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Abstract	Robots play a crucial role in various industries, and while humanoid robots often come to mind when considering robots that assist humans, their implementation is technically challenging and has limitations to replace human roles. Therefore, research is needed to enhance human experiences through appropriate technology. This study explores and verifies whether the application of appropriate technology, in this case water drawing, can provide positive value to users. It also proposes a modality to improve communication between robots and humans through non-verbal interaction. The study was conducted through a survey showing scenario videos of adult, child, and elderly to the subjects, and having them evaluate how the interaction methods of the water-drawing robot affect likability, satisfaction, and perceived value in various situations. The results showed that the water-drawing robot positively influenced likability, satisfaction, and perceived value, with a high correlation among the three variables. Therefore, the interaction of the water-drawing robot positively affects user experience, and using appropriate technology like water drawing can provide positive experience, suggesting that the adaptation of appropriate technology can enhance valuable experiences and positively impact humans.

Keywords (separated by '-')	Water Drawing - Human-Robot Interaction - Appropriate Technology - Non-verbal Communication - Human Factor

Research on a Water-Drawing Robot Using Appropriate Technology: Focusing on Interaction Methods and User Experience

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Keywords: Water Drawing · Human-Robot Interaction · Appropriate Technology · Non-verbal Communication · Human Factor

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1 Introduction

1.1 Research Background

Robotics, which has been primarily used in industrial settings, is advancing in everyday life in forms such as guide robots and serving robots. In the past, robots performed repetitive tasks to assist humans, but with the advancement of technology and AI, the use of robots has expanded to interact with users in various situations. Although humanoid robots could be considered as an ideal form to assist humans, the technologies are still too complicated to be adapted in real life. Therefore, further studies on robots using appropriate technology are necessary.

The term 'appropriate technology' originally refers to technology that considers the political, cultural, and environmental conditions of the community where it is used, enabling sustainable production and consumption, and ultimately improving the quality of human life. Generally, it aims to produce products using locally sourced materials suitable for the local environment. On the other hand, in this study, we redefined the term appropriate technology which means a technology that uses low technology and simple mechanisms.

From a previous study [1], a water-drawing robot called WADE was created to provide new experiences and entertainment targeted for amusement parks. This robot can print an image on the ground using water instead of paint or ink, which also enables sustainability since it does not cause any pollution on the surface. This study aims to understand how robots with appropriate technology could enhance user experience.

1.2 Research Objectives

This study empirically analyzes whether the emotional interaction of a water-drawing robot can provide positive value to users. The purpose of this study is to develop a robot that can perform human roles using appropriate technology, thereby enhancing the user experience. Instead of using highly advanced technology, this study focuses on exploring new possibilities in robotics with appropriate technology and proposes practical robots for daily use.

2 Research Questions and Methods

In this study, we reviewed 11 previous studies in the HRI (Human-Robot Interaction) field to identify the characteristics of emotional expression elements in robots. The review showed that most of these studies mainly focused on non-verbal communication (body movements, eye movements, facial expressions, paralinguistic cues, anthropomorphic expressions, etc.).

According to Han Hoon, due to human psychological tendencies, robots are perceived as social entities, making the design of robots' emotional and intentional expressions crucial [2]. Soo-ah Kim stated that motion language plays a significant role in supplementing or independently conveying meaning, enhancing intimacy, and activating communication [3]. These previous studies confirm that non-verbal expressions significantly impact communication between robots and users. Therefore, this study aims

to investigate whether non-verbal elements using appropriate technology can enhance emotional expression in robots and improve user experience [4–14].

2.1 Research Method (Model and Hypotheses)

The WADE robot can express emotions through non-verbal communication modalities such as eye movements, head movements, and water drawing technology, as mentioned in previous studies. This study aims to evaluate the water drawing technology whether it can be considered as a third interaction modality and have a significant impact on users among the other two(eye movements and head movements). The following Table 1 and Fig. 1 gives a research model and hypotheses are set as follows (see Fig. 1).

Table 1. Research questions and hypotheses.

No.	Research questions and hypotheses.
H1	Does water-drawing positively impact user experience?
H1–1	Anthropomorphized interactions incorporating water-drawing technology will positively influence likability.
H1–2	Anthropomorphized interactions incorporating water-drawing technology will positively influence satisfaction.
H1–3	Anthropomorphized interactions incorporating water-drawing technology will positively influence perceived value.

