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The Kitchen Product Design Oriented to the Motor Capability of Armless People

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ABSTRACT

The research adopts the methods of questionnaire, interview and behavior observation to study the Motor Capability of armless people in four dimensions (strength, dexterity, reach and mobility), summarizes the product design strategy using lower limbs and feet from six dimensions (position, shape, force, precision, task and environment) based on the Capability-Demand theory, and designs on this basis.

Keywords: Armless people, Inclusive design, Motor capability, Kitchen product

INTRODUCTION

There are 24.72 million physically disabled people in China (China Disabled Persons' Federation, 2021), of which the upper limb disabled account for about 18.43% (Zhiquan Liu, 2003). Armless people are the most serious group of people with upper limb disabilities. At present, there are few auxiliary devices designed for the motor capabilities of armless people and most of them use products designed for ordinary people clamping by their feet during the process of cooking, which makes it difficult to ensure the operation efficiency, safety and comfort.

THEORETICAL RESEARCH ON MOTOR CAPABILITY

The Capability-Demand theory was proposed by the i-design team in response to the initiative of Equal, which puts forward paying more attention to the disabled and the elderly, and contributes to the social integration (John Clarkson et al., 2015). The capabilities in this theory represent the capabilities of users, which are divided into sensory, cognitive and motor capabilities. Among them, the user's motor capabilities can be subdivided into reach, dexterity and mobility (Waller S. et al., 2010). Demands indicate the demands of products for user's capabilities (hereinafter referred to as product demands). The relationship between the two depends on the specific ongoing activities and the background of the activities (Persad et al., 2007). When the product demands are higher than the user's capabilities, there will be the user exclusion phenomenon. The more complex the product demands require, the more excluded users will be. And we can reduce the product demands to better match user's capabilities to reduce exclusion.

Figure 1: Result of motor capability questionnaire for armless people (under kitchen scenario).

RESEARCH ON MOTOR CAPABILITIES OF ARMLESS PEOPLE

Studying the motor capabilities of armless people will help designers understand the advantages of this kind of people's motor capabilities. It is assumed that users' sensory and cognitive abilities are normal in order to exclude the influence of other users' capabilities on the experiment. From the perspective of research dimension, the user's motor capabilities are divided into four dimensions: strength, reach, dexterity and mobility. The questionnaire design refers to the research on users' motor capabilities in capability-demand theory. For example, according to the dexterity of the user's main hand, it is set that there is no need to do any precise action to control the cooker knob, pick up the pin from the desktop with fingers, write with a pen and do other more difficult things (Department of Social Security, 2000). After observing the behavior of high-frequency operation in the kitchen scene, the author abstracts and sorts it from easy to difficult (see Figure 1). The evaluation methods of participants mainly include the following five dimensions: ① 0 point mean "can't do it", which can't be mastered by any practice; ② 1-3 points mean "relatively difficult", which is still difficult to master after a long time of practice; ③ 4-6 points mean "average", which takes some time to practice and master; ④ 7-9 points mean "relatively easy", which requires certain strength and accuracy; ⑤ 10 points mean "very easy", which can be completed quickly and comfortably. A total of 14 valid questionnaires were collected from armless people, of which 57.14% were men and 42.86% were women; most of which are young and middle-aged, accounting for 64.29% at the age of 31 to 40.

Strength Capability: There are 6 items including 1.1-1.6 sorted out (see Figure 1). The results show that when pressing and other force application operations are needed, sitting posture is a better operation posture; the score of holding articles with feet is also high (especially when the weight is small) among various operation modes, suggesting that toes clamping mode can be considered as one of the user's operation modes in the design of lighter products. While some behaviors that require more fine movements and strength

ability score lower such as screwing the bottle cap, showing that we should try to avoid the product demands with excessive strength requirements.

