

Application of Infrared Technology in Household Water Tap Design and Evaluation

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Abstract. Based on previous research results, this study examined the use of water taps and observes the experiences of different age groups when using new product designs. The results indicated that, although new designs can meet the demands of different generations, first-time users have a relatively low understanding of a product from its appearance; hence, if a new design deviates from common user cognition, even it could solve user problems, it still has low user acceptance.

Keywords: Infrared technology · Universal design · Washing behavior · Water tap · Use evaluation

1 Introduction

In Taiwan, it is common to see three generations living under the same roof, thus sharing the same toilet and bathing space. All family members, whether old or young, or those with limited physical mobility, use the same facilities every day. The toilet and bathroom space in Taiwan has area of about 4.95 m² on average, and the design does not separate the bathing and toilet areas. Based on previous research results [1], this study aims to investigate the user habits and problems of different generations, improve the washing equipment-water tap design, and construct an experimental model. It further re-investigates users to learn how different generations or people with different physical abilities use washstands and conduct washing behavior.

2 Literature Review

2.1 Main Equipment of Bathroom Space in Taiwan

The Construction and Planning Agency, Ministry of the Interior, issued a “Manual for the Residential Bathroom Experience”, from which Taiwanese may gain some knowledge about bathroom equipment. The Manual specifies the dimensions of common bathroom equipment: washstands are categorized into desk type, rack mounting type, and wall mounting type (Fig. 1).

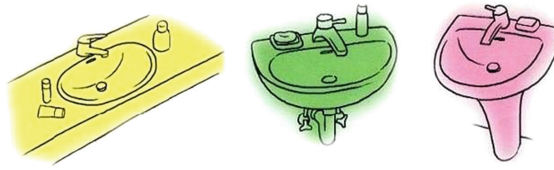


Fig. 1. Basic washstand types (Construction and Planning Agency, Ministry of the Interior, “Manual for the Residential Bathroom Experience”)







					
1. Handle rotation type	2. Cross rotation type	3. Traditional rotation type	4. Mixed type	5. Automatic sensing	6. Automatic temperature control

Fig. 2. Water tap types (Formosa bathroom website)

There are currently six types of household water taps for bathrooms in the market. The left three types are connected to pipelines through one hole, while the other three are connected through three holes (Fig. 2).

2.2 Introduction and Application of Infrared Sensors

New technology can change space opportunities. For example, bathroom equipment manufacturers have examined the elderly market and developed products for elderly people with limited physical mobility, which helps them solve various problems, such as difficulty in stand for a long period, cleaning the toilet in winter, and increased useful space in a bathroom. An induction power control device can automatically switch on or off power through infrared detection. Thus, even if the elderly forget to switch off the power, it can automatically control the switch, making it convenient for elderly people, as equipment and space design interact. Spaces change with advancement in science and technology; just as science and technology will change with space use.

2.3 Summary

Mostly areas of activity of the elderly are at home due to degeneration of physical functions, and the bathroom is the place with the highest accident rate in the home space. Currently most bathrooms do not have dry and wet separation design, which can

no longer meet user demand. The user behaviors of using bathrooms are very complicated, as their usage behaviors vary due to difference in physical functions. To make bathrooms more people-oriented, infrared sensor technology can avoid awkward situations in bathroom usage (deodorization, silencer); enable those with limited physical mobility usage without burden (universal design); and provide users with a more comfortable and private space (peep-proof, emergency care). The application of infrared sensors can make bathrooms more comfortable, cleaner, and safer. Based on the current household bathroom equipment and the different use conditions and demands of users in Taiwan, this study proposed a water tap design for bathroom equipment for Taiwanese users, and validated the indicators of subsequent design and evaluation.

3 Previous User Issues

This study examined the problems and demands of products from the perspective of users, and summed up four factors that trouble users when using bathroom equipment: “water flow and temperature control”, “face washing method and cleaning”, “handrail setting and height”, and “storage space” (Table 1), added human factor engineering and human body dimensions, and offer possible countermeasures.