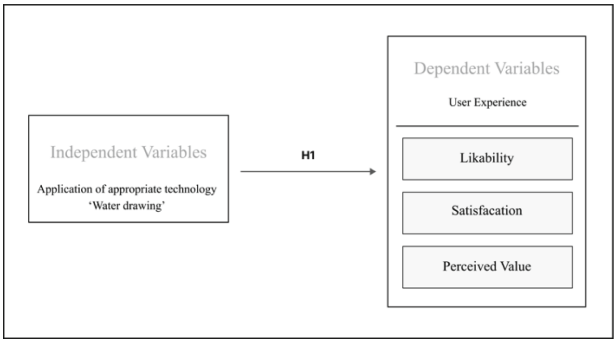

Fig. 1. Research model of a correlation between Independent variables and Dependent variables

2.2 Deriving Evaluation Factor

To derive evaluation factors, studies on usability and user experience evaluations related to robots, products, and services were analyzed, extracting likability, satisfaction, and functionality as applicable evaluation factors. The functionality, in this case, is redefined as perceived value to assess the expected effects as an interaction modality rather than evaluating the water drawing technology itself. The final evaluation factors are organized as follows [15–18] (Table 2).

Table 2. Evaluation Factors.

Variable	Evaluation Criteria (questionnaire)
Likability	Q1. I like the reaction of the robot Q2. The robot felt friendly
Satisfaction	Q3. The robot is expressing an expression that matches each user's situation. Q4. The water drawing method is satisfactory
Perceived Value	Q5. Robots are performing interactions with appropriate technology Q6. The interaction of the robot meets the expectations

2.3 Experimental Method

The experiment was designed to show three user scenario videos featuring an adult, a child, and an elderly to the subjects, and have them rate the interactions of the water-drawing robot in each scenario on a 5-point Likert scale. Although the WADE robot was designed for entertainment purposes in amusement parks, in this study we changed the environment to a general park setting to evaluate its interactions for more general use (Fig. 2 and Table 3).

AQ1

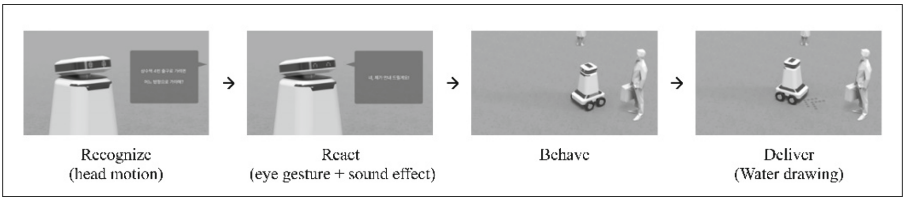

Fig. 2. Interaction sequence of the simulation video

3 Results

3.1 Demographic Analysis and Reliability Verification

The experiment was conducted by online survey May 22 to 27, 2024. Among the 51 participants, 31 were in their 20 s (61%), and 20 were in their 30 s (39%). Gender distribution was similar, with 29 females (57%) and 22 males (43%). In this study, Cronbach's α coefficient was calculated to verify the internal consistency of the measured factors and ensure their reliability. Factors with a coefficient of 0.6 or higher were considered reliable. The results of the reliability verification indicated that all factors measuring the dependent variables scored 0.6 or higher, confirming that the measurement indicators meet the required reliability standards (Tables 4 and 5).

Table 3. Interaction Scenarios.

Target user group	Non-verbal communication methods	Water-drawing	Application Scene
Adult	Eye movements pseudo-voice nodding	Composite information (arrows + text)	
Child	Eye movements pseudo-voice nodding	Emotional expression (emoticons)	
Elderly	Eye movements pseudo-voice nodding	Graphic information (arrows)	

Table 4. Demographic Analysis.

Variable	Description	Frequency (n = 51)	Percentage (%)
Age group	20 s	31	61
	30 s	20	37
Gender	Male	22	43
	Female	29	57

Table 5. Descriptive Statistics and Reliability Verification.

Variable	Metrics	M	SD	Sk	K	Cronbach's α
Likability	Q1	3.98	.948	−.984	.983	.802
	Q2	4.14	.980	−.949	−.083	
Satisfaction	Q3	3.61	1.060	−.400	−.630	.842
	Q4	3.86	1.096	−.857	.197	
Perceived Value	Q5	3.55	1.270	−.663	−.545	.786
	Q6	3.88	1.089	−.919	−.343	

3.2 Research Question and Hypothesis Verification Results

The correlation analysis of likability, satisfaction, and Perceived value is shown in Table 6. All three variables positively correlated, affecting each other. Satisfaction and Perceived value had a high correlation of 0.845. The average scores of the variables were calculated, with likability scoring the highest at 4.06. The factor asking about the robot's likability specifically scored in the 4-point range. Satisfaction scored 3.74, and Perceived value scored 3.72, both receiving relatively good evaluations.

Table 6. Correlation Analysis.

