

Development of an Augmented Reality Handwashing Tool for Children with Autism Spectrum Disorder

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Abstract—This paper introduces an innovative Augmented Reality (AR) handwashing tool for children with Autism Spectrum Disorder (ASD). Traditional handwashing training often needs more practical engagement, resulting in adequate muscle memory development. Traditional methods may need to address these children's needs more effectively, leading to suboptimal handwashing or avoidance. This study presents an Augmented Reality (AR) handwashing tool, leveraging the Microsoft HoloLens2 platform, to offer an engaging learning experience tailored for children with ASD. The tool simulates a bathroom setting, guiding users through handwashing steps using dialogues, text, and audio. Evaluations included observations, interviews, and a controlled experiment involving five children with ASD. Feedback highlighted the tool's engaging nature, mitigating tactile sensitivities and anxiety linked to regular handwashing. Results showed improved handwashing practices after using the AR tool. This AR approach can foster better hand hygiene in children with ASD. Future research will focus on personalizing the tool, studying long-term engagement, and combining therapeutic strategies to enhance its effectiveness and applicability in enhancing life skills for children with ASD.

Index Terms—Augmented Reality, Autism Spectrum Disorder, Handwashing Training, HoloLens 2, Hygiene

I. INTRODUCTION

Handwashing is a crucial hygiene practice vital in preventing the spread of infectious diseases and other harmful germs. Mastering proper handwashing techniques is particularly important for children as they are more susceptible to infections and illnesses due to their explorative nature and close interactions with others. However, for children with Autism Spectrum Disorder (ASD), learning and practicing proper handwashing techniques can pose significant challenges. People with ASD are often hypersensitive to certain sensory stimuli, which can be overwhelming and cause distress or discomfort. The sound of running water from a faucet or the touch of cold water can overstimulate someone who has ASD and cause them to steer away from washing their hands.

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Additionally, these challenges are exacerbated in unfamiliar environments. Children with ASD face unfamiliar environments that are very common encounters, such as schools or new social settings, where sensory stimuli are heightened due to the novelty of the surroundings. Moreover, individuals with ASD may experience delayed cognitive or learning skills, making it difficult for them to remember and execute the proper steps of handwashing correctly. Consequently, existing handwashing training methods rely on theoretical instruction and visual aids, often short of supporting muscle and physical memory development. As a result, many children must fully develop proper Handwashing skills or even avoid washing their hands altogether.

To address these limitations and support the development of healthy sanitation habits in children with ASD, this research project proposes an innovative approach: augmented reality technology to develop an immersive and interactive handwashing training tool that effectively teaches children with ASD how to wash their hands properly. Augmented reality offers a unique opportunity to enhance training by providing the ability to control overlaying digital content onto the physical world to create a dynamic and engaging environment for learning. By utilizing AR, we aim to provide a guided and immersive experience in a bathroom environment, fostering the development of proper handwashing techniques through an interactive, engaging, and personalized approach.

This paper introduces a pioneering approach that utilizes augmented reality to instruct young children with ASD in proper handwashing hygiene, aiding them in cultivating improved sanitation habits. The primary objective of this study was to begin the development of an augmented reality handwashing training tool that effectively teaches children with ASD how to wash their hands properly. Utilizing the Microsoft HoloLens 2 as the AR platform, which can be seen in Fig. 1, the handwashing tool was created as a universal Windows platform application for the HoloLens 2 device. The application contains a bathroom setting with interactive

elements, such as sinks, soap dispensers, and towels. Upon start, the app uses a dialogue system and text panels that guide the user through the step-by-step handwashing process, providing audio instructions, visual cues, and interactive feedback. To evaluate the efficacy of the AR handwashing



Fig. 1. Camper using the HoloLens 2 device during application test.

tool, observations were conducted on children with ASD using the application. Also, feedback was obtained through interviews with both the users and their parents, focusing on their perceptions of the tool's effectiveness, user experience, and suggestions for improvement. Additionally, children were tasked with washing their hands before using the tool, using the tool, and then they were tasked with washing their hands again. Videos of the child with ASD were taken before and after the training to evaluate whether the tool was effective.

