sustainability

MDPI

*Article*

# Study on the Design of a Water Dispenser for Visually Impaired Families

**Qiong Shen [1], Feng Zhou [1,*], Yichen Wang [2], Shiyuan Tang [1] and Pengyu Zhang [1]**

[1] College of Mechanical Engineering, Donghua University, Shanghai 201620, China; shenqiong@dhu.edu.cn (Q.S.); claudia306@163.com (S.T.); zhangpengyu990301@163.com (P.Z.)
[2] Industrial Design Apartment, School of Design, Pratt Institute, 200 Willoughby Ave, Brooklyn, NY 11205, USA; ywang137@pratt.edu
* Correspondence: zhoufeng@dhu.edu.cn; Tel.: +86-198-2127-3731

**Abstract:** In visually impaired families, there are different needs in terms of the access to drinking water, and the existing research on the design of water dispensers is insufficient. In order to solve this problem, a diverse analysis, based on the inclusive design concept, of household users' operating abilities and water dispenser preferences was carried out. Subsequently and guided by the analysis, a new water dispenser product was developed. The methods used to extrapolate the needs of visually impaired families were observation and interviews, while the questionnaire research was used to understand the user preferences. Secondly, the accessibility of the existing water dispenser was tested for visually impaired, elderly, middle-aged, and young users in the visually impaired family. Three design strategies were proposed that combine the needs and product preferences of the users: the multimode simplification of steps, water quality detection, and adaptive multichannel feedback. The water dispenser was redesigned on the basis of these. On the premise of meeting the different abilities of the users in visually impaired families, the design practice improves the users' experience of water dispensers, and provides a practical method reference that has value for related product designs.

**Keywords:** inclusive design; visually impaired families; water dispenser; user diversity

**Citation:** Shen, Q.; Zhou, F.; Wang, Y.; Tang, S.; Zhang, P. Study on the Design of a Water Dispenser for Visually Impaired Families. *Sustainability* **2022**, *14*, 2081. https://doi.org/10.3390/su14042081

Academic Editor: Andreas N. Angelakis

Received: 19 January 2022
Accepted: 8 February 2022
Published: 11 February 2022

**Publisher's Note:** MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

**Copyright:** © 2022 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

## 1. Introduction

With the advent of an aging society and the development of the digital age, the per capita screen-use time has increased, and there is a rapid growth trend of visually impaired people, including blind and low-vision people [1]. In China's visual impairment classification standard, according to the range of the best corrected vision, visually impaired people are divided into Grade I and Grade II in terms of the blindness levels, and into Grade III and Grade IV in terms of the low-vision levels [2]. Globally, there are nearly 285 million visually impaired people, of whom more than 80% are over 50 years old [3]. As a necessary behavior for survival, there are different needs for drinking water in various scenarios because of the improvements in the living environments and the continuous popularization of health preservation concepts [4]. At present, there are innovative designs of water dispensers that are based on the perceptual needs of users [5], and there are also studies on the design of a remote wireless control system for water dispensers from a technical perspective [6]. However, in the design of the existing domestic water dispensers, there is still a lack of related designs that take into account the visually impaired. In the preliminary study, a design practice was carried out to solve this problem by reducing the visual requirements for the use of water dispensers for the visually impaired. The physical button operation, the water outlet button, with a certain angle, and the angular shape, which facilitates the recognition of the direction for the visually impaired, were designed to meet the needs of the visually impaired for using the water

dispenser independently, and for improving their use experiences. However, the verification results show that the needs of the visually impaired and normal-sighted users at home are mutually exclusive. The research that only focuses on the use abilities of the visually impaired ignores the needs of the other family users with normal vision. On the basis of the concept of inclusive design, this study creatively takes the subjective needs of the users into consideration by taking the abilities and needs of various users in visually impaired families as the fundamental determinants of the water dispenser design, so as to make inclusive design more practical and sustainable.

There are two innovative aspects of this study: the focus on the use scenarios of visually impaired families, and on building a design framework that meets the diverse needs of users on the basis of their abilities. The study of a water dispenser that is based on the users' diverse needs and abilities provides a method reference for the purpose of solving the problem that a single product has certain limits when it comes to meeting the diverse needs of users with different abilities. This study delivers respect for the diversity and differences among users so that the design can more effectively contain the diversity of needs within limited resources.

This study involves the verification of practical results, and it adds the evaluation of the users' abilities in the usability testing stage of the existing water dispensers. According to the test results, the usability indictor—the user capability function—was constructed to calculate the inclusive mean. The inclusive mean and the availability mean were used as the research verification indicators [7]. For the design scenario of visually impaired families whose users' abilities are different, the verification method of the inclusion mean and the availability mean can more objectively reflect the overall availability of water dispensers to users of various ability levels.

## 2. Background

Inclusive design refers to the attempt to design products and services to meet the needs of as many users as possible, without special application or special design [8]. By comparing the ability level required for the product use with the user's actual perception and their cognition and motor ability levels, the product tolerance is evaluated [9]. Design exclusion theory is one of the core research achievements of inclusive design. Rachel et al. conducted a qualitative survey for 10 years in order to study how to reduce the obstacles for disabled students to obtaining courses in higher education, and they finally obtained a design framework to guide the students so that they can become independent learners [10]. Li Fang et al. paid attention to the allocation of limited resources in a human–machine system. Taking the design of the home environment as an example, they describe how to respond to different needs in a differentiated way so as to maximize the design value of the whole system and achieve the purpose of inclusiveness [11].

