

# Service Design of Artificial Intelligence Voice Agents as a Guideline for Assisting Independent Toilet Training of Preschool Children

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## Abstract

**Background** Infants aged 3 to 5 interact with their surroundings and face developmental challenges in many ways. Therefore, it is necessary to review the services provided not only from the perspective of adults such as parents and teachers but also from the perspective of preschool children as the main users of the services. This study explores the difficulties experienced by infants in childcare and educational institutions such as daycare centers and kindergartens, and aims to solve them from a multidisciplinary perspective.

**Methods** This study consists of three steps: defining the problem, designing the prototype as a solution to the problem, and the experiment as a step to verify the effectiveness of the prototype.

**Results** This study provides the implication that education and childcare centers can solve situations of existing problematic preschool children's experience with a toilet by installing a guideline applying an AI voice agent. It was found that the participants' fear and embarrassment when using the toilet alone was significantly reduced. Thus, guidelines with AI voice agents might allow the effect of helping preschoolers to have a positive perception of the toilet, not as an embarrassing and intimidating space.

**Conclusions** We identify the cause of difficulty in training preschool children to use the toilet and we seek practical solutions by applying a 'multi-disciplinary perspective'. In addition, we create a prototype in the form of 'AI voice agents' and verify its effectiveness through experiments. It is expected that our findings will be a practical solution to the problem of toilet training in education and childcare centers and homes. Moreover, as the introduction of the agent is expanded, it is hoped that the toilet, which is used to be a 'dead spot for childcare,' will serve as an opportunity to transform it into a 'smart childcare space.'

**Keywords** Preschool Children, AI Voice Agent, Independent Toilet Training, Co-Design, Multidisciplinary Perspective

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## 1. Introduction

### 1. 1. Purpose of the study

As many preschool children attend education and childcare centers in Korea, for their adaptive development, what they experience in these centers is as important as what they experience at their homes. Thus, the influence of preschool children's experiences in education and childcare centers on their development has been extensively studied. For instance, Byeon and Seo (2015) compared the effects of preschool children's experiences in forest activities and education and childcare centers on their development. Meanwhile, kindergartens and daycare centers are spaces for teachers to work and for preschool children to receive education and childcare. This means that the experiences of teachers in these centers should also be considered. According to Jang and Lee (2018), teachers under higher job stress tend to exhibit degraded role performance in terms of childcare and basic lifestyle guidance, education and teaching activities, counseling, and emotional support. In other words, excessive work stress perceived by teachers in education and childcare centers can negatively affect their role performance. According to Denham et al. (2012), teachers' mutual respect and positive communication toward the children provide opportunities for autonomy and promote social and emotional development through the showcase of sensitivity toward preschool children. Therefore, education and childcare centers should be considered a space for interaction between preschool children and teachers, as well as that for communication between teachers and parents, who are the primary caregivers for preschool children. However, despite the importance of holistically dealing with the perspectives and experiences of early childhood education and the use of early childhood education and childcare centers for preschool children, teachers, and parents, research in this aspect remains insufficient.

Identifying the potential needs and problems of users and suggesting a solution to the problem form the core of the design for problem-solving. Three to five-year-old preschool children are users who have been experiencing childcare for a long time, but since they are not aware of the problem themselves, they can be regarded as a vulnerable social group. For this group, we will discuss the difficulties that preschool children experience through teachers who are considered concerned people who have been experiencing preschool childcare with preschool children for a long time. In combination with design researchers who study design thinking, we will present a more scientific and accurate solution to the problem.

In this study, interviews were first conducted with seven preschool children aged three to five, three teachers who are currently working in education and childcare centers, and two parents in order to determine the difficulties related to the use of education and childcare centers from the viewpoints of preschool children, teachers, and parents. After deducing these difficulties, we proposed using a multidisciplinary approach from the viewpoint of co-design in relation to these difficulties. In particular, we used 5 whys, how might we, storyboard, and interviews. Through this process, a prototype of the difficulties that preschool children may face when using the toilet in education and childcare centers and solutions to these problems was created. To this end, an experiment was conducted on five preschool children to verify whether the prototype was effective in forming a habit of independent toilet training<sup>1)</sup>.