This research aims to contribute to the field by exploring the potential of AR as an innovative and effective tool for promoting better hygiene habits in children with ASD. By utilizing the immersive and interactive nature of AR, we seek to enhance the traditional handwashing training approach and address the specific challenges faced by children with ASD.

In the subsequent sections, we will delve into the background of handwashing training for children with ASD, discuss the methodology employed in developing the AR handwashing tool, present the study findings, and offer conclusions and future directions for research.

II. BACKGROUND

Children with Autism Spectrum Disorder face unique challenges in developing proper sanitation and handwashing

habits. ASD is characterized by neurodevelopmental differences, including sensory sensitivities, social communication difficulties, and restricted repetitive behaviors [2]. These challenges can significantly impact a child's ability to engage in and sustain essential hygiene practices, such as handwashing. As little to no work is done on the concept of an AR handwashing tool for children with ASD, this section will dive into these challenges in further detail and discuss how AR can be a potential solution.

A. Challenges with Handwashing for Children with ASD

Children with ASD may experience heightened sensitivity to sensory stimuli, such as the sound of running water and soap texture, making handwashing a difficult, overwhelming task. Hypersensitivity to sensory stimuli can make tasks overwhelming, and it was also found to cause aggressive and self-harming behavior [1].

Additionally, ASD often involves resistance to changes in routine or new environments. In changing or new situations, these children experience high anxiety and discomfort because their normal is inhibited, which causes them to lose control of their emotions, resulting in disruptive behavior [2]. Children with ASD may struggle to adapt to unfamiliar bathrooms or settings, making it challenging to establish consistent handwashing habits, especially in novel or public places.

Lastly, Children with ASD may have delayed cognitive or learning skills, impacting their ability to understand and remember the step-by-step process of handwashing. Additionally, challenges in social communication may lead to difficulties in following verbal instructions during handwashing.

B. Augmented Reality (AR) Training Tools

Augmented reality technology offers a promising solution to address the challenges faced by children with ASD in handwashing training. AR allows for integrating digital content into the real world, creating interactive and immersive learning experiences. AR training tools can simulate real-life scenarios, offering a safe and controlled environment for skill-building, which is particularly beneficial for individuals with sensory sensitivities.

As there is little research on a specific AR handwashing training tool, [3] discusses the APD Handwash Android App, which performs an estimated calculation on simulated germs on hand. The app allows users to take pictures of their hands before and after washing, using powder or dyes to visualize the effectiveness of the handwashing process, which can be seen in Fig. 2. This app is a valuable resource for understanding the current state of handwashing evaluation and can inform the development of an AR handwashing tool for children with ASD. Overall, AR training systems are promising to enhance the user experience and improve training outcomes. Still, more research is needed to determine their effectiveness and how they can be optimized for different application fields. proving

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C. Current Handwashing Training Methods

Traditional handwashing training methods often rely on theoretical instruction and visual aids, which may not effectively address the specific needs of children with ASD. For example, during the pandemic of 2020, public health campaigns encouraged frequent handwashing with guidelines on the technique to use. However, these campaigns found it difficult to convince people to practice these handwashing techniques because of the duration and complexity that the procedures entailed [3].

The study in [5] reported significant improvements in adherence to handwashing best practices across all self-reported variables, achieving over 89% adherence across recommendations by the end of the project. Adherence to the 20-second washing duration recommendation was the most significant improvement. Signage and support aids, such as timers, were effective strategies for enhancing attention to handwashing best practices. Although the study was not conducted on children with ASD, the findings suggest that incorporating timers, which could easily be done in AR, could positively affect the handwashing practices in children with ASD.

Additionally, [3] shows that the APD Handwash Android App demonstrates the potential of technology in evaluating handwashing techniques. However, it does not specifically cater to the unique needs of children with ASD, who may face additional challenges in learning and practicing proper

handwashing techniques. By examining the APD Handwash Android App and its approach to handwashing evaluation, researchers can identify areas for improvement and adaptation to suit the needs of children with ASD better.

These methods lack the necessary elements of muscle and physical memory development, as they do not provide an immersed and guided experience in a bathroom environment. Consequently, many children with ASD struggle to develop proper handwashing skills or may avoid washing their hands altogether, putting their health at risk.