When the required ability to use the water dispenser in the family environment exceeds the actual ability of the family user, this indicates that the water dispenser has low tolerance and design rejection occurs. For example, the use ability required by the touch-operated water dispenser exceeds the ability level of the visually impaired and thus excludes them. The way to improve the degree of inclusion is to reduce the visual requirements of the products. An important goal on the road to inclusive societies is to help the visually impaired live independently. At present, most visually impaired people are using the most advanced auxiliary tools that are based on communication technology, such as voice prompts, multimodal interaction [12], haptic feedback [13], and gesture recognition, in order to carry out daily activities. Khan [14] analyzed the advantages and disadvantages of assistive technologies for visually impaired people in smart phones and designed a friendly interactive interface for the visually impaired, thereby providing a design reference for subsequent studies in this field [15]. Okonji et al. rated the difficulty and importance of using computers to carry out various Internet activities for visually impaired people, and they found that sending and reading emails are the activities with the highest priorities. Faced with this situation, Khan et al. designed "Tetra Mail" [16], a

client-friendly email for the visually impaired. Smith focused on the current hot topic of virtual reality and studied how to eliminate the obstacles for disabled people to using virtual reality equipment, which can challenge the transcending physiology or consciousness, and can bring changes to the lives of the visually impaired [17]. Chen Yi-bing and other scholars produced an innovative design for household water dispensers that is based on the users' emotional needs [5]. Song Juan proposed a remote wireless control system for water dispensers, which includes the remote user terminals and control terminals of household appliances [6]. Wu Ge designed an intelligent water dispenser, which is based on the Internet of things, through the combination of a water level sensor, a water temperature sensor, and a single-chip microcomputer, which can meet the requirements of intelligent control and mobile phone remote control [18]. Chen Wei et al. proposed a thermostatic control method for water temperature that can accurately control the temperature for instant hot drinking water equipment [19]. Zhang Hong-mei et al. solved the safety problems in the use of water dispensers through the design of a liquid level sensor to detect the water volume, a photosensitive sensor to detect the water cup, and by equipping a voice alarm module in their study of instant hot water dispensers [20]. On the basis of this, design strategies are obtained for product development, such as changing the touch operation to the physical operation in order to adapt to the ability levels of the visually impaired. The premise of user behavior is that the product function meets the user's needs. Products that fail to meet the user's needs are actively rejected by the user before the use behavior occurs. The needs of users are diverse, and design methods dominated by a single user (such as the visually impaired) can easily conflict with the different needs of other family users. Therefore, the interactive relationship between users and water dispensers is not only the compatibility and matching relationship between the two abilities, but also the competitive selection relationship between the users' diverse needs and the products that can only meet those specific needs [21]. Normally sighted users personally prefer to purchase multifunctional and stylish touch-screen water dispensers, while the visually impaired may be passively rejected by the product because of the lack of ability. Design schemes that take into account the abilities of visually impaired people for use simplify product functions and provide simpler modes of operation, which will be actively rejected by other people with normal vision for failing to meet their needs.

From the perspective of inclusive design, this study aims to solve three major challenges. It is difficult to meet visually impaired people in daily life and investigate their needs because they have lower self-esteem and are more sensitive than ordinary people. On the basis of a consideration to the diversity of household users' operating ability levels and preferences with regard to water dispensers, the common and different needs of users should be met. In the product verification stage, the simple and average data processing method of the availability index lacks consideration of the diversity of the user capabilities. Facing this situation, the consideration of the user capabilities should be included in the data processing of the availability test. On the basis of this, this research focuses on the use scenarios of visually impaired families and builds a research framework that develops from the diversity of the abilities and the needs of the users of visually impaired families. The details of the research framework are shown in Figure 1. Three strategies for water-dispenser design for visually impaired families are summarized: the multimode simplification of steps, water quality testing, and the multichannel feedback adaptation.