Dexterity Capability: A total of 16 items including 2.1-2.16 are sorted out (see Figure 1) and we can see from 2.1-2.8 that movements that use the lower extremities and feet to perform simple non-fine movements (such as pressing), contact manipulations that require only part of the existing limb area (such as the bottom of the toes), and wide grasping without the toes or wide range of joint movement scored higher. 2.9-2.16 suggest that the design of cylindrical auxiliary experience is easier to clamp and transfer positions than flake things when it is necessary to transfer items. From different switch forms, the push switch is relatively simple and the experience of applying force on the horizontal or vertical plane is the same.

Reach Capability: 6 items from 3.1 to 3.6 are sorted out (see Figure 1). It can be seen that the standing posture with back against an object has stronger reach capability than the sitting posture and it is easier to reach the positions such as half meter in front and half meter on the right and left, while the upper half meter is more difficult, it requires the higher flexibility of the lower limbs and the balance of the body.

Mobility Capability: Total 4 items from 4.1 to 4.4 are sorted out (see Figure 1). The scores of going up and down stairs and walking are high. Most of the respondents are able to stand and walk normally, but the scores of going up and down high stools are relatively low, indicating that this action requires users to have good balance without the assistance of upper limbs.

It can be seen from the questionnaire results that the higher the score of the corresponding survey results, the easier the users' action is to do and the stronger the users' motor capability for the action. When the product use mode matches the user's strong motor capability, the armless person will be easier to use and more friendly to the user.

RESEARCH OF FOOD PROCESSING PRODUCTS FOR ARMLESS PEOPLE

This paper takes the steps of processing food materials in the kitchen scene as an example to analyze and explain the key points and demands of armless people. The research adopts the methods of behavior observation and data collection combined with one-to-one in-depth interviews. A total of 6 armless people were observed and interviewed, and all 6 respondents had occupations and sources of income. The interview mainly asked about basic personal information and scored the existing common kitchen food processing products from multiple dimensions (see Figure 2). Among them, knives have the highest use frequency and necessity of the cutting tools, but its operation takes the longest time with the difficulties. Although the use frequency of the vegetable cutting tool is low, it takes the least time with the simplest operation. It is a good supplement to cut. Therefore, we will focus on two products of knives and vegetable cutting tools when selecting research products.

The research mainly discusses the use mode and process of Chinese kitchen knives, and it takes the right foot as an example (see Figure 3). One of the

	Study-time	Usage frequency	Operation time	Difficulty of operation	Operating comfort	necessity of use
Knife	4.20 difficult to learn	3.60 frequently used	3.60 time consuming	3.60 Difficult to operate	2.80 uncomfortable	4.20 necessary
Skin-peeler	2.00	1.25	1.75	1.75	3.25	2.25
Scissors	3.00	4.00	2.83	2.16	2.80	3.66
Veggie chopper	2.25 easy to learn	1.00 uncommonly used	1.25 Short operation time	1.50 easy to use	3.75 comfortable	3.00 generally necessary
Meat grinder	2.25	1.25	1.25	1.75	4.00	1.75

Figure 2: Scoring results of armless people on common used food processing tools.