D. The Potential of AR to Transform Handwashing Training

By leveraging augmented reality technology, researchers and educators can revolutionize handwashing training for children with ASD. AR training tools can create a dynamic and engaging learning environment, providing interactive feedback and personalized guidance tailored to the individual's needs. Moreover, using AR can help desensitize children to sensory stimuli related to handwashing, promoting a positive and successful learning experience.

In conclusion, this paper's background highlights the challenges children with ASD face in developing proper sanitation and handwashing habits. It introduces the potential of augmented reality training tools to address these challenges and emphasizes the limitations of current handwashing methods. By exploring the use of AR as an innovative approach to handwashing training, this research seeks to improve hygiene habits for children with ASD and enhance their overall well-being.

III. METHODOLOGY

The methodology for this research project is divided into two areas. One area is the actual AR handwashing application development, and the other is the data collection methods.

A. Design and Development of the AR Handwashing Training Tool

The research design and development of the augmented reality handwashing training tool for the HoloLens 2 involved several key steps to create an immersive and interactive learning experience for children with ASD.

a) *Conceptual Design:* The initial stage involved conceptualizing the AR tool's design and functionality. This was done by creating an outline of the key features. The tool's key features include having a fully interactive bathroom environment, meaning the user could grab, hold, and touch the objects in the bathroom. Since the tool is only for handwashing training, it was decided to only keep a soap dispenser, sink, and towel dispenser for the environment. The tool was also decided to incorporate game-like mechanics to draw the user's attention.

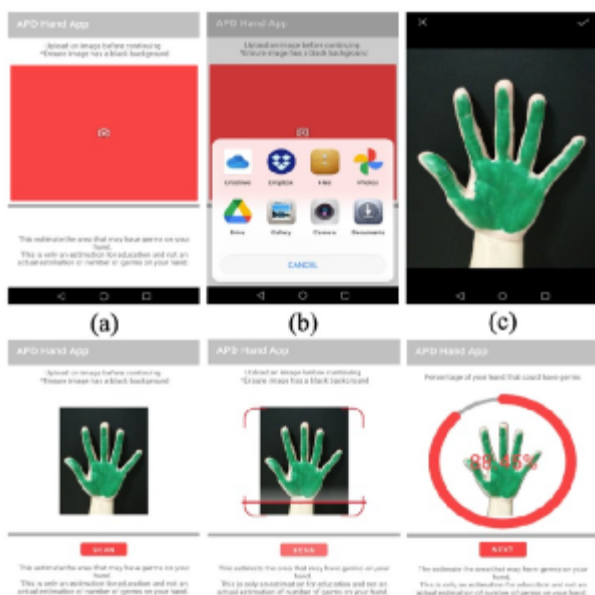


Fig. 2. The APD Handwash Android App, Discussed in [3].

b) Development Tools and Resources: We employed a combination of powerful development tools and resources to create the AR handwashing training tool on the HoloLens 2. Unity, renowned for its ability to create immersive experiences, was selected as the primary game engine and development platform. Visual Studio was also installed to facilitate seamless integration with the HoloLens 2, providing essential development support. Furthermore, a Mixed Reality Toolkit (MRTK) was needed to enhance the application's functionality and interaction capabilities. MRTK served as a valuable resource, offering a set of pre-built components and scripts specifically designed for mixed reality applications, streamlining the development process, and ensuring optimal performance on the HoloLens2 device.

Once the correct tools were installed and the Unity project was configured for MRTK, we began designing the virtual bathroom environment, a crucial aspect of the handwashing training tool. To enhance the visual fidelity and realism of the environment, we opted to acquire bathroom assets from the Unity Store. Specifically, we utilized assets from the "Classic Public Bathroom" [4] and "Pixel World Project" [5] packages, which provided a wide array of high-quality 3D models, textures, and materials essential for creating a convincing virtual bathroom setting. These assets allowed us to craft an immersive and interactive environment, complete with a sink, soap dispenser, towel dispenser, and other elements necessary for the handwashing training, as depicted in Fig. 3. Using these assets saved valuable development time and ensured that the environment's design met the expectations of our target audience, children with ASD, making it engaging and relatable for effective learning.

c) User Interface and Interaction: The user interface and interaction of the augmented reality (AR) handwashing tool were thoughtfully designed to provide an engaging and immersive learning experience for children with ASD. The virtual bathroom setting featured essential handwashing elements, including a sink, soap, and towel dispenser, each allowing user interaction. An example of these interactive elements can be seen in Fig. 3. Various user interface (UI) elements were set in place to guide the user through proper handwashing steps. The UI elements include clear and concise textual instructions displayed in text panels, ensuring the children are guided through the process effectively.