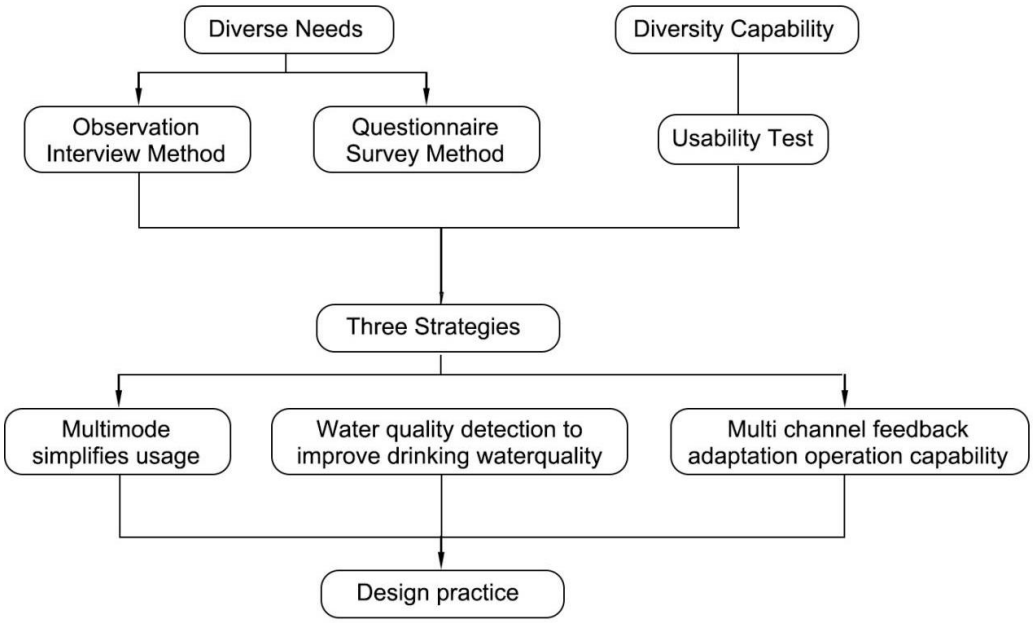



**Figure 1.** Research framework.

## 3. Research Methodology

### *3.1. Extrapolating Drinking Water Demand*

In order to understand the drinking water needs of different visually impaired people, semistructured interviews were conducted in three parts (basic information, drinking-water-related, and family life) with 10 visually impaired people. The blindness of the respondents covered primary and secondary visual disabilities. Five families of visually impaired people with different family structures were selected for on-site observation and interviews: a blind male living alone; a blind husband and wife; two double-blind couples cohabiting with middle-aged and young children; a double-blind husband and wife cohabiting with an elderly father; and a blind daughter cohabiting with middle-aged and young parents. On the basis of the interview results and observations, it was found that instant hot drinking is a primary demand of the visually impaired. By asking the interviewees' opinions on the existing instant hot-drinking-water dispenser, it was determined that the portable and small desktop drinking water dispenser is an appropriate product to meet the needs of visually impaired people. The market research of water dispensers shows that most of the desktop water dispensers on the market are touch operated. In the face of this situation, after the discussion with the focus group, the following five points for the use of water dispensers for the visually impaired were summarized: a small volume; both the inside and outside are easy to clean; simple and fast operation of, namely, hot drinks; a voice prompt and confirmation; and the choice to use physical operations. Visually impaired household users can be divided into "visually impaired" and "sighted" people. Considering that children's products are special, and that children are not economically independent and need the help of adults to complete many tasks, they were not interviewed. In order to understand the drinking water needs of the family users with normal vision, semistructured interviews were conducted with four elderly users and four middle-aged and young users with regard to the family drinking water behavior and the use needs of the visually impaired summarized above. In the interview, it was found that, compared with the kettles that most visually impaired people use, the drinking water equipment used by the sighted people has more functions, and most of them are touch-controlled.

Through the analysis of the results of the observation and interviews, it is concluded that there are three common drinking water needs of visually impaired families: a small volume, meeting the standard of healthy drinking water, and simple and fast operation.

The people with normal vision proposed that, while the operation steps of the water dispenser were simplified, the function to meet individual needs should be retained.

There are two different conflicts in the needs of the users in the visually impaired families: the choice between physical operation or touch operation, and whether to provide a voice-prompt function. People with normal vision prefer touch operation for reasons such as fashion and the better resistance to contamination. However, the text information on some touch screens is too small for elderly users to read and recognize. Nevertheless, elderly users often complete their own operation by means of location memory because the structure and information content of the touch screen of the water dispenser are simple. With the advancement of technology, home appliance products are developing towards networking, information, and intelligence [22]. Compared to the physical operations with high-mold opening costs and limited use times, touch operations are more sustainable. Therefore, diversified functions and de-keying have become the development trend of water dispenser appliances. However, visually impaired people often cannot use touch operation alone. The use logic of the touch screen is inconsistent with the use habits of visually impaired people, who search for the location of the button first, and then use.

Young and middle-aged users do not accept voice prompts because they seem noisy. For elderly users with hearing loss, effective voice prompts need to reach a suitable volume. The voice prompt is an important means for the visually impaired to obtain information. The information transmission mode of reading aloud, word by word, requires the visually impaired to spend time waiting. For mobile phone intelligent products with complex functions and the need to deliver a large amount of content, visually impaired people are willing to spend the time [23]. However, for water dispensers with relatively simple functions, the voice prompt not only reduces the efficiency of the information acquisition, but also increases the costs of the products, which does not conform to the realistic economic situation of the low incomes of visually impaired people [24]. Remote operation with the help of mobile phone screen-reading software can be used as a solution, but relying only on mobile phone control requires extra access for the visually impaired.

In summary, the drinking water needs of visually impaired families are sorted out, as is shown in Table 1. Among the visually impaired families, the visually impaired, the elderly, and the young and middle-aged users have three common needs and two different needs. It can be seen that there are two major pain points faced by visually impaired families when choosing a water dispenser. One is that there are too few choices that meet the use abilities of visually impaired people on the basis of meeting the demand for hot water and drinking. Second, the existing water dispensers cannot meet the different needs of the visually impaired family users.

**Table 1.** The demands for water dispensers for a visually impaired family.

| User Type | | Different Demand | | Common Demand |
|---|---|---|---|---|
| | | Voice Prompt | Touch Operation | |
| Sighted people | Young and middle-aged | Reject | Easy to clean, beautiful | Compact size; in line with healthy drinking water standards; simple and fast operation |
| | Elderly | Accept; high volume required | Text too small to read; elderly often operate on their own by location memory | |
| Visually impaired | | In great request | Cannot be used alone | |

*3.2. Figures, Tables and Schemes*

In order to understand the preferences of visually impaired family users for water dispensers, as well as their willingness to pay for this preference, a questionnaire survey was conducted on visually impaired elderly and young and middle-aged users in order

to ask them about the acceptable price for a water dispenser, the demand for different functions, and the preferences with regard to the operation methods (Table A1). Through the investigation and the sorting of the functional designs of 30 water dispensers from 10 relevant representative enterprises, the research function list of the desktop water dispensers in the questionnaire was determined. The respondents were invited to score the questions according to a Likert five-level scale, where 1 means "very unacceptable", 2 means "not acceptable", 3 means "general", 4 means "acceptable", and 5 means "very acceptable". The visually impaired people interviewed include users with visual disabilities from Level One to Level Four. The reliability analysis of the questionnaire results shows that the Cronbach $\alpha$ coefficient reached 0.912, greater than 0.9, which indicates the high reliability of the questionnaire [25]. A total of 137 questionnaires were issued and collected, of which 134 were valid. Among the valid questionnaires, 22 were completed by the visually impaired, 48 were completed by elderly users, and 64 were completed by middle-aged and young users.

The results of the questionnaire show that the price of a water dispenser around CNY 500 was a suitable price that was acceptable to the three types of users. The water dispensers at this price do not have a filtering function and pure water needs to be added by the users. The data results of the functional demand degree, the operation mode, the temperature regulation mode, and the acceptance of the information feedback mode were analyzed by a one-way ANOVA in SPSS20.0 software, and $p < 0.05$ was considered statistically significant. The calculation results are shown in Table 2.