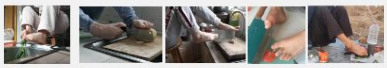
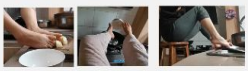
	Preparation	Pretreatment & treatment	Finish
Schematic	 ①Keep a stable sitting posture ②Place cutting boards and knives	 ③ Clean the ingredients and transfer the ingredients to the cutting board ④Cut the ingredients into sections, blocks, slices, strips, and cubes	 ⑤ Transfer the ingredients to the pot ⑥Clean and place knives and cutting boards
How to use	① Support up and down with one foot, leaning against the back of the chair for support ② Clamp the back of the knife and the cutting board with the toes of both feet and place it on a flat surface	③ Use the soles of your feet to wash the vegetables, and place the ingredients on the cutting board with your toes ④ **Left foot:** fix the ingredients with the left foot; press the back of the knife with the left toe; tap the back of the knife with the left foot; hold the back of the knife with the left toe and rotate the ankle | **Right Foot:** The right toe grips the handle/blade part, moving up and down and back and forth | **Left and right feet:** The left and right toes work together to clamp the cutter head part of the knife handle, and move up and down to cut	⑤ Use the front half of the soles of the feet to gather together, cooperate with the toes to hold the ingredients or containers, and transfer them to the pot ⑥Use the front half of the sole of the foot, dip in the detergent and rub between the knife surface and the cutting board, sometimes with the help of a cleaning cloth
Product demands	Strength 1.1，1.5；Dexterity 2.9，2.10；Reach 3.1-3.3；Mobility 4.4	Dexterity 2.9-2.12；Reach 3.1, 3.2	Dexterity 2.4，2.5；Reach 3.1，3.2
Problems	1. The kitchen countertop is high and the sitting surface also needs to be raised which is easy to cause a fall event 2. For kitchen knives that are put down, the handle and blade are difficult to hold and clamped. The contact surface is smooth and the temperature is low.	1、The distance between the eyes and the feet is far, and the details of the fixed position cannot be clearly seen, which is easy to accidentally hurt; 2、The Precision of the toes is poor, and the fixed ingredients are prone to slip due to temperature, humidity and shape, which are prone to accidental injury; 3、There are three ways of clamping, the upper part of the blade, the lower part of the blade and the handle, all of which face problems such as small contact surface, smooth contact surface, low contact surface temperature, the toes are wide open or need to be twisted 4、In order to provide greater cutting force, the foot strikes the back of the knife downward, and the force application surface is small, which is the line of the back of the knife. At the same time, it becomes more difficult to fix the knife when it is impacted downward and the ingredients are more likely to slip 5、It involves fine operation, which takes a long time and requires high flexibility of the feet, vision, flexibility and balance of the body	1、The transfer efficiency is low, the amount of each transfer is small, it is easy to fall, and can not make it completely clean; 2、Rotating the bowl/dish requires fine and slow motion operation, requires feet off the ground and lacks support, and the speed is too fast to cause splashing 3、When cleaning the knife, the friction force is small, and the clamping tool falls off and easily scratches the feet 4、Difficult to effectively clean the blade due to the field of vision and the flexibility of the body

Figure 3: Survey results on the use of cutting tools by armless people.

most prominent problems is that the lower limb operates tools without the suitable grasping and force application position, and armless people will use their toes to clamp the tool surface or handle. At this time, the toes are required to open larger and clamp the cutting tool to twist, facing the problems of small contact surface, smooth and low temperature as well as the small downward cutting force. Secondly, due to the long distance and line of sight occlusion, users can't see the fixed position and other details, or sit on a higher seat, or slip easily due to the shape, humidity of fixed ingredients, etc., which are very easy to cause injuries. Operating the cutting tool involves fine movements and it takes a long time, requiring high foot dexterity, strength and balance of body, even vision and so on.

The vegetable cutting tools can save time and labor compared with using a kitchen knife. Currently, most of the vegetable cutting tools on the market need both upper limbs to participate while using. Meanwhile, it also involves a variety of complex motion behaviors such as rotation, pressing, fixation and reciprocating (see Figure 4). When dealing with large food materials, it is usually necessary to pretreat the food materials with a knife before using

