.606**	-.142	-.404*
	Sig. (2-tailed)	.000	.453	.027
	N	30	30	30
Assembly	Pearson Correlation	-.433*	-.297	-.131
	Sig. (2-tailed)	.017	.111	.490
	N	30	30	30

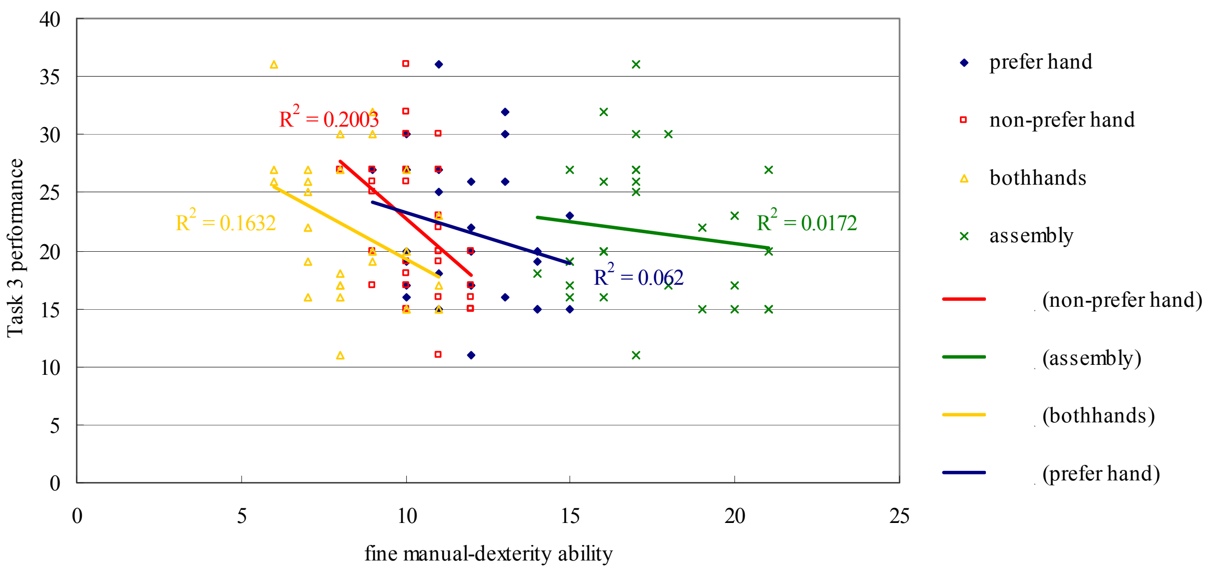
*. Correlation is significant at the 0.05 level (2-tailed).

**. Correlation is significant at the 0.01 level (2-tailed).

Table 5. Coefficient of Correlation between Fine Manual-Dexterity Ability and 3 Task Performances







The users' performances were analyzed by examining the completion time for each task. Although a wide range of dexterity skills were assessed, there might be other equally relevant aspects of hand function that were not put into consideration. The results showed evidence of a relationship between fine-hand dexterity ability and task performance as shown in table 4 and table 5. In task 1(Insert SIM card and battery),) assessing preferred hand performance, both hand and assembly measures from Purdue pegboard test demonstrated significant correlations between scores and time taken ($p<0.01$). Those older participants with higher overall fine-hand dexterity scores were faster in achieving the correct sequence of tasks than the others with lower overall fine-hand dexterity scores. Considering the preferred hand and both hands, these two exhibited a statistically strong negative correlation (r=.589 & r=.606) on task 1. This outcome suggested that the three types of manual function and task 1 performance were associated in older adults, i.e., the decrease in manual function might predict decreased performance. However, in task 2(turn on the phone), only the test results of the preferred hand performance variablerevealed significant correlations between scores and time taken ($p<0.05$). This result indicated the preferred hand ability demonstrated a medium strong negative correlation (r=.431) on task 2. Likewise, in task 3 (To insert and remove a memory card), assessing the preferred hand and non-preferred hand performance, also presented significant correlations between scores and time taken ($p<0.05$). This result showed a negative correlation (r=.448 & r=.404) between the preferred hand and non-preferred hand ability on task 3.