1) The terminology of "toilet training" generally includes extensive definitions, but this paper defines 'toilet training' as learning to take care of all processes after a bowel movement.

## **1. 2. Research questions**

This study explored various difficulties and problems related to the use of early childhood education and childcare centers from the perspectives of infants, teachers, and parents and sought to develop services to resolve the common difficulties found. For this purpose, the following research questions are addressed in this paper. 1) What difficulties do preschool children, teachers, and parents face in terms of using early childhood education and childcare centers? 2) Given the problems found above, what is the specific service plan that can help the common difficulty effectively? 3) Can the specific service plan resolve the common difficulties?

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## **2. Theoretical considerations**

### **2. 1. Perspective of child and family studies: Vygotsky's sociocultural theory**

The sociocultural theory, proposed by Vygotsky (1962), emphasizes the role of sociocultural environments in the development of preschool children. Vygotsky emphasized the role of language as a main mediator that connects an individual's mental function with sociocultural environments. He also proposed the concept of the zone of proximal development (ZPD), defined as the distance between the actual developmental level at which preschool children independently solve problems and the potential developmental level, which becomes achievable with the help of more knowledgeable adults or peers (Vygotsky, 1978). A child's development occurs within the ZPD, and it is necessary to provide assistance for the child's performance that occurs within their ZPD. Vygotsky's theory, which emphasized social intervention in preschool children's development as the scaffolding concept, was further developed by researchers who tried to identify the factors of effective teaching (Wood & Middleton, 1975; Wood, Brunner, & Ross, 1976). Scaffolding refers to a structure that serves as a stepping stone for preschool children's cognitive development by providing them with guidance and assistance from adults or peers at a higher level, thereby helping them learn. Such scaffolding can work more effectively when an emotional atmosphere with responsive and warm interactions is considered, as well as when it is provided to help preschool children perform tasks at their ZPD level (Kim, Park, & Kwang, 2001).

In this regard, this study aims to identify an effective approach to help preschool children experience scaffolding in each of their ZPD levels in education and childcare centers while assisting the teachers to provide adequate scaffolding to each student.

### **2. 2. Perspective of design–design thinking, design process**

Most of the previous service designs were designed based on the designer's understanding of the service; thus, there was a certain gap between the design plan and the actual needs of users. To close this gap, the co-design method, collaborating with stakeholders by using the design thinking process, can be used (Blomkamp, 2018). Design thinking refers to the use of designers' intuitive thinking methods to solve complex problems (Liedtka, 2018), and co-design refers to the collaboration between designers and non-designers for collective creativity (Sanders & Steppers, 2008). Co-design is closely related to traditional participatory

design (Holmlid, 2009). Its core lies in emphasizing the participation of experienced people, and it is based on the following principle: "Experienced people can only express their experience through participation." Co-design plays an increasingly important role in the process of design problem-solving because it can generate more innovative ideas and meet the needs of users (Steen & De Koning, 2011). Therefore, this study aims to use the co-design method to define the complex problems of infants and to propose services to solve these problems.

### **2. 3. Perspective of human-centered interaction**

User experience-oriented human-computer interaction (HCI) can be used to improve the inconvenient experiences that people encounter in daily life by using technologies including mobile devices, gesture and natural computing, sensors, embedded and wearable computing, Big Data, social & collaborative computing, and AI (Chung & Jun, 2020 cited in Liu et al., 2014). AI is one of the most popular topics of HCI in light of that expanding AI agent's role as a target of relationship building beyond the functional aspect of performing a given task. For example, the interactive storytelling method and gameplay experience provided by the social robot KindSAR can increase children's engagement and accurately respond to their suggestions (Chung & Jun, 2020 cited in Fridin, 2014). In addition, learning robots can support language development in preschoolers. Children are asked various questions from an early age, and these behaviors deal with areas that require causal reasoning, such as curiosity and learning motivation (Kory & Breazeal, 2014).