**Table 2.** Results of questionnaire survey on water dispenser.

| Functional Requirement | Sighted People | | Visually Impaired | $p$ | Mean Value |
|---|---|---|---|---|---|
| | Elderly | Young and Middle-Aged | | | |
| Water quality detection | 4.23 | 3.84 | 3.95 | 0.180 | 4.01 |
| Water shortage reminder | 4.08 | 3.70 | 4.09 | 0.103 | 3.96 |
| Water volume memory | 3.75 | 3.37 | 3.09 | 0.041 | 3.40 |
| Water temperature memory | 3.75 | 3.36 | 3.50 | 0.143 | 3.54 |
| Large screen display | 3.71 | 3.33 | 2.91 | 0.025 | 3.32 |
| Water volume setting | 3.71 | 3.31 | 3.55 | 0.188 | 3.52 |
| Voice control | 3.46 | 3.05 | 3.86 | 0.009 | 3.46 |
| Phone control | 3.62 | 3.17 | 3.82 | 0.051 | 3.54 |
| Acceptance of panel operation mode | | | | | |
| Phone operation | 3.65 | 3.33 | 4.09 | 0.011 | 3.69 |
| Physical button | 3.77 | 3.31 | 3.77 | 0.005 | 3.62 |
| Touch operation | 4.00 | 3.70 | 2.68 | 0.000 | 3.46 |
| Physical knob | 3.50 | 3.05 | 3.64 | 0.004 | 3.40 |
| Acceptance of temperature adjustment mode | | | | | |
| Phone settings | 3.77 | 3.64 | 3.86 | 0.587 | 3.76 |
| Digital representation | 3.88 | 3.66 | 3.73 | 0.457 | 3.76 |
| Conventional three gears | 3.90 | 3.88 | 3.41 | 0.050 | 3.73 |
| 5 degrees per adjustment | 3.83 | 3.52 | 3.82 | 0.086 | 3.72 |
| Shows how to make milk | 4.08 | 3.87 | 3.14 | 0.001 | 3.70 |
| Acceptance of information feedback | | | | | |
| Anthropomorphic voice | 3.63 | 3.23 | 4.23 | 0.001 | 3.70 |
| Mechanical sound | 3.83 | 3.22 | 3.77 | 0.001 | 3.61 |
| Indicator light | 4.17 | 3.89 | 2.50 | 0.000 | 3.52 |
| Screen text | 3.79 | 3.64 | 2.55 | 0.000 | 3.33 |

Note: The conventional three gears refer to room temperature, warm water, and boiling water.

The analysis results show that the demand degree of the water quality detection is the highest (mean = 4.01), which shows that the first demand for using a desktop water dispenser is still the safety of the water quality. The additional function with the most obvious difference in demand is the voice control ($p = 0.009 < 0.05$), followed by the large-screen display ($p = 0.025 < 0.05$), and the water volume memory ($p = 0.041 < 0.05$). In terms of the additional functions, elderly users have a higher demand for large-screen displays, while visually impaired people have a higher demand for voice control and mobile phone control. In terms of the operation mode, visually impaired people prefer mobile phone control, while sighted users prefer the touch operation. In addition to the functional requirements of the water dispenser, multiple water dispenser operation modes can be provided for choice. In terms of the temperature adjustment methods, elderly users mostly prefer the temperature option expressed by the usage, while young and middle-aged users prefer the conventional three-level representation. Visually impaired people prefer to use mobile phone settings, and they least accept the method of expressing the temperature options by usage. In the design of the temperature selection mode, multiple selection modes can be provided at the same time to meet the preferences of different users. As for the information feedback, the sighted users are not receptive to the voice prompt and mostly prefer the indicator prompt, while the visually impaired users mostly prefer the voice prompt. On the basis of the consideration of the users' ability levels, the design of the information feedback can consider a multichannel mode.

### *3.3. Analysis of Users' Ability Levels for Water Dispenser*

In order to understand the difficulties encountered by household users with different ability levels when using water dispensers, 20 subjects with experience in using drinking equipment were invited to conduct a usability test, which included: eight visually impaired users (average age = 52, SD = 15.03), three who were completely blind, four who were semiblind, and one low-vision user; six elderly users (average age = 64, SD = 5.39); and six middle-aged and young users (mean age = 41, SD = 14.73). A Joyang JYW-H9-type hot table water machine was used in the experiment. The subjects were required to perform the following tasks on the target water dispenser: fill the water tank; take out 200–300 mL of drinking water between 40 and 60 °C; take out 600 mL of drinking water at 100 °C (the water volume of the water tank is less than 600 mL when taking out water); and determine the reason for stopping the water flow. The three tasks were carried out in two rounds altogether. Before the formal experiment, the subjects were allowed to learn about and master the product in order to ensure that they all understood the functions and usage of the target water dispenser. After the experiment, the subjects were interviewed to collect their subjective opinions. The experimental observation variables were the task completion rate (1 point for completion alone; 0.5 point for completion with the help of the guide; 0 points for failure/abandonment), the number of errors, and the interview results. By looking back at the experimental video, the experimenter recorded the number of errors, described the error situation, and analyzed how the users organized and processed the information.

The test results show that the task completion rate was M = 51.0% for the visually impaired group, M = 80.7% for the young and middle-aged group, and M = 70.8% for the elderly group. The task completion rate was analyzed with a one-way ANOVA. There was a significant difference in the completion rates between the normal-sighted group and the visually impaired group ($p = 0.000 < 0.05$), while there was no significant difference in the completion rates between the elderly and the young and middle-aged groups ($p = 0.219 > 0.05$). The results show that the visual acuity level had a significant effect on the task completion rate. The statistics of the error conditions and the times are shown in Table 3. The complaints submitted by the subjects are summarized into the following three points: the child lock is unnecessary; the preset water volume is inappropriate; and the water dispenser is too short to use with an ordinary thermos cup. In addition, the young and middle-aged users suggested that the keystrokes are loud and somewhat noisy, elderly users wanted to increase the text size of the keys to highlight the water button, and

the visually impaired wanted to add additional mobile phone operations or voice prompts. The results of the user operation errors were analyzed as follows: First, with regard to the outer design of the target water dispenser, the statistical results show that, because the water tank is hidden, there are more errors, which included the failure to recognize the use mode of the water tank handle ($n$ = 9), and the failure to recognize the position of the water tank ($n$ = 7) in the normal vision group. The clamping structure on the return of the water tank is not obvious, which resulted in the visually impaired group ($n$ = 8) and the elderly group ($n$ = 5) making mistakes many times. Furthermore, because of the unclear design, the sighted group mistakenly identified the decorative parts of the water dispenser as the water button (which should operate the screen) many times ($n$ = 18), while the visually impaired group made this mistake less ($n$ = 3).