4. Discussion

Despite a considerable body of literature on the assessment of manual dexterity, there have been few studies of its functional implications for older adults. Because small electronic products tend to have minute working parts during assembly operation procedures, their use requires fine manual skills. While most prior works examining the impact of manual skills on technology product use by older adults have focused on input devices, the current study herein examined fine manual skills in the use of various assembly tasks of small electronic products. The experimental results and observations revealed that older adults suffered from temporary or permanent barriers that also reduced the usability of both hands while operating these tasks. One kind of barriers was that older adults showed a tendency to push force using wrong part of the hand when interacted with the tiny parts of in a small electronic product, especially in tasks that required manual dexterity for task initiation, task performance, and task completion, including (a) locating a target requiring the coordination of hand movements, (b) reaching, involving transportation of the arm and hand in space, (c) manipulation, such as grip formation, grasp, and release, and (d) postural control. For older adults, this dexterity demand was complicated; therefore, an alternative design would allow the action to be executed efficiently, which also typically reduced design exclusion and increased user satisfaction.

In this research, the Purdue Pegboard was utilized as an assessment tool to measure a factor called finger dexterity that was defined as the ability to make rapid, skillful controlled movement of small objects where fingers were primarily involved. This was different from the factor of manual dexterity, which was defined as the ability to make skillful and well directed arm-hand movements in manipulating fairly large objects under speed control. In general, some critical dexterity functions for small electronic product interactions were considered in this session. The results from task 1 showed significant correlations in relationships among preferred hand, both hand ability, assembly function and task performance. This finding was in accordance with the results of

Hourcade et al. [7]. Task 1(Insert SIM card and battery) required the use of both hands at the same time to Insert SIM card and battery. When older participants tried to open the mobile phone battery cover, it seemed to be difficult for them to push and grip using the index finger and thumb to generate opposing forces. Furthermore, when the fingers or palm were employed to exert forces on some small items, the movement and force were aligned in the same direction for older adults, resulting in a requirement for the friction contact. Pushing back and down was used to depress buttons and phone cover, such as that required for this task. It was more difficult to push back than down because the wrist had to rotate at certain degrees if the finger and palm were required to push upwards. Task 1 required the use of both hands to perform a combination of pushing or gripping. One hand was often required to hold or stabilize the mobile phone, while the other performed fine precision movements.

Results were found in accordance with the assumption of this research in task 2 from older participants' observations and spoken protocols. For older participants, finger duration and movement rectitude varied as predicted as a function of the probabilistic association strength. Since electronic products were developed smaller than ever before, their related control parts were produced more miniature as well. Moreover, there were more and more operating behaviors similar to task 2 requiring for exercising small electronic products; this pattern was presented and constrained in difficult conditions. Given the decline in muscle mass and other functional capacities such as force for task performance, speed, endurance and dexterity with age [3, 9, 10], older adults exhibited problems in the shorter touching duration and straighter pointing direction. As a result, it is important to quantify the manual endurance of older adults not only for the design of work, but also for the design of products and systems of daily use that might be utilized by older adults.

In order to perform task 3, pinch gripping, the ability to develop fingertip opposable forces between the thumb and fingers of the hand, was required. Pinch grips were commonly used to manipulate controls such as socket plug and line insert (Fig. 2.), which only required minimal forces. However, while interacting with such assembly works; older adults did not have enough strength to power the pinch for mini card insertion and replacement in the right direction. In the design field, careful provision of shape and surface texture of controls should allow older adults to operate a product with a loose grip formed with his or her preferred combination of thumb and fingers. The maximum gripping force that could be generated by a pinch grip was dependent on the size and shape of the object to be taken. Rectangle and thin objects such as the memory card tended to be difficult to pinch and grab as the fingers often slipped on the surface. The best shape for pinch grip turning allowed the thumb and fingers to grasp either side of long strip for older adults.

Figure.2 Hand Requirements When Assembling Part of a Small Electronic Product

5. Conclusion

As aging progresses, various decreases in fine hand functional capacity may limit some older adults' potential to engage in dexterity-demanded physical work. If a person's physical capabilities have become marginal, the quantity of life will diminish in the living environment, which may lead to poor quality of life, low self-confidence and efficacy. This research focused on the potential constraints of small electronic product usability that could limit the efficiency of an older person. The results of this research provided hand dexterity data including a certain range of different capabilities of older adults. Repeatedly, using the assembly works as an example, the data demonstrated the limits of the amount of force needed to operate tiny electronic product parts for different aged population. Furthermore, such data can be applied by designers to develop future cases for more an accessible design. The data would also be used to demonstrate an increase of the number of people who were able to use the product easily and effectively if the dexterity requirement was maintained below a certain declined level. The results of the research provided evidence in the hope that manufacturers could define the potential markets for their products based on strength required for easy operation in the future work.

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