In this regard, the voice-based interface is expected to play a significant role in a building learning system for children. Therefore, this paper proposes a service using which children can solve their problems themselves by applying AI agents to their autonomous activities and lives.

### **2. 4. Consideration**

Referring to Vygotsky's Theory, linguistic help considering each child's level seems to be essential to help children learn. However, considering that infants are sensitive to visual stimuli due to their developmental nature, providing assistance through the medium may be useful to minimize other visual stimuli that attract children's attention other than verbal stimuli that are useful to children. In this regard, this study attempts to find difficulties that may arise in the situation in institution such as kindergarten of infants and toddlers from various perspectives. In addition, it is intended to suggest ways to solve this in a developmentally useful way for infants. In particular, based on the theoretical consideration that help through language is useful for infants, a solution using technology based on this will be finally presented and its usefulness will be confirmed. In this process, we tried to define the problem and explore specific solutions using the co-design method. The AI agent covered in this study is the final design result to be presented through collaboration between this Co-design method and a multidisciplinary perspective. This takes into account the theoretical elements of child family studies in the form of minimizing visual stimuli that may attract children's attention other than verbal stimuli useful to children.

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### 3. Research methods

#### 3. 1. Structure of research methods

This study was conducted in three steps: defining the problem, designing the prototype as a solution to the problem, and designing the experiment as a step to verify the effectiveness of the prototype. In the first step, we conducted “interviews” to listen to practical experiences, “How might we?” activities to expand ideas, “5 whys” to explore the root causes, and “storyboard making” to empathize with the infants. After defining the problem in detail in these four ways, in the second step, we developed the prototype, which involved sketching and setting stages. In the sketching stage, we used a co-design method from the perspective of design. In the setting stage, we developed the prototype design using the theoretical background of HCI. The effectiveness of the designed prototype was verified experimentally.

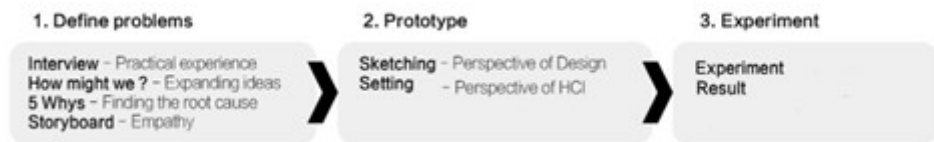


Figure 1 Co-design process

#### 3. 2. Definition of problems and causes using co-design methods

##### 3. 2. 1. Interview

The interview was conducted with 12 people: 3 to 5-year-old children (7), teachers teaching children of that age group (3), and the parents of these children (2). The purpose of the interview was to identify problems, suggest improvements in the toilet environment in childcare centers, and introduce the necessary services to improve the toilet environment and guidelines in childcare centers.

We found many situations in which preschool children have to go to the toilet alone in childcare centers. They are afraid of going to the toilet alone or feel shy and have difficulty asking teachers for help with defecation. Moreover, they have to wait alone until the teacher comes to the restroom for help. From the teachers' perspectives, it is often difficult to accompany a child every time because of the distance between the classroom and restroom or because the teachers have to handle other children as well. There are many cases in which teachers cannot provide specific toilet guidelines or instructions to each child in person. The interview data indicated that it is necessary to provide a separate defecation and toilet system in childcare centers' restrooms and additional systems that can provide more independent toilet guidelines for preschool children.

##### 3. 2. 2. How might we?

Before developing the study design, “How might we?” activities were conducted as a method to clearly define the problem. These activities aimed to determine “how to safely and happily go to the bathroom for children on their own” by freely expressing opinions. We then determined the common problems faced in this process. A design thinking process was used

to find the solution. In the process of freely expressing opinions using this technique, the importance of “guidelines that children can easily understand” was derived, and the need for practical and useful solutions was recognized.



Figure 2 How might we?