Table 1. Improvement measures

Direction		Indicator	Problem	Countermeasure
Water flow and temperature control	Water flow control	Reduce repetitive operation	It will cause water to splash in all directions if water flow is directly adjusted to maximum amount	With infrared sensing, users do not need to switch it on and can use it directly
		It is easy to accurately control water flow		
		Tolerance for error operation		
	Water temperature control	Water temperature control is easy to understand	Hot water is normally not used	Put aside rarely used water temperature
		Operation instruction and feedback.		
		Tolerance for error operation		

(Continued)

Table 1. (Continued)

Direction		Indicator	Problem	Countermeasure
Face washing method and cleaning	Face washing method	Suitable for all kinds of methods	Different people have different face washing habits, but it is a complicated operation	Design a water flowing method for face washing that enables water to directly contact with the face
	Cleaning and drying	Easy to clean	The table can easily get damp after used, but few people clean or wipe it	Design an arc-shaped washstand, and adopt ultra repellent nano treatment to direct water drops to the wash port
		Durable without maintenance		
		Keep the washstand table dry		
	Wash basin	Easy to wash articles	Hair can easily become stuck in the wash port; small articles, such as earrings, can easily fall into the wash basin	Set the wash basin in the left-rear corner. Even when hair or earrings fall on the washstand, it will not be immediately washed into the wash basin
Handrail setting and height	Washstand height	Users will not get tired after a long time of use	The washstand is generally too low for users, and it is inconvenient for people with limited physical mobility	Select rack mounting washstands and raise the height to 77 cm; meanwhile, consider whether height is convenient for wheelchair users
		Suitable for all kinds of methods		

(Continued)

Table 1. (Continued)

Direction		Indicator	Problem	Countermeasure
	Handrail setting	Secure and safe support structure	Metal external mounting handrails give people a cold, rigid feeling and are not aesthetically pleasing	Design a round handrail, and integrate it with the washstand to enhance its internal structure
Storage space	Articles storage	Provide proper storage space	It is not large enough due to too many family members	Though it can make it more convenient for users by increasing the storage space, it can also make it messier. A proper storage space shall be designed after evaluation

Supplementary: Human Factors Engineering and Human Body Dimensions —

According to literature, in order to meet the demands of different users, the washstand height from the floor to the top of the washstand is 77 cm; however, with the change of times, washstands are now not only places where users wash their faces and brush their teeth, but more importantly have other functions, like cleaning. The useful area of washstands is larger. According to the behavior pattern of participants, the wash-stand is expanded: the sink is 33 cm long, 55 cm wide, and 11 cm deep. Water taps are used as the basis for subsequent design according to the best splash point (water out-let is 30–36 cm from users and 16–23 cm from the washstand).

4 Design Proposal

There are two behavior patterns in using water taps—water holding and splash cleaning; however, most water taps only provide the water holding function. When users want splash cleaning, they must splash by holding water in their hands, which can more easily wet the washstand top and wastes water. If a water flow method that allows splash cleaning is adopted, it would be more convenient for users and reduce the waste of water. Regarding water flow and temperature control, most users do not control water flow or temperature. They often switch on/off water taps and even let the water

flow without switching it off. If infrared sensing replaces common switches, it is not only convenient to use, but can save water resources. Users only need to ignore the rarely used water flow and temperature, and adopt infrared sensing as the main function and control of the auxiliary function, thus, household water taps will be more human-oriented in operation.

5 Validation and Conclusion

This study made design improvements based on previous research and design countermeasures, while validation is mainly based on usage procedures of bathroom users. This study learned the demands of different groups of users through evaluation, questionnaires, and interviews, and offers improvement measures. This research involved 42 participants, and can be used as the judgment standard for comparison between product testing and importance, as well as among different groups of users (Fig. 3).