**Table 3.** Task operation errors and times.

| Error Content | Sighted People | | Visually Impaired |
|---|---|---|---|
| | Young and Middle-Aged | Elderly | |
| Unable to identify water tank location | 4 | 3 | 1 |
| Unable to identify water-tank-handle usage | 5 | 4 | 6 |
| Situated the water tank in the wrong direction | 1 | 5 | 8 |
| Water tank lid overturned or not properly closed | 3 | 3 | 6 |
| Wrong selection of water temperature | 1 | 2 | 8 |
| Water volume not selected | 3 | 8 | 12 |
| Forgot to press the child lock | 9 | 11 | 9 |
| Touched screen by mistake | 3 | 6 | 8 |
| Identified the wrong water button | 10 | 8 | 3 |
| Ignored the sound of water shortage | 3 | 6 | 6 |

In the touch-operation design of the target water dispenser, it was a common and easy mistake for the three groups of subjects to forget to open the child lock. When given the use steps in advance, the elderly and the visually impaired groups did not select the water volume many times, indicating that they were still used to judging the water volume by themselves. Through the observation during the test process, it could be seen that the visually impaired people conducted the next step after fumbling for the positioning of their hands. Because the parameters of the target drinking machine can be modified without unlocking, the task failed many times when the visually impaired person mistakenly touched the screen ($n$ = 8) in the process of positioning. In addition, the visually impaired group also failed to confirm the setting parameters twice, and the water temperature was selected incorrectly many times ($n$ = 8). The water tank water-shortage-prompt sound that rings only once, and the flashing white light that is not obvious, also caused the elderly group and the visually impaired group to often ignore the prompt information.

## 4. Results and Discussion

On the basis of the results of the interviews, the usability test, and the questionnaire survey, and with the aim of meeting the three common needs for water dispensers and solving the problems of the differences between the voice prompt and the touch operation, the design problems were explored and analyzed. The following three design strategies for water dispensers for visually impaired families are proposed.

### *4.1. Multimode Simplifies Use Steps*

According to the usage habits and the personal preferences of home users, the operation steps were redefined and multimode operations were provided to users. The two core steps of using the water dispenser are highlighted: confirming the temperature and

dispensing the water. The noncore functions, such as the user's independent decisions with regard to the water amount, will not affect the operations of the core steps. In this way, the visually impaired and those with normal vision can actively choose the operation mode according to their current needs and abilities. Thus, the new design simplifies the steps of use, meets the personalized needs of users, and improves the product experience for multiple users in visually impaired families.

Faced with the problem that visually impaired family users have different demands for the voice prompt and the touch operation, and on the basis of the strategy of multimode simplification, the touch operation and the physical operation were reserved. Through the design of a physical button, the required abilities of the users were reduced, and the people with normal vision could use the noncore functions with their preferred touch interface. Screen reading software is an auxiliary technology that is frequently used by the visually impaired. Compared to professional braille electric display and braille touch equipment, screen reading software is easier to use and has a more affordable price. A total of eight visually impaired respondents from the early interview and eight visually impaired subjects used screen reading software to assist them in their daily lives. The younger visually impaired people could skillfully use their mobile phones to complete online shopping, order takeouts, and other activities similar to those undertaken by people with normal vision, which explains the high demand by visually impaired people for the mobile phone operation of water dispensers noted in the questionnaire survey (4.09/5). By providing only brief voice prompts for the operation direction of the visually impaired, the drinking machine can be independently used by the visually impaired without affecting the experiences of the sighted users.

### *4.2. Water Quality Testing*

The preliminary observation and interview found that the visually impaired people would clean the drinking water equipment every morning because they could not perceive the cleanliness of the machine. The regular cleaning of machines can effectively prevent the buildup of precipitant. In order to guide the cleaning more scientifically and efficiently, the system is designed to automatically record the length of use of the machine. When the preset period of use is exceeded (you can change the default number of days through your mobile phone), a cleaning reminder will be sent through the large-screen indicator. After the cleaning, the data will return to zero and a new record will be started.

The TDS (total dissolved solids) is an important factor that affects the water quality. When the concentration of TDS is higher than 1000 mg/L, the taste of the water will deteriorate and cause the problem of excess precipitant in the machine [26]. Therefore, when the concentration of TDS is too high, a red light on the touch screen will turn on to remind the users to change the water so as to effectively ensure their health. The TDS detection function refers to the design of the water quality detector system and is based on the single-chip controller proposed by Zhang Qiuyan et al. [27]. The digital TDS water quality sensor and the temperature collection module are placed inside the drinking machine for data collection, and the signal is sent to the mobile application to check the specific TDS value through the WiFi module. Before using the water dispenser, the users' worries can be eliminated, and the quality of the drinking water can be improved by observing the water quality indicator's prompt to clean, or by understanding the specific water quality on the mobile phone.

### *4.3. Multichannel Feedback to Adapt Operation Capability*

The original jyW-H9 interface has only one sound feedback, which is not good for visually impaired or elderly users. The preliminary interviews show that the water dispensers in visually impaired families are often placed in the kitchen. In the case of strong background noise in the kitchen, the tactile channel is less negatively affected than the auditory channel [28]. On the basis of the use habits of the visually impaired, the information feedback mode was designed to be dominated by the sense of touch and to be

assisted by the sense of hearing, without weakening the visual orientation. For the use of those with normal vision, indicator guidance and a variety of easy-to-distinguish prompt sound effects were added to improve the user's perception during the use of the process. Degenerating vision is the biggest obstacle for elderly users to using information technology [29]. The design of a touch interface should conform to the vision and cognitive abilities of elderly users.

## 5. Design Practice

With the design strategy mentioned above, as well as the preliminary research and the theoretical guidance of the inclusive design method, a water dispenser for visually impaired families was designed. The key principles for the design included making a smaller product, with prominent buttons, as well as an overall sense of cohesion. This model has the following four characteristics: a high nozzle design for different cup heights; an exposed water tank to make the product structure clearer to users; a square thick water tank cover for convenience; and a 3-L capacity tank for family use.