Additionally, a text-to-speech object was integrated to cater to different learning styles, verbally announcing each step at the start, further reinforcing the instructions. A directional indicator was implemented to aid spatial understanding and orientation, accurately pointing the users toward the next step's location. Combining interactive objects, step-by-step textual guidance, audio prompts, and spatial indicators fostered a seamless and accessible learning experience, empowering children with ASD to master proper handwashing techniques confidently.

d) Game Structure: The game structure of the augmented reality (AR) handwashing training tool designed for children with ASD follows a carefully crafted and interactive approach to facilitate effective handwashing instruction. The game's core revolves around a central "GameManager" object, housing a game manager component as the handwashing guide throughout the training process. Within the game, the "GameManager" keeps track of the current handwashing step, which encompasses a series of distinct actions essential for proper hand hygiene. These steps include turning on the faucet, wetting hands, dispensing soap, scrubbing each hand's front and back, rinsing hands, turning off the faucet, and drying hands with a towel. The GameManager is notified after completing each of the steps seen in Fig. 4. The interactive nature of the core game objects seen in Fig. 3, allows children to interact with them physically, simulating real-world handwashing actions. Additionally, text panels display the current handwashing instructions to ensure children follow each step accurately, guiding them through the process. Furthermore, a text-to-speech object audibly communicates the step instructions, enabling children to hear clear and concise guidance.

A directional indicator points to the relevant objective for each handwashing step to enhance spatial understanding and direction during the training. For instance, if the GameManager's current step is "TurnOnFaucet," the indicator will move to guide the user toward the faucet, prompting them to interact with it to activate the water. Throughout the training, the "GameManager" continuously monitors the child's progress, updating the UI text panel and issuing relevant audio instructions upon completing steps to ensure

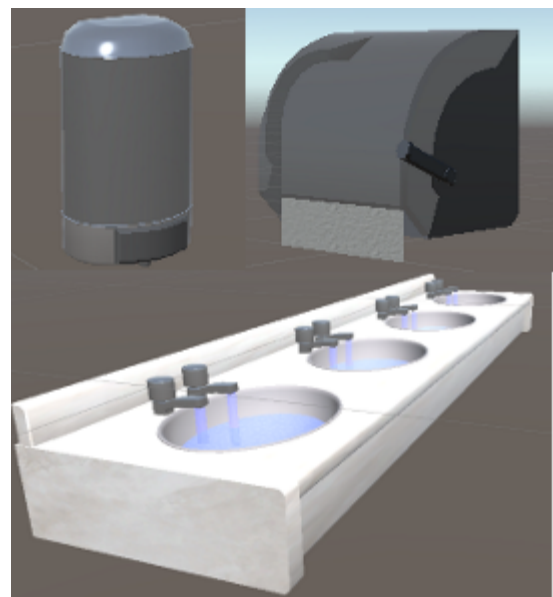


Fig. 3. Core Game Objects from [4] and [5].