5.1 Questionnaire Analysis

To validate the improvements and evaluation of water taps, this research engaged common users, seniors (above 60 years old), children (above 8 years old), and disabled people, for evaluation and importance testing of the indicators of water taps, in order to learn the opinions and comments of different age groups on the use of water taps. The basic data of the participants are shown in Table 2.

5.2 Product Use Satisfaction Survey

This study measured on a 5-order evaluation Likert scale, as completed by participants. After the evaluation survey, this study sorted the survey data of participants, adopted SPSS software for data processing and statistical analysis, and obtained the average scores and evaluation of each indicator of use of water taps through independent t test. In the participant evaluation table, when t is negative, it means the measured value is lower than the expected value, in other words, it exceeds expectation; when t is



Fig. 3. Entity detection model

Table 2. Statistical table of basic data

Basic data		Number of people	Percentage
Gender	Male	22	52.4 %
	Female	20	47.6 %
Age group	Young adults	15	35.7 %
	Senior people	12	28.6 %
	Children	10	23.8 %
	Disabled people	5	11.9 %
Face washing habit	Splash by holding water in hands	15	35.7 %
	Cleaning with a towel	14	33.3 %
	Storing up water for cleaning	13	31.0 %
Type of household	Mixed type	28	66.7 %
Water taps	Rotation type	14	33.3 %

Table 3. Evaluation on use of water taps by participants

Indicators	Measured value	Expectation	t	Significance (single-tailed)
Easy to understand how to operate it from appearance design	3.60	4.19	-4.08	0.00*
Control water flow according to splash amount	4.05	3.86	1.26	0.10
Has specific operation instruction and feedback	3.81	4.26	-3.29	0.00*
Water temperature control is easy to understand	4.21	4.05	1.38	0.09
Columnar water flow from below can be easily and accumulatively controlled	3.98	3.95	0.21	0.42
Effectively reduce repetitive operation	4.36	3.88	3.39	0.00*
It can return to the original state if wrong use methods are used	3.79	4.21	-2.62	0.01*
Use method corresponds to different demands	4.29	3.86	2.82	0.00*
It can be easily cleaned	3.69	3.81	-0.83	0.20
Not easy to damage and durable	3.17	4.33	-7.05	0.00*

*P < .05

positive, it means the measured value is higher than the expected value, in other words, there is room for improvement. The presentation and explanation of the statistical analysis results are as follows:

Evaluation on Use of Water Taps by Participants. Table 3 shows that there is significant difference between “effectively reduce repetitive operation” and “usage method corresponds to different demands”, meaning that all participants feel that the

Table 4. Evaluation on use of water taps by young adults

Indicators	Measured value	Expectation	t	Significance (single-tailed)
Easy to understand how to operate it from appearance design	3.87	4.67	-3.21	0.00*
Control water flow according to splash amount	4.40	4.20	0.62	0.27
Has specific operation instruction and feedback	4.00	4.40	-1.47	0.08
Water temperature control is easy to understand	4.53	4.47	0.31	0.38
Columnar water flow from below can be easily and accumulatively controlled	4.07	4.13	-0.27	0.39
Effectively reduce repetitive operation	4.27	3.93	1.14	0.13
It can return to the original state if wrong use methods are used	3.80	4.13	-1.08	0.15
Use method corresponds to different demands	4.53	4.00	2.26	0.02*
It can be easily cleaned	4.00	4.27	-1.00	0.16
Not easy to damage and durable	3.27	4.53	-4.50	0.00*

*P < .05

product can effectively reduce repetitive operation and meet different demands; however, as the product appearance is relatively novel, it cannot be immediately understood, and specific instructions and tolerance of errors are required. As water tap usage habits can differ, the new function of (splash face washing) is added; however, participants feel the new water taps are not durable. The temperature control handle in the design is not different from those currently on the market, thus, there is no cognitive difference among participants. As dual-purpose water taps are not common on the market, it is necessary to enhance operational instructions.