### 3. 2. 3. 5 whys

The “5 why” activity was conducted to explore the need for guidelines that preschoolers can easily understand, derived through the ‘How might we?’ activities. From the perspectives of preschoolers and childcare teachers, “lack of autonomy due to the absence of a toilet usage manual” was identified as the most fundamental problem in restrooms in education and childcare centers (Figure 3). We found another problem: “The restroom becomes a blind spot for childcare due to the lack of a device to share the work of teachers in the restroom, and teachers are also in a difficult situation” (Figure 4). In conclusion, these two fundamental problems became the basis for confirming the necessity of a practical solution and designing the prototype.

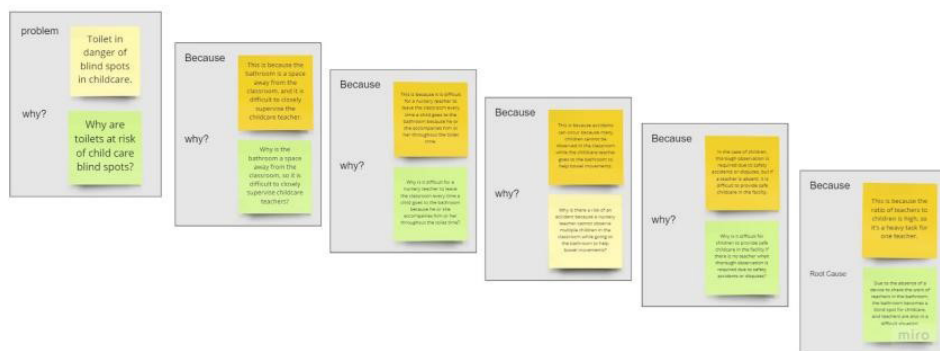


Figure 3 Five whys – standpoint of children

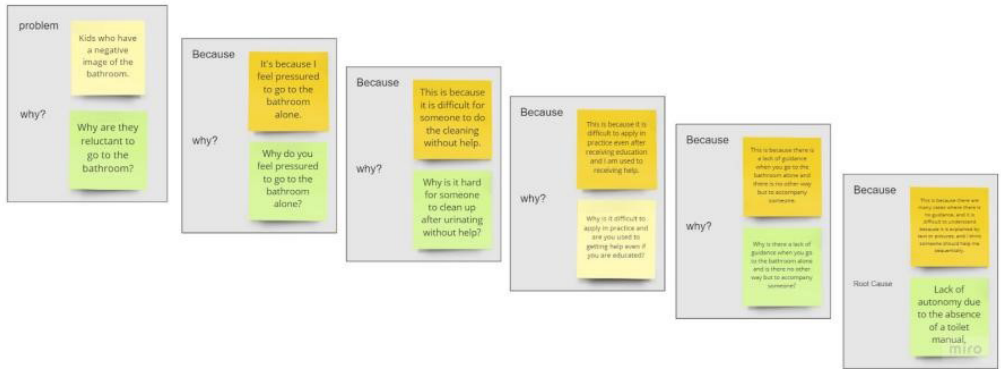


Figure 4 Five whys – childcare teachers

### 3. 2. 4. Storyboards

We illustrated a storyboard to understand and empathize with preschool children’s toilet experiences. While creating the story, our study found the necessity of solving problems that preschool children might experience while using the toilet by themselves, such as waiting alone passively in the toilet until teachers come to help them.



Figure 5 Storyboard–Understanding preschool children’s toilet experience

## 4. Prototyping

Most existing guidelines for assisting preschool children's toilet training have employed traditional implementations, such as sticking pamphlets on the inside door of each stall or conducting classes about toilet manners in education and childcare centers. The ultimate goal of toilet training is to let preschool children learn how to use the toilet, particularly getting accustomed to toilet training practically. To implement a practical tool to help learn about toilet training, this paper proposes the use of an AI voice agent.

## 4. 1. Sketching

Given that the traditional assisting method is held through one-to-one interaction with a teacher in the education and childcare center, the AI agent can act as a practical tool by setting an interactive dialogue. Moreover, the AI agent can have a specific personality that is considered suitable to encourage learning toilet training, such as adjusting nuance in the dialogue construct.