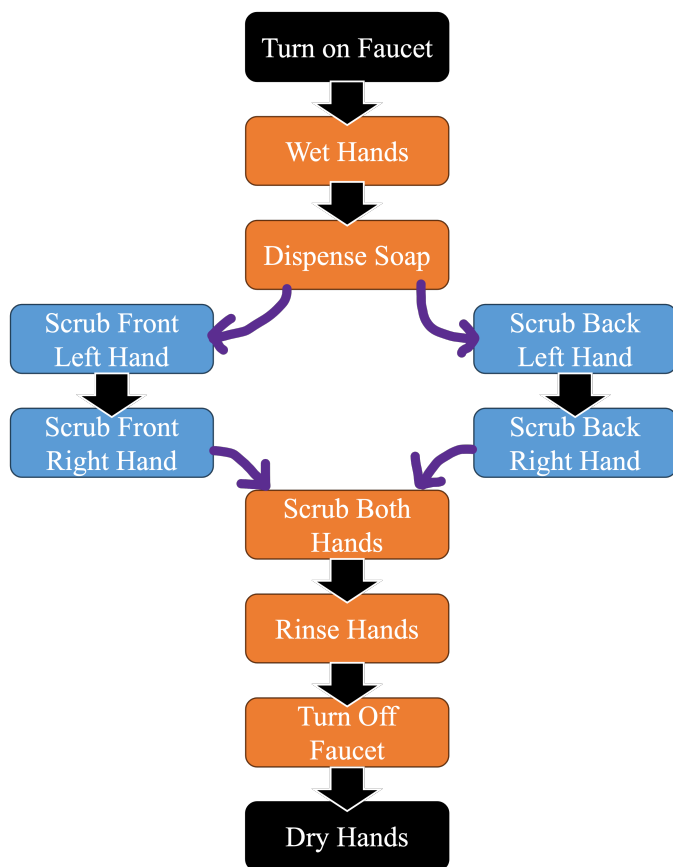


Fig. 4. Demonstration of User Interface.

a smooth and effective learning experience. The UI elements and interactable objects can be seen in Fig. 5.

Unfortunately, as a prototype, the current version of the AR handwashing training tool focuses primarily on providing children with ASD a comprehensive understanding of proper handwashing techniques through interactive and engaging methods. While additional features and elements for "winning" the game are yet to be fully integrated, the primary objective is to promote effective hand hygiene skills among children with ASD, offering them a valuable tool to develop sanitation habits crucial for their well-being.

B. Data Collection

Data collection for evaluating the AR handwashing tool for children with ASD was conducted through two comprehensive approaches. The initial method involved demonstrating the AR handwashing tool to children with ASD at a specialized ASD camp. The children interacted with the application throughout the demonstration, and real-time feedback was gathered to gauge their experiences and engagement with the tool. Subsequently, in-depth interviews were carried out with each child, providing valuable insights into their perceptions and responses to the handwashing training. Furthermore, to

gain a comprehensive understanding of the tool's impact, interviews were conducted with the parents of the participating children with ASD, offering additional perspectives on the tool's effectiveness in improving handwashing practices.

The second approach involved a controlled experimental study to measure the tool's impact on handwashing skills objectively. Five test subjects, comprising children with varying degrees of ASD aged between 8 and 10, participated in the study. Pre- and post-application videos were recorded for each test subject during handwashing activities. Based on the recorded videos, a carefully designed scoring system was then utilized to assess the tool's effectiveness. The scoring system allocated points for each completed handwashing step and additional points were awarded for specific scrubbing steps that involved extended durations. This quantifiable data allowed for a rigorous evaluation of the tool's efficacy, enabling comparisons of pre- and post-application scores to determine the extent of improvement in handwashing skills among children with ASD. The combination of real-time feedback and quantitative scoring facilitated a comprehensive evaluation of the AR handwashing tool's potential to enhance hand hygiene practices for children with ASD.

IV. RESULTS

A. Interview Findings

The interviews conducted with parents and children with ASD who used the AR handwashing tool provided valuable insights into its effectiveness and impact on the handwashing behavior of the participants. Several key themes emerged from these interviews:

- *Engagement and Interest:* Parents supported the idea that the AR tool's "video game" aspect piqued the children's interest, making handwashing a more engaging and enjoyable experience. By turning handwashing into a playful and interactive activity, the tool effectively captured the attention of children with ASD.



Fig. 5. Demonstration of User Interface.

- *Reduced Sensory Stimulus:* Participants appreciated the removal of the tactile aspect of handwashing through AR. This reduction in sensory stimuli made the handwashing process less overwhelming for children with ASD, who often experience sensory sensitivities.
- *Anxiety Reduction:* AR technology allowed children with ASD to see the handwashing steps and experience the process in a virtual environment. This visualization helped reduce anxiety related to the uncertainty of the handwashing routine.
- *Generalization to Other Skills:* Parents acknowledged the potential of AR in various areas of learning for children with autism, not just limited to handwashing. AR technology could be extended to help children understand social interactions, appropriate behavior, and responses.
- *Immediate Response:* Observations revealed that when the children used the AR handwashing tool, they exhibited proactive behavior by washing their hands in the real world as soon as the AR game started. This indicates that the tool's impact was immediate and motivating.