Evaluation on Use of Water Taps by Young Adults. Table 4 shows that young adults feel that it is difficult to understand how to use it from the appearance design, thus, it is necessary to provide operation instructions to enhance the operational interface and make it easier for users to understand how to use it; additionally, because operation is relatively more complicated than common water taps, young adults feel it is not durable. However, unlike common water taps, the design has a splash face washing device, which young adults feel can meet different demands and exceed their expectations.

Evaluation on Use of Water Taps by Seniors. Table 5 shows that it is relatively difficult for seniors to understand how to operate the water tap from the appearance design, they feel that it is difficult to return to its original state if they use it wrong, and that it is not durable. However, they feel the splash water amount and columnar water flow can be accurately and intuitively controlled. As the designs are consistent with

Table 5. Evaluation on use of water taps by seniors

Indicators	Measured value	Expectation	t	Significance (single-tailed)
Easy to understand how to operate it from appearance design	3.33	4.00	-2.60	0.01
Control water flow according to splash amount	4.00	3.50	2.57	0.01
Has specific operation instruction and feedback	3.75	3.92	-0.84	0.20
Water temperature control is easy to understand	4.08	3.92	0.98	0.17
Columnar water flow from below can be easily and accumulatively controlled	4.00	3.67	2.35	0.01
Effectively reduce repetitive operation	4.67	3.92	3.65	0.00*
It can return to the original state if wrong use methods are used	4.00	4.67	-2.97	0.00*
Use method corresponds to different demands	4.50	4.00	3.32	0.00*
It can be easily cleaned	3.75	3.92	-1.08	0.15
Not easy to damage and durable	3.08	4.75	-7.15	0.00*

*P < .05

their use habits, seniors find them easy to understand and operate. However, as the appearance is novel, it makes it relatively more difficult for seniors to judge how to use it from the appearance. Moreover, as operation is more complicated than before, it is easier to operate incorrectly; thus, operation instructions are required to prevent operational errors. In addition, as the operation is relatively complicated, seniors feel the water tap is easily damaged. Moreover, regarding “effectively reduce repetitive operation” and “use method corresponds to different demands”, as an infrared sensor and splash device are installed, seniors feel the water tap can effectively reduce repetitive operation, meet different demands, and is more convenient to use.

Evaluation on Use of Water Taps by Children. Table 6 shows that children feel the water tap should have more specific operation instruction and feedback for users to read. Due to the height of children, it is necessary to reconsider the position of the water handle.

5.3 Interview Results and Analysis

In this research, participants first observed and operated the newly designed toilet and bathroom equipment, and then completed the questionnaire and accepted interviews, through which this study obtained the evaluations regarding the usage of the design by different age groups. This study recorded the problems arising from the use and

Table 6. Evaluation on use of water taps by children

Indicators	Measured value	Expectation	t	Significance (single-tailed)
Easy to understand how to operate it from appearance design	3.60	3.80	-0.77	0.22
Control water flow according to splash amount	3.70	3.70	0.00	0.50
Has specific operation instruction and feedback	3.60	4.50	-3.86	0.00*
Water temperature control is easy to understand	4.00	3.80	1.00	0.17
Columnar water flow from below can be easily and accumulatively controlled	3.80	4.20	-2.12	0.02*
Effectively reduce repetitive operation	4.00	3.70	1.15	0.13
It can return to the original state if wrong use methods are used	3.70	3.90	-0.85	0.20
Use method corresponds to different demands	3.70	3.70	0.00	0.50
It can be easily cleaned	3.30	3.30	0.00	0.50
Not easy to damage and durable	3.30	3.20	0.49	0.31

*P < .05

interaction of participants, and effectively obtained the data required for the experimental objectives, as based on the behavior and cognition process of the equipment described by the participants, which can provide a more complete new direction for solving problems of household bathroom equipment.