In contrast, children can feel overwhelmed when performing a new behavior from start to finish. Behavioral shaping can be an effective way to teach children the behavior they have never attempted before. In particular, behavioral shaping is implemented in a way in which the final target behavior for the child to acquire is set, the behavior acquisition process is subdivided into the smallest unit, and then the child is reinforced to perform each step until they can finally perform the target behavior. This method is more effective in that it can provide reinforcement to each child according to the individual performance level of preschool children attending kindergarten and childcare centers.

Moreover, from the perspective of the sociocultural theory, preschoolers can develop more adaptively when they receive help through scaffolding within their area of proximal development. To this end, rather than presenting guidelines for performing new behaviors all at once, we can help preschoolers learn gradually by providing guidance for defecation processing within each child's ZPD by setting detailed steps. In addition, by setting the character and tone, it feels as if the child is talking to their peers rather than being a rigid, mechanical AI agent; the children can feel that there is a real person helping them. This will be effective in helping children accept the help of AI agents more intimately and naturally.

Thus, by applying the AI agent's attribution that can have a personality based on Vygotsky's theory and by adjusting the nuance of the dialogue construct, we designed a complementary utterance that allows preschoolers to respond when they say they have completed a certain step in the logic of the AI agent's dialogue. This can help preschoolers intimately accept the help of the AI agent and encourage them to follow the instructions.

## 4. 2. Setting

We named the AI voice agent Ddongddong, which means "Poop Poop," to catch the interest of preschool children. Ddongddong was characterized as having a kind and positive personality and was set to compliment the children, in a bright and cheerful manner, for completing each step. In addition, we created Ddongddong's interactive dialogue in friendly utterances similar to those of a preschool child's friend in order for them to feel less anxious and more comfortable, although they are in the restroom by themselves.

The flow of logic of Ddongddong's dialogue was designed as shown in Figure 6, and the logic was created according to the following principles: First, Ddongddong can only be activated by a command that instructs its name. Second, Ddongddong should confirm the user's command by questioning "you want to [utteranced command] right?." Third, if a user says "no," Ddongdoni should say "I didn't get it. Can you tell me again?." In contrast, if a user says "yes" to the same question, Ddongddong should guide them to the next step by suggesting what the



user should do in the upcoming instructions. Finally, Ddongddong should verify whether the user has completed the task by saying, “Did it go well?”

The AI voice agent is an algorithm with a dialogue comprising 14 instructions, which are presented in Appendix 2. Due to the principle demanding confirmation of teachers in childcare facilities in Korea, we did not include the steps of dressing and washing hands at the end of the final guidelines. When a user inputs a command to start interaction with the AI agent, Ddongddong turns on and provides an appropriate guide according to the procedures listed in Appendix 2.

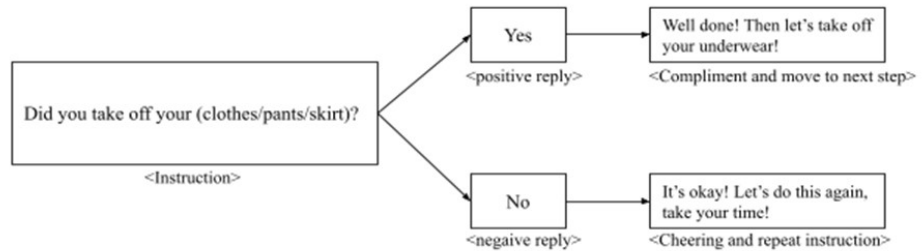


Figure 6 Logic of Ddongddong's dialogue for toilet training guidelines

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## 5. Experiment

To verify the effectiveness of the designed prototype, we recruited five participants attending an education and childcare center or daycare center. The participants, with ages ranging from 4 to 6, comprised two females and three males. We also engaged the participants' parents in both preliminary and post-interviews to understand the participants more objectively.