B. Experimental Results

To quantitatively assess the impact of the AR handwashing tool on the participants' handwashing skills, pre and post-application scores were collected and compared. Each participant's performance was evaluated based on different handwashing steps, and a cumulative score was calculated.

1) *Pre-Application Scores:* Table I shows the handwashing scores of each participant before using the AR handwashing tool.

TABLE I
PRE-APPLICATION SCORES

Participant	A	B	C	D	E
TurnOnFaucet	1	1	1	1	1
WetHands	0	0	1	1	0
DispenseSoap	1	1	0	1	1
ScrubFrontLeftHand	1	0	0	0	1
ScrubBackLeftHand	0	0	0	0	1
ScrubFrontRightHand	1	0	0	0	1
ScrubBackRightHand	1	0	0	0	1
ScrubBothHands	3	0	0	1	1
RinseHands	1	1	0	1	0
TurnOffFaucet	1	1	1	1	1
DryHands	1	0	0	0	0
Score	11	4	3	6	8

2) *Post-Application Scores:* Table II presents the handwashing scores of each participant after using the AR handwashing tool.

The post-application scores indicate an improvement in handwashing skills for most participants. The tool's intervention increased scores in various handwashing steps, demonstrating its effectiveness in facilitating skill development in children with ASD.

TABLE II
POST-APPLICATION SCORES

Participant	A	B	C	D	E
TurnOnFaucet	1	1	1	1	1
WetHands	1	0	1	0	0
DispenseSoap	1	1	1	1	1
ScrubFrontLeftHand	1	0	0	1	1
ScrubBackLeftHand	1	0	0	0	2
ScrubFrontRightHand	1	0	0	1	1
ScrubBackRightHand	1	0	0	0	2
ScrubBothHands	2	2	1	1	2
RinseHands	1	1	0	1	1
TurnOffFaucet	1	1	1	1	1
DryHands	1	1	1	1	0
Score	12	7	6	8	12

Overall, the combination of qualitative feedback from interviews and quantitative data from pre- and post-application scores supports the potential of the AR handwashing tool in assisting children with ASD in developing and maintaining proper handwashing habits. The results indicate that AR technology can be an engaging, effective, and beneficial tool for children with ASD, for handwashing and other learning areas. Further research and continuous development are essential to explore the full potential of AR technology in supporting the needs of individuals with ASD.

V. CONCLUSIONS

Developing an Augmented Reality (AR) handwashing tool tailored specifically for children with Autism Spectrum Disorder (ASD) has shown promising results in enhancing their handwashing experience and skill development. This research report presented the findings from interviews with parents and children with ASD who used the AR handwashing tool and the results from the pre-and post-application handwashing scores.

The interviews highlighted several key benefits of the AR handwashing tool. Parents strongly supported the tool, emphasizing its ability to capture their children's interest through the "video game" aspect. The removal of tactile stimuli during handwashing and the visualization of the process in a virtual environment helped reduce anxiety and sensory sensitivities commonly experienced by children with ASD. Additionally, the observations revealed that the tool's interactive nature motivated children to proactively engage in handwashing, showing its immediate impact on their behavior.

The pre-and post-application handwashing scores further substantiated the effectiveness of the AR tool. After using the AR tool, the participants demonstrated improved handwashing skills, indicating its potential to facilitate skill development in this population. The positive changes in handwashing behaviors reinforce the significance of utilizing AR technology to address challenges faced by children with ASD in acquiring and maintaining essential hygiene habits.

Beyond handwashing, the interviews also shed light on the broader applications of AR technology for children with autism. Participants and parents recognized the potential of AR in various learning areas, including social interaction training and behavior management. This indicates that AR technology can be a versatile and valuable tool for addressing various developmental needs in children with ASD.

The implications of this research are substantial for both the field of autism intervention and technology-based learning. The AR handwashing tool represents a novel approach to teaching essential hygiene routines in a way that is engaging, enjoyable, and effective for children with ASD. By leveraging AR technology, educators, therapists, and caregivers can create a more inclusive and supportive learning environment that caters to the unique needs of children on the autism spectrum.