The steps for use for the visually impaired, the elderly, and the young and middle-aged in the visually impaired families are shown in Figure 2. First of all, before using the water dispenser, users can obtain the electronic instruction manual through the raised code on the fuselage. The convex shape of the code and the braille above it are conducive to the use habits of the visually impaired. In this way, the visually impaired can use the screen reading software to actively and efficiently obtain the text information and enjoy customer service consulting and other after-sales services. Under the guidance of the manual, which is connected to the mobile phone and the water dispenser, they can also modify the default hot water temperature and the water volume, as well as check the water quality.

In order to reduce the locating burden on the visually impaired, the water dispenser is divided into upper and lower operating spaces, according to the use modes of the sighted and the visually impaired. The lower area is the physical operation place used by the visually impaired person. The water tray has grooves that are convenient for the positioning of the cup. The water drop symbol on the water-dispensing button reminds the user that they can take out water below. The convex design is conducive to tactile recognition. The button is accompanied by a voice prompt for the temperature: Press the button once to produce normally warm water, press it twice quickly to produce hot water. If the button is pressed again while dispensing, the water flow will stop. By default, the hot water temperature is 75 °C and the water will automatically flow after starting. The infrared detection sensor above the water outlet detects the position of the cup. When there is no cup and the water outlet button is pressed, the system will not dispense and produces a voice prompt that tells the user that there is no water cup. After the user habits are determined over time, the frequency of using the mobile phone to adjust the water temperature and the water quantity will be reduced. The design of this mode meets the needs of the visually impaired to use water dispensers independently and safely, and it conforms to their usage habit of using two-step drinking water (selecting the temperature and water outlet).

The upper area of the drinking machine is the touch screen with the noncore functions and the physical water-dispensing button, and the touch button on the touch screen is capacitive and meets the price expectation [30]. A black screen with large white text is in line with the visual needs of elderly users. Users can press any area of the screen to activate it and then open the child lock to modify the settings and confirm the current water temperature and quantity. If there is no operation, it will return to the default state after 6 s. The setting changes need to be confirmed twice in order to avoid elderly users or the visually impaired accidentally changing the settings. Users press the physical button to start taking out water, and there is a light to remind the users of the temperature. The water will stop flowing if the button is pressed again. The design of this mode is in line with the preferences of young and old users.