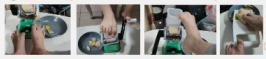
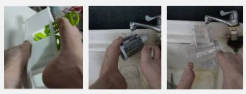
	Preparation	Pretreatment & treatment	Finish
Schematic	 ① Install Vegetable Cutter and Blades	 ② Wash ③ Pretreatment with knife ④Transfer  ⑤ Control switch and speed ⑥ Press the ingredients ⑦ Replace the blade ⑧Transfer	 ⑨ Take out the blade ⑩Clean the blade ⑪ Clean the container ⑫ Storage
How to use	Use the toes to hold the blade and insert it into the card slot, if it is electric, also need to operate the plug	Use a knife to pretreat the ingredients, cut the ingredients, and then put the ingredients into the vegetable cutter with toes	Requires toe-grip blade cleaning and use the front of the foot to enter the container for overall space cleaning
Product demands	Dexterity 2.9-2.12; Reach 3.1, 3.2	Dexterity 2.1-2.12; Reach3.1, 3.2; Strength 1.1, 1.4	Dexterity2.4, 2.8; Reach3.1, 3.2
Problems	1. The installation process is complicated and takes a lot of time and energy 2. The installation action have many processes, such as installing the blade which requires fine hand operation	1. Even if a vegetable cutter is used, food materials still need to be pretreated in most scenes, and knives are still used in the process 2. When it is necessary to change the processing mode of food materials (slice or shred), it is necessary to remove and install blades 3. It is difficult to transfer food materials which need to be poured out of the container	1. Take out the blade every time you clean it, and install it again next time you use it 2. During the use of the vegetable cutter, the ingredients in the container often stick together, and it is necessary to go deep into the container for cleaning, which is difficult to clean.

Figure 4: Survey results on the use of vegetable cutters by armless people.

	Preparation	Pretreatment& treatment	Finish
How to use	• Comfortable, foot-friendly posture	• The foot is better for gripping or control • Improve foot contact surface comfort • Provides an easier and easier way to apply force to the foot	• A fast and efficient transfer method that is more suitable for the foot • A more appropriate way to clean product with your feet
Use flow	• Reasonable storage method • Quick and easy installation	• Simplify the cutting method and reduce the cutting time • More effective fixation of ingredients to prevent slippage • Provide different cutting methods according to different ingredients	• Transfer ingredients in one step, eliminating intermediate transfer steps • Easier cleaning process

Figure 5: Summary of armless people's demands for food processing products.

the vegetable cutting tools. In addition, they are difficult foot operations that often disassemble and replace the blade, and clean the container and blade after use.

Based on the above research on knives and vegetable cutting tools, the paper comprehensively sorted out and analyzed the demands of armless people while using food processing products (see Figure 5).

Product Design Strategies for Armless People

According to the design strategy of products using hand interaction in the Capability-Demand theory (Inclusive design toolkit, 2022), combined with the specific motor capabilities and demands of armless people, we analyze and summarize the design strategy of using foot interaction with products, which can be used to guide the follow-up design practice (see Figure 6).

① **Position Dimension**: The product design requires to consider the use posture, use gap, flexibility and foot lifting height of armless users as well as avoiding the discomfort while using. By taking the food processing products discussed above as an example, it is recommended that armless people choose the sitting position, and the height difference between the hip sitting surface and the operating surface is 0.1H (H is the height of