As it was difficult to conduct the experiment in education and childcare centers due to COVID-19 restrictions, the experiment was conducted individually at the home of each preschool child. In addition, we used the Wizard of OZ method of HCI in the experiments, rather than applying practical algorithms to AI voice agents, as the study focuses on exploring whether guidelines in the form of a voice agent can effectively assist preschool children with toilet training rather than verifying the performance of an AI voice agent in the restroom. Hence, depending on the Wizard of OZ method, the experimenters conducted the experiments as if the prototype Ddongddong were actually installed in the restrooms.

First, the purpose and method of the experiment were explained to the children's parents, and then the experiment was conducted after obtaining their consent for the experiment. In addition, after explaining the experiment's procedure to the children so that they could understand it, the experiment began when they agreed to participate in the experiment.

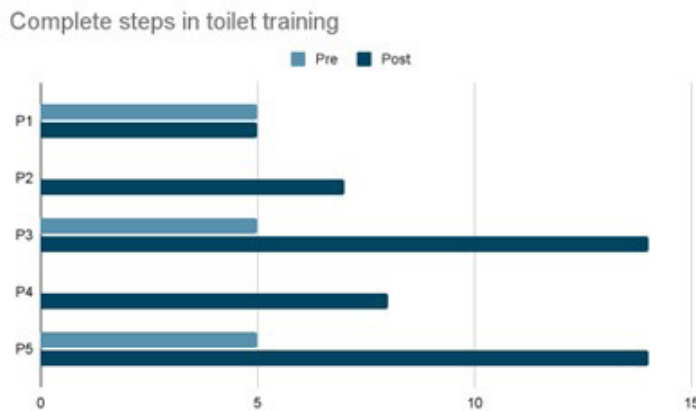
As a preliminary interview to investigate each participant's ability to take care of themselves after the bowel movement, we asked the parents up to what stage the children can succeed

on their own if there is no teacher around in the guidelines drawn up. Then, with a Bluetooth speaker placed in the restroom, an experiment was conducted to verify up to what stage they can succeed on their own in the presence of Ddongddong. After the experiment, semi-structured interviews were conducted with the preschool children and their parents to determine the advantages and disadvantages of the AI voice agent.

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## 6. Results

The prototype experiment results are shown in Figure 7. All experimental children, excluding child A, showed improved bowel movement processing performance level after the experiment compared to the pre-experiment. The degree of performance improvement levels differed depending on the age and characteristics of the children. However, when there was an improvement in performance level, the child with the largest difference showed nine steps of improvement (step 5 to step 14), and the child with the smallest difference showed seven steps of improvement (step 0 to step 7).



**Figure 7** Results of each participant's complete steps in toilet training as of using Ddongddong

Child A, the only one with no improvement, succeed up to step 5 both before and after the experiment. However, unlike finishing step 5 alone before the experiment, during the experiment, he attempted to cut four pieces of toilet paper, but he cut each piece separately, misunderstanding the guideline of step 6. Thus, he could not attempt the next step. This means that there was a slight improvement in the step after the experiment.

In addition to these changes in the possible stages of toilet training, observations during the experiment showed that the participants hesitated about entering the restroom alone before the AI agent prototype experiment; in contrast, they showed willingness to use the toilet by themselves after the experiment. During the guidance dialogue with Ddongddong, the participants comfortably answered "Yes" or "I'm done" as if talking to a friend, even though they expressed curiosity by asking Ddongddong "Where are you now?." Most of

the participants mentioned, “I think I can do better next time” or “It was good that the Ddongddong helped me.” Their parents answered that it would be a great help in toilet training if an AI agent could provide constant service to them.

However, Ddongddong’s dialogue has limited response questions and fails to meet the participants’ expectations because it repeats the same guideline and does not progress to the next step with a flexible interaction depending on utterances that are devoid of the terms “yes” and “no.” In this vein, the participants and their parents commented that guidelines with visualization materials or more abundant dialogues, which can respond to questions during the interaction rather than a one-way dialogue, would yield more effective results for preschoolers’ toilet training.