Variable	Likability	Satisfaction	Perceived Value	M
Likability	1			4.06
Satisfaction	.749**	1		3.74
Perceived Value	.758**	.845**	1	3.72

**$p < .01$

The analysis confirmed that interactions including water drawing positively impacted user satisfaction, likability, and Perceived value. Particularly, water drawing technology, combined with anthropomorphic emotional expression, elicited positive responses in overall likability and satisfaction. Additionally, as a sustainable technology using water, water drawing significantly influenced users' Perceived value evaluation.

4 Conclusion

4.1 Research Results and Discussion

This study aimed to confirm the potential of interaction using appropriate technology to enhance user experiences. The analysis showed that the emotional interaction of the WADE robot with water-drawing technology positively impacted users in terms of likability, satisfaction, and perceived value. The highest average score was for likability, followed by satisfaction and perceived value. These results indicate that anthropomorphic interaction technology, including water drawing, can provide sufficient satisfaction in human-robot interactions. Moreover, providing new experiences through appropriate technology can enhance the quality of human life. Therefore, this study proposes innovative interaction methods for HRI based on the anthropomorphic characteristics of service robots using appropriate technology.

4.2 Research Limitations and Future Directions

Limitation. This study analyzed the positive value of anthropomorphized interactions, including appropriate technology, through empirical research to contribute to improving the quality of human life. Additionally, it focuses on developing human-centered HRI, aiming to contribute to better HRI development in the future. Based on the study results, the following limitations and suggestions for future research are presented:

Future Directions. This study used virtual modeling animations instead of actual robot prototypes for user evaluation. Future studies should address this limitation by implementing real prototypes to assess overall user satisfaction and experience more accurately.

The experiment tested different scenarios and interaction methods for each age group, verifying the value of water-drawing technology. However, the study lacked control groups for comparison. Future research should investigate the impact of water-drawing technology on interaction enhancement by including control groups.

The study was conducted online with a small sample of 51 participants, primarily in their 20 s and 30 s. Future research should involve a larger sample size and broader age range for more accurate results. Additionally, qualitative interviews should be conducted to analyze the impact on user experience and propose practical design suggestions.

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Chapter 54

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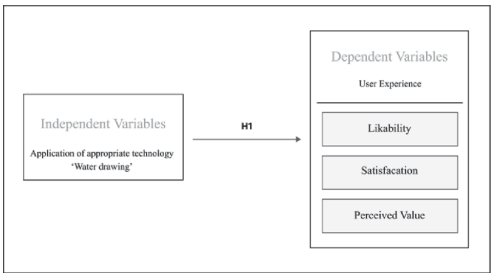
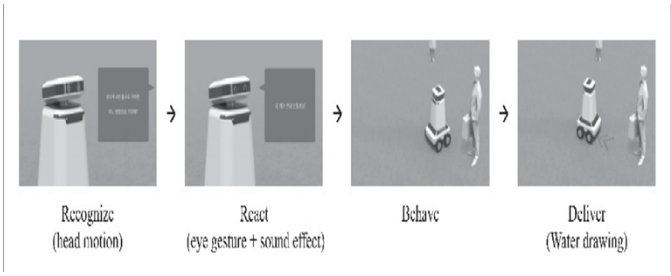
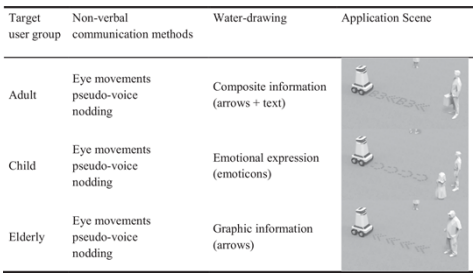
3	Fig1		Flow chart illustrating the relationship between independent and dependent variables. The independent variable is "Application of appropriate technology: 'Water drawing'." An arrow labeled "H1" points to the dependent variables, which include "User Experience," with subcategories "Likability," "Satisfaction," and "Perceived Value."
4	Fig2		Flowchart depicting a robot's interaction process in four stages. First, "Recognize" with head motion, showing a robot with a speech bubble. Second, "React" with eye gesture and sound effect, featuring another speech bubble. Third, "Behave," illustrating the robot approaching a person. Fourth, "Deliver" with water drawing, showing the robot next to the person. Arrows indicate the sequence of actions.
5	Tab3		Table illustrating non-verbal communication methods, water-drawing techniques, and application scenes for different target user groups: adults, children, and the elderly. For adults, methods include eye movements, pseudo-voice, and nodding, with composite information using arrows and text. Children use similar methods with emotional expression via emoticons. The elderly use graphic information with arrows. Application scenes depict interactions with a robot, showing different communication styles for each group.