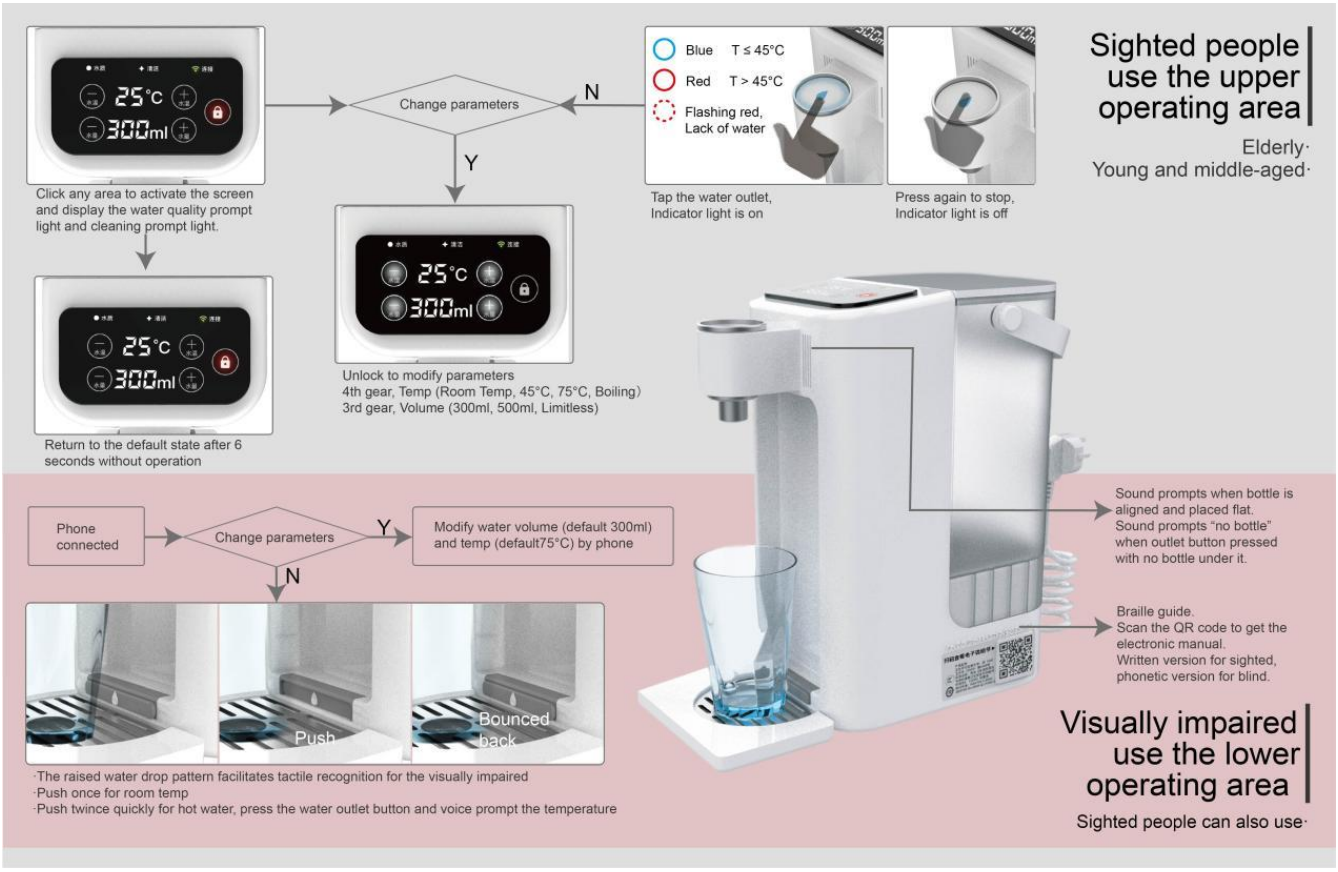



**Figure 2.** Product design and details.

## 6. Conclusions

On the basis of the different needs of visually impaired family users, this study investigated and analyzed how water dispensers meet the corresponding needs. The qualitative results and the quantitative data were obtained through interviews, a questionnaire survey, and a usability test. Three strategies for the design of the water dispenser were obtained: the multimode simplification of steps, water quality testing, and the multichannel feedback adaptation. According to the preferences and skills of visually impaired and sighted people, the drinking machine is divided into an upper touch operation area and a lower physical operation area with an auxiliary mobile phone control mode. This provides auditory feedback for the visually impaired and adds visual guidance and various prompt sound effects for the sighted in order to improve the perceptions of users in the process of using. Users actively choose the operation mode according to their current needs, which improves the product experience of visually impaired family users. The research on water dispensers that is based on the diverse needs and abilities of users provides a reference for solving the problem that a single product has a certain limit when meeting the needs of users with different abilities. This respects the diversity and differences of the users and meets the needs of more users on the basis of improving the independent usage by visually impaired people. This design perspective considers visually impaired users to be as important as sighted users, delivers emotional care, and makes it so that the design is a bridge to the positive interaction among peoples, environments, and products.

The sample size of the user survey and the test is not rich enough. Because of the limited resources, although the visually impaired people contacted in this study are representative to some extent, they are not sufficient to cover all of the user characteristics. The research on the structure and technology of the functional support of the water dispenser is not thorough and detailed enough. The verified model fails to fully realize the set function and users cannot go through the whole operation process during the test

because of the limitation of the cost, which led to some errors in the verification test results. In the analysis of the user competence–availability indicators, this calculation method can evaluate the product inclusion more effectively. However, the behaviors and abilities of users will also involve personal habits, experience, and other factors in real-life scenarios, and it is difficult to completely exclude the influence of these factors in the process of usability testing.

**Author Contributions:** Conceptualization, Q.S. and S.T.; methodology, Q.S. and F.Z.; validation, S.T. and Y.W.; formal analysis, Q.S. and F.Z.; investigation, S.T.; resources, Q.S.; data curation, Y.W. and P.Z.; writing—original draft preparation, S.T. and P.Z.; writing—review and editing, Q.S.; visualization, S.T. and Y.W.; project administration, F.Z. and P.Z. All authors have read and agreed to the published version of the manuscript.

**Funding:** This project is supported by the "Light of Textile" Higher Education Teaching Reform Project of the China National Textile and Apparel Council [grant number: 2021BKJGLX135]; and by Unpopular "JueXue" and the National History; and by other research projects of the National Social Science Fund of China [grant number: 19VJX160].

**Institutional Review Board Statement:** Not applicable.

**Informed Consent Statement:** Informed consent was obtained from all subjects involved in the study.

**Data Availability Statement:** No new data were created or analyzed in this study. Data sharing is not applicable to this article.

**Conflicts of Interest:** The authors declare no conflicts of interest.

## Appendix A

**Table A1.** Research on the preferences for table water dispensers for visually impaired families.

| **Research on the Preferences for Table Water Dispensers for Visually Impaired Families** |
|---|
| 1. Your gender<br>□ Male □ Female |
| 2. Your age |
| 3. Which type of user are you?<br>□ Senior (60+)<br>□ Young and middle-aged (20–60)<br>□ Visually impaired |
| 4. Please enter your mobile phone number |
| 5.Where is the drinking water equipment often placed at home?<br>□ Living room<br>□ Kitchen<br>□ Bedroom<br>□ Dining room<br>□ Study<br>□ Somewhere else |
| 6. Acceptable price of water dispenser<br>□ Less than CNY 200<br>□ CNY 200–500<br>□ CNY 500–1000<br>□ More than CNY 1000 |
| The tabletop water dispenser is a new type of water dispenser that can be placed on the table more compactly than the traditional vertical bucket water dispenser. It is roughly divided into three parts: the water tank, the operation panel, and the water receiving area. |

The capacity of the water tank is between 2 and 5 L. Its biggest feature is that it instantly heats the water for drinking, according to the set temperature, and heats the water to the desired temperature within a few seconds.

7. For the function of the water dispenser, what is your requirement?

| | Very unacceptable | Not acceptable | General | Acceptable | Very acceptable |
|---|---|---|---|---|---|
| Water quality detection | □ | □ | □ | □ | □ |
| Water shortage reminder | □ | □ | □ | □ | □ |
| Water volume memory | □ | □ | □ | □ | □ |
| Water temperature memory | □ | □ | □ | □ | □ |
| Large screen display | □ | □ | □ | □ | □ |
| Water volume setting | □ | □ | □ | □ | □ |
| Voice control | □ | □ | □ | □ | □ |
| Phone control | □ | □ | □ | □ | □ |

8. What is your preference for the operating mode of the water dispenser panel?

| | Very unacceptable | Not acceptable | General | Acceptable | Very acceptable |
|---|---|---|---|---|---|
| Phone operation | □ | □ | □ | □ | □ |
| Physical button | □ | □ | □ | □ | □ |
| Touch operation | □ | □ | □ | □ | □ |
| Physical knob | □ | □ | □ | □ | □ |

9. What is your preference for the following water temperature regulation methods?

| | Very unacceptable | Not acceptable | General | Acceptable | Very acceptable |
|---|---|---|---|---|---|
| Phone settings | □ | □ | □ | □ | □ |
| Digital representation | □ | □ | □ | □ | □ |
| Conventional three gears | □ | □ | □ | □ | □ |
| 5 degrees per adjustment | □ | □ | □ | □ | □ |
| Show how to make milk | □ | □ | □ | □ | □ |