Interview Results of Young Adults. Young adults have the most suggestions regarding operation instructions and feedback, and feel that there is still room for improvement of the operational interface of the product, and it is necessary to make it easier for all users to understand how to use it. Some participants feel the splash water outlet position is not as good as expected, and can easily splash on clothes, thus, they feel it is better to allow users to actively contact it. As the water tap has more functions, they all think it can be easily damaged after long time use. However, it is impossible to test its durability during the testing period; thus, it is difficult to prove whether it is durable.

Interview Results of Seniors. It is relatively difficult for seniors to understand how to use it from its appearance, and relatively easier for them to use the product wrong, thus, they have many suggestions regarding the operational interface and instructions, and hope there are larger graphic signs, sounds, and other feedback. Regarding the infrared sensor on the columnar water mode, seniors feel that can reduce the body burden caused by repetitive operation and is more convenient for use. As the water tap has more functions, they all think it can be easily damaged after long time use.

However, it is impossible to test its durability during the test period; thus, it is difficult to prove whether it is durable.

Interview Results of Children. It is relatively difficult for children to understand the operational instructions, and required several times of wrong operation before learning correct usage. While some children could not use the splash face washing mode, and thus, have the most feedback regarding this mode. Regarding the handle near the water tap, it is relatively difficult for some children to control and switch on due to their height, thus, it is necessary to reconsider the position of the handle.

Interview Results of Disabled Participants. The disabled participants feel the water tap can effectively reduce repetitive operation and body burden. However, they all stated that durability is the primary factor they consider when choosing a water tap. The design appearance of the water tap makes it difficult for disabled participants to understand how to use it, and they initially used it wrong. Therefore, regarding disabled people, specific operational instructions are extremely important. As some disabled people are looked after by nurses, the water tap is switched on and off for them, which can save water and lessen the burden.

6 Research Conclusion

From the perspective of universal design, the household toilet and bathroom spaces are designed for seniors, disabled people, and all family members. Therefore, this research refers to domestic and foreign relevant information and research results in order to investigate the different use conditions and demands of existing household toilets, bathroom equipment, and users in Taiwan, proposes design planning and suggestions for toilet and bathroom equipment, and verifies lacking conditions that require improvement of washing equipment, according to the degree of satisfaction with the proposed design. It can be known through the questionnaire and interview analysis that, for all participants, there is still some room improvement in the understanding of easy operation, difficult to damage, and good duration in the design appearance of water taps, especially because many appearances are different from the appearances used in the past, the participants must become accustomed to the new mode of use. Regarding the aspect of difficult to damage and duration, many participants raise questions; however, as water tap is not used for long duration testing, it is unable to judge its duration degree. The usage demands of elderly and disabled people are quite similar, and fault tolerance and reduction of repeated use are specially required, as repeated operation generates more burden than for young people, and they will experience more significant issues. For children, clear operation tips should be considered first, as children are relatively short, it is difficult for them to use the handle beside the water tap; however, duration and cleanness are not considered for children.

Overall, the design and operation tips of water taps are unclear, and while some users do not initially know how to operate the taps, through several wrong uses, they can learn. In the process of operation, there are some small details that require modification, such as the approximate range and sensitivity of the infrared sensor, and the feedback degree of the button for water pressure, have room for improvement. After overall analysis, it is found that, although more diversified operations, as compared

with previous water taps, can meet the different usage demands, there should be more operation tips and feedback in order that users can accept such a new product. The duration degree can be accurately judged only when participants use the water tap for the long-term at home. For a new type of water tap, the users will first judge whether its appearance can be easily understood. If it is complicated, it is possible to make users understand how to operate more easily through clear operation tips and feedback; and provided that there remain operation errors, there should be a mechanism to recover the original mechanism. Correspondence to different demands and reduction of repeated operation are to reduce the physical burden of the user, while easy cleaning and duration are necessary conditions for everyone.

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