After the experiment, in an interview with parents, it was said that the child's anxiety (about going to the bathroom alone) significantly decreased. Even six months after conducting the experiment, we could hear the actual use of the provided recording file to help train the use of toilets. Even six months after the experiment, children who participated in the actual experiment remembered the voice agent 'ddongddong' and thought they were together when using the toilet, and it confirms some of the effects of relieving tension and anxiety.

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## 7. Discussion

When comparing our qualitative results of using the prototype with the participants’ previous experience of using the toilet, the participants' fear and embarrassment when using the toilet alone was found to be significantly reduced. Thus, the guidelines provided by AI voice agents can help preschoolers develop a positive perception of the toilet rather than as an embarrassing and intimidating space. Particularly, as one participant mentioned, “I can do better next time” after completing the experiment, the proposed prototype proved that it has the potential to elevate users’ self-efficacy and confidence levels.

From the perspective of child and family studies, the study results imply that education and childcare centers can address the problems faced by preschool children when using the toilet by providing them with instructions through an installed AI voice agent. As the prototype is designed to ask for help from protectors or teachers whenever participants want, children in the centers do not always have to go to the toilet with the teachers. In this regard, teachers can manage the preschoolers assigned to each of them more effectively, particularly in the case of education and daycare centers that have a toilet far away from the classroom or in cases in which the teachers cannot always accompany each child to the toilet due to a lack of human resources.

From the perspective of HCI studies, this study demonstrates that, using an AI voice agent, we can address the difficulties in the daily lives of humans with minimum technologies compared to recent AI studies, which have applied cutting-edge technologies, such as

automated AI-driven robots, for interaction with children. Therefore, this study enhances the significance of HCI by using an affordable method without unnecessary technology abuse. We not only found the effectiveness of the prototype by employing the Wizard of Oz method alone but also suggested the need for improvement, such as more interactive dialogues and visualizing an AI voice agent, for preschool children's independent toilet training.

This study has limitations regarding preschoolers who might not have fully concentrated on toilet training or have difficulties practicing each step of toilet training, as the proposed prototype is only processed by voice. In terms of the developmental characteristics of preschool children, they might frequently misunderstand instructions if the guidelines are only provided through voice. In fact, one participant tore a sheet of tissue four times, while the AI agent guided the participant to tear four sheets of tissue. To address this issue, we can consider implementing a visual AI agent. This can stimulate preschoolers' interest in toilet training, as most of the participants frequently asked the AI agent, "Ddongdong, Where are you?" expressing curiosity to actually see the AI agent who was talking to them during the experiment. Thus, this study leaves room for studying AI agents with visualizing guidelines to encourage preschoolers' toilet training.

The other limitation of this study is that the experiments were conducted in preschoolers' homes and not in actual education and daycare centers, due to COVID-19 restrictions. If the study had been conducted in these centers, we could have achieved reliable results for the effectiveness and validation of the prototype, which would have facilitated quantitative measurements.

Despite the abovementioned limitations of the designed prototype, we received positive reactions to employing an AI voice agent as a guideline to assist preschoolers' toilet training from the participants. In this vein, we found that our prototype is valuable for parents who have preschool children, although the study was started to tackle difficulties for preschoolers in education and childcare centers. Hence, we argue that our prototype guides preschool children to have independent toilet training by using AI voice agents in the restroom not only in education and daycare centers but also at homes.

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## 8. Conclusion

We identified the cause of "difficulty in training preschool children to use the toilet" and sought practical solutions by applying a "multi-disciplinary perspective." In addition, we created a prototype in the form of an "AI voice agent" and verified its effectiveness experimentally. Our findings are expected to provide a practical solution to the toilet training problem in both education and childcare centers and homes. Moreover, as the scope of the agent is expanded, it is hoped that the toilet, which used to be a "dead spot for childcare," can be transformed into a "smart childcare space." Overall, AI voice agents are expected to help preschool children learn independent hygienic toilet training and to have a positive impact on their autonomy and self-efficacy.

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Appendix

<https://docs.google.com/document/d/1IiWNnUSXz460iEsuwJkxA2Sn90kYodM8rxGLYnd0EM/edit?usp=sharing>