10. What is your preference for the following information feedback methods of water dispenser operation?

| | Very unacceptable | Not acceptable | General | Acceptable | Very acceptable |
|---|---|---|---|---|---|
| Anthropomorphic voice | □ | □ | □ | □ | □ |
| Mechanical sound | □ | □ | □ | □ | □ |
| Indicator light | □ | □ | □ | □ | □ |
| Screen text | □ | □ | □ | □ | □ |

## References


1. European Blind Union Facts and Figures. Available online: http://www.euroblind.org/about-blindness-and-partial-sight/facts-and-figures.html (accessed on 21 March 2021).
2. We, B.; Wei, G.-Q. Comparison of the Standards and Evaluation Methods of Visual Disability in Two National Sample Survey of the Handicapped. *J. Pract. Prev. Blind.* **2007**, *1*, 24–26.
3. World Health Organization Blindness and Vision Impairment. Available online: https://www.who.int/news-room/fact-sheets/detail/blindness-and-visual-impairment (accessed on 14 April 2021).
4. Hu, B.; Kong, X.M.; Hu, G.L. Analysis on the Development Space of Domestic Drinking Fountain Market. *Mod. Bus.* **2015**, *6*, 18–19.
5. Chen, Y.B.; Wan, Z.J.; Yu, D.J.; Ye, J.Y. Innovative Design of Household Water Dispenser Based on User's Perceptual Needs. *Packag. Eng.* **2020**, *41*, 173–179, 197.
6. Song, J.; Zeng, S.X.; Xu, R. Wireless Remote Control System of Drinking Machine. *Bull. Sci. Technol.* **2014**, *30*, 162–165.
7. Dou, J.H. Research on Inclusive Human-Computer Interface Evaluation and Optimization Methods. Ph.D. Thesis, University of Science and Technology Beijing, Beijing, China, 2020.
8. Keates, S. BS 7000-6:2005 Design Management Systems. In *Managing Inclusive Design Guide*; Gerontechnology: London, UK, 2005.
9. Persad, U.; Langdon, P.; Clarkson, J. Characterising user capabilities to support inclusive design evaluation. *Univers. Access Inf. Soc.* **2007**, *6*, 119–135.
10. Hewett, R.; Douglas, G.; McLinden, M.; Keil, S. Balancing inclusive design, adjustments and personal agency: Progressive mutual accommodations and the experiences of university students with vision impairment in the United Kingdom. *Int. J. Incl. Educ.* **2020**, *24*, 754–770.
11. Li, F.; Dong, H. Design "Inclusion" and "Exclusion" in the Context of Competition. *Design* **2020**, *33*, 59–61.
12. Paek, T.; Chickering, D.M. Improving command and control speech recognition on mobile devices: Using predictive user models for language modeling. User Model. *User-Adapted Interact.* **2007**, *17*, 93–117.
13. Brewster, S.; Chohan, F.; Brown, L. Tactile feedback for mobile interactions. In *Human Factors in Computing Systems*; University of Glasgow: Glasgow, UK, 2007.
14. Khan, A.; Khusro, S. An insight into smartphone-based assistive solutions for visually impaired and blind people: Issues, challenges and opportunities. *Univers. Access Inf. Soc.* **2021**, *20*, 265–298.
15. Khan, A.; Khusro, S. Blind-friendly user interfaces—A pilot study on improving the accessibility of touchscreen interfaces. *Multimed. Tools Appl.* **2019**, *78*, 17495–17519.
16. Khan, A.; Khusro, S.; Niazi, B.; Ahmad, J.; Alam, I.; Khan, I. TetraMail: A usable email client for blind people. *Univers. Access Inf. Soc. Int. J.* **2020**, *19*, 113–132.
17. Smith, K. Universal life: The use of virtual worlds among people with disabilities. *Univers. Access Inf. Soc.* **2012**, *11*, 387–398.
18. Wu, G. Design of intelligent water dispenser based on Internet of Things. *Internet Things* **2017**, *7*, 91–92.
19. Chen, W.; Wei, Z.K.; Quan, Y.B. In Intelligent Thermostatic System for Instant Hot Drinking Water Equipment, In Proceedings of the 2020 China Home Appliance Technology Conference, Ningbo, China, 29–30 October 2020; pp. 1378–1384.
20. Zhang, H.M.; Tang, M.L. Design and realization of instant thermal intelligent water dispenser. *South. Farm Mach.* **2019**, *50*, 200–201.
21. Li, F.; Dong, H. Development and Challenges of Universal Design and Inclusive Design Principles. *J. Nanjing Arts Inst.* **2018**, *24*, 71–78, 210.
22. Cheng, D.Z. Talking about the Intelligence in Home Appliances. *Archit. Eng. Technol. Des.* **2018**, *20*, 3986.
23. Williamson, K.; Schauder, D.; Stockfield, L.; Wright, S.; Bow, A. The role of the internet for people with disabilities: Issues of access and equity for public libraries. *Aust. Libr. J.* **2001**, *50*, 157–174.
24. Ding, Y.R.; Xiao, P. Review of Research on the Information Behavior of Visually Impaired People. *Libr. Trib.* **2019**, *39*, 10.
25. Zhang, H.; Tian, M.F. Application of Reliability Analysis in Survey Questionnaire Design. *Stat. Decis.* **2007**, *21*, 25–27.
26. Liu, W.J.; Wang, X.T.; Shu, Y.W.; Guan, J. Essential Elements Needed by the Human Body and Drinking Water Health. *Water Wastewater Eng.* **2017**, *53*, 9–12.
27. Zhang, Q.Y.; Gao, P.A.; Li, X.M. Design of An Intelligent Water Quality Detector. Foreign Electron. *Meas. Technol.* **2021**, *40*, 112–115.
28. Wilkins P A; Acton, W.I. Noise and accidents—A review. *Ann. Occup. Hyg.* **1982**, *25*, 249–260.
29. Wang, L.; Rao, P.L.; Gavriel, S. Design Guidelines for Information Technology Products for Chinese Elderly Users. *Chin. J. Ergon.* **2013**, *19*, 82–85.
30. Qu, W.P. Capacitive Touchscreen Will Lead the Market Trend. *Radio Telev. Netw.* **2010**, *17*, 82–84, 89.