In conclusion, developing an AR handwashing tool for children with ASD demonstrates its potential for effectively teaching children with ASD how to wash their hands properly. The combination of positive feedback from interviews and improvements in handwashing scores suggests that AR technology can play a vital role in addressing the unique challenges faced by children on the autism spectrum. This research contributes to the growing body of knowledge in technology-based interventions and autism support, paving the way for future innovations that promote inclusive and meaningful learning experiences for all children, including those with autism.

VI. FUTURE WORK

The AR handwashing training tool for children with ASD has shown promising results, but there are still avenues for further exploration and improvement. Future work in this area could focus on the following aspects to enhance the tool's effectiveness and impact:

a) Long-term Engagement Studies: Long-term engagement studies with a larger and more diverse group of children with ASD could provide deeper insights into the tool's sustained effectiveness. Tracking handwashing habits over an extended period could help determine if the positive effects persist over time and whether the tool leads to consistent handwashing routines.

b) Personalization and Customization: Investigating ways to personalize and customize the AR handwashing training tool for individual children with ASD could enhance its relevance and effectiveness. Tailoring the tool to cater to different sensory sensitivities, learning styles, and skill levels could further optimize the learning experience and ensure greater success in acquiring handwashing skills.

c) Incorporating Social Stories: Integrating social stories within the AR handwashing tool could help children with ASD better understand the context and importance of handwashing in various real-life scenarios. Social stories are narratives that describe social situations and appropriate responses, which

could be beneficial for children with ASD in comprehending the significance of hand hygiene in different contexts.

d) Multi-platform Development: Expanding the tool's compatibility with other AR and VR platforms could widen its accessibility and reach. While the initial development focused on the HoloLens2, adapting the tool to other devices would enable more children with ASD to benefit from the interactive handwashing training experience.

e) User Interface Improvements: Continuously refining the user interface to be more intuitive and user-friendly would enhance the tool's overall usability. Simplifying navigation, improving visual cues, and optimizing text-to-speech functionality can promote effective interaction and learning for children with ASD.

f) Integration with Therapeutic Approaches: Collaborating with therapists and educators to integrate the AR handwashing tool into therapeutic programs and school curricula could maximize its potential impact. Aligning the tool with established therapeutic approaches for children with ASD could result in a more comprehensive and structured learning experience.

g) Data-driven Analysis: Conducting extensive data analysis on the collected user feedback and performance data could offer valuable insights into specific areas for improvement. Analyzing user interactions, learning patterns, and preferences would provide evidence-based guidelines for refining the tool's design and content.

h) Expanding Content: Considering the success of the AR handwashing tool, exploring opportunities to develop additional AR training modules for other essential life skills could be beneficial. Expanding the tool's content to cover other daily routines, such as toothbrushing, bathing, or getting dressed, could support a more holistic approach to promoting independence and self-care for children with ASD.

By addressing these areas of future work, the AR handwashing training tool can continue to evolve and be optimized to meet the specific needs of children with ASD. This research paves the way for ongoing advancements in using AR and VR technologies to support and empower children with autism in acquiring crucial life skills, ultimately improving their quality of life, and enhancing their overall well-being.

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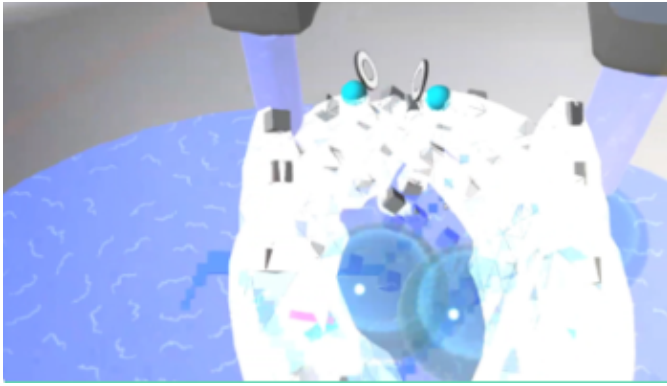


Fig. 6. Handwashing in AR.

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