A-Position requirements	**1、Posture** -If you need to operate carefully, choose a sitting position. If you need more stretching ability, choose a standing position with your back against the object. Try to avoid the standing position. - For seated operation, the height difference between the sitting surface of the buttocks and the operating surface should be kept at 0.1H (the height of the user)	**2、Consider clearance** - Feet and lower limbs can access products and controls, and keep lower limb joints in joint functional position as much as possible	**3、Allow ambidextrous use.** - Supports use of left or right foot - Try to avoid using both feet at the same time	**4、Consider foot lift** - Consider standing or standing with your back against an object to raise your feet - Consider seated foot lift height	**5、Avoid awkward reach requirements** - Avoid sticking your feet over your head or behind your back - In terms of product accessibility, extending the lower limbs to the front is better than the left and right sides, better than the top
B-Shape: Flexibility of use	**6、Allow different grips** - Provide as many grips as possible	**7、Help users to change grip.** -Easy switching of grips	**8、Consider clearance.** —Products and controls are accessible to the feet and lower extremities, avoiding holes where the feet cannot be reached, etc.	**9、Allow ambidextrous use** - Support using left or right foot or left or right toe - Try to avoid using both feet at the same time	
B -Shape: Suitability for the task	**10、Promote good grips.** - Consider grip size and accuracy according to the type of task	**11、Consider ankle position** - When grasping, the ankle should be in the joint functional position as much as possible			
B -Shape: Ease of gripping	**12、Minimize strength requirements.** —Provide annular, cylindrical, sheet shape clamping and supplemented by contour changes, the specific size should be determined according to the function of the product	**13、Take care with turning controls** - Use a low-effort lever for turning			
B-Shape: Contact area	**14、Consider surface texture** - The friction force of the surface texture in the contact area is large - elastic or viscoelastic surface (rubber texture)	**15、Distribute pressure** - Distribute the pressure on the feet evenly across the contact area.	**16、Avoid sharp contact points** - Avoid corners or edges coming into contact with the feet		
C-Force requirements	**17、Consider force requirements.** - If excessive force is required, the force application method needs to be adjusted - The weight of the product is preferably less than 1kg, and it is better to bear 500g on one foot	**18、Enable pushing down** —Try to give priority to applying force methods such as pressing down and pedaling	**19、Provide gripping aids** - Provides annular, cylindrical, and sheet-like shape clamping with contour changes when gripping forcefully	**20、Consider force direction** - Press down instead of up - away from the body instead of pushing towards the center of the body	**21、Consider ankle position.** —When grasping, the ankle should be in the joint functional position as much as possible
D-Precision requirements	**22、Consider precision requirements** - If the accuracy is too high, the operation method needs to be adjusted (such as piercing the eye of the needle), and the accuracy standard is judged according to the user's characteristics	**23、Consider vision and dexterity** - Avoid tasks that require vision and dexterity for precise alignment - Use the lower limbs to do simple non-fine movements, only need to touch a part of the limb area, no large-scale grasping such as toes, and no large-scale joint movements	**24、Avoid complicated movements** - Avoid simultaneous movements in different directions		
E-Task requirements	**25、Duration** —Longer duration should reduce weight	**26、Avoid repetitive movements** —Avoid strain from repetitive movements	**27、Optimize the process, simplify the steps** - Reasonable design to simplify operation steps and reduce time	**28、Task failure** —Minimise consequences of task failure	**29、Feedback** —Provide feedback on the appropriateness of the forces generated
F-Environmental context	**30、Friction** —Sweaty feet, shoes and socks, wet, lubricant conditions with different friction	**31、Temperature** —Toe sensitivity, flexibility changes with temperature	**32、Illumination** —Relying on touch in low or invisible light conditions		

Figure 6: Design strategies for using feet to interact with products.

the operator). ② **Shape Dimension**: It needs to support the flexible use, is suitable for tasks and easy to grasp, and considers the contact area between the product and the body. For armless users, there are a variety of gripping methods (such as toe gripping and instep gripping) provided, it selects the grip according to the task type and provides annular, cylindrical and sheet shapes supplemented by changes in contour. And it can also be considered from the surface friction and contact area. ③ **Force Dimension**: It should take the force bearing capacity of lower limbs into considerations; the weight of a single foot shall be maintained at 500g (5 potatoes); the force application method of downward pressure shall be given priority; we should focus on the direction of force and try to make the ankle and wrist in the joint functional position, which could avoid joint damage caused by long-term force application (Yulan Ding, 2017). (see Figure 6).

CONCLUSION

This paper studies the motor capabilities of armless people and the demands for food processing products through two surveys. The research on armless people can provide the reference for product design for this vulnerable group. As a group with the low attention at the social, market and design levels, the research expands the connotation and scope of inclusive design to a certain extent. More importantly, it can help more newly created armless people to reduce the cost of learning, quickly adapt to life and improve their self-care ability, and to a certain extent, it can also reduce the psychological and physical pressure of such users and their family members.

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