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# Design of a healthcare ecosystem to improve user experience in pediatric urotherapy

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**Abstract**

This paper addresses challenges in pediatric urotherapy, focusing on low patient compliance and motivation. Informed by creative sessions with children aged 9-13y, a novel urotherapy ecosystem concept is designed. It includes a smart drinking bottle, context-aware reminder watch, home uroflowmeter, smartphone app, and clinician portal. Interconnected products, embodied interaction, stigma-free design, and a digital training buddy aim to enhance engagement, motivation, and patient experience. This concept showcases the potential of integrating diverse design methodologies in healthcare design.

*Keywords: healthcare design, user experience, user-centred design, interaction design*

## 1. Introduction

Many school-aged children (5 – 13 years) experience daytime urinary incontinence (Austin et al., 2016; Nieuwhof-Leppink, Schroeder, et al., 2019), resulting in low self-esteem, shame and stress, thereby negatively impacting their quality of life (Bower, 2008; Thibodeau et al., 2013). The recommended first-line treatment is urotherapy (Chang et al., 2017), involving re-education and rehabilitation of the bladder and pelvic floor muscles. During urotherapy children receive age-appropriate information and instructions on drinking and toileting habits, which require repeated practice for optimal results (Mattsson et al., 2010; Rivers, 2010). The products designed to support urotherapy include a variety of tools, such as bladder diaries (Ku et al., 2004a), timer watches (Hagstroem et al., 2010), wetting alarms (Mattsson et al., 2010), and uroflowmeters (Yamanishi et al., 2000) (Figure 1). Traditional bladder diaries consist of paper-based schedules where patients manually record their urinary output (using a measuring cup), fluid intake, and leakage accidents over several days (Austin et al., 2016). It provides child, parent and clinician with insights on symptoms and treatment progress and help to create self-awareness of drinking and toileting habits. Therefore, the bladder diary plays a key role in urotherapy (Chang et al., 2017; Maternik et al., 2015; Schäfer et al., 2018). Timer watches, on the other hand, sound an alarm at fixed time intervals to remind children to drink and void regularly. This product encourages children not to postpone going to the toilet until they experience an urgent need or have accidents, but rather to urinate at set intervals with a more relaxed pelvic floor (Hagstroem et al., 2010). Wetting alarms utilize specialized underwear with conductive material that triggers an alarm when wet. The goal is to restore bladder signal awareness and promote an appropriate response in children with persistent urinary incontinence (Mattsson et al., 2010). Lastly, traditional in-clinic gravimetric uroflowmeters are designed to measures urine flow during urination and provide real-time biofeedback. These devices offer children

direct feedback on their voiding behaviour through a uroflow curve, which can help to (re-)establish voluntary pelvic floor control (Yamanishi et al., 2000).

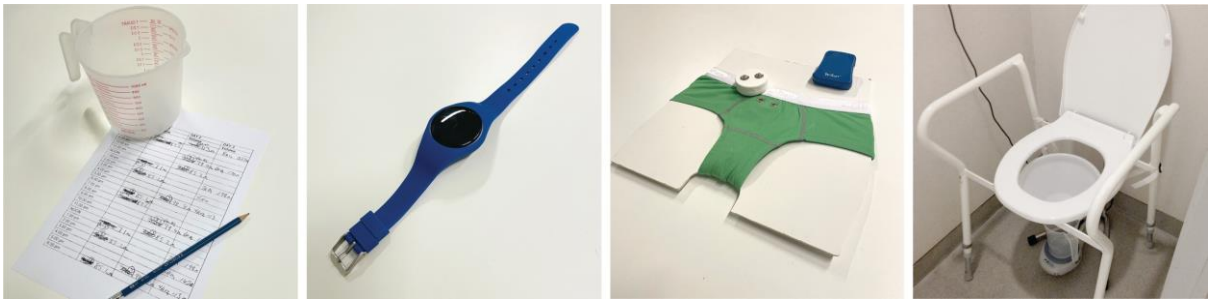

**Figure 1. Range of urotherapy supporting products from left to right: a paper-based bladder diary, timer watch, wetting alarm, and gravimetric uroflowmeter**

Unfortunately, the success rate of urotherapy is only 40%-56% (van Gool et al., 2014; Schäfer et al., 2018; Vijverberg et al., 2011) with lack of motivation and low patient compliance as crucial reasons for poor treatment outcome (Nock and Photos, 2006). We believe the products supporting urotherapy play a crucial role in motivating the child and parents during urotherapy. For example, patients describe paper-based bladder diaries as cumbersome and inconvenient, resulting in low patient compliance (Ku et al., 2004a). Furthermore, these traditional urotherapy supporting products might be perceived as technologically outdated, especially in today's digital times. One possible explanation for this could be that the design methodology behind existing products primarily focuses on scientific evidence to ensure compliance with evidence-based guidelines. In contrast, users' needs are not or insufficiently investigated during the design process, resulting in products that do not fulfill users' expectations (Klijn et al., 2006; Ku et al., 2004b; Kwinten et al., 2020; van Leuteren et al., 2019; Myint et al., 2016; Nieuwhof-Leppink, de Jong, et al., 2019). It is our hypothesis that a holistic design approach, combining Evidence Based Design (Hamilton and Watkins, 2009; Shah and Chung, 2009) and User Experience Design (Desmet and Schifferstein, 2011; Hassenzahl, 2013; Wright and McCarthy, 2010), is essential for the effective development and implementation of a solution to enhance urotherapy outcomes. This approach was applied in the creation of a urotherapy ecosystem concept with the goal of creating more engaging products that increase motivation. This paper presents the key design features of our novel urotherapy ecosystem concept.

## 2. Methods

User Experience Design principles were employed to prioritize users' needs and experiences. To gain initial insights into children's perspectives on urotherapy products and validate concept ideas during iterative design, qualitative research was conducted through focus groups and co-creation sessions. Nineteen children (M:13, F:6), aged 9 to 13 years, undergoing a 10-day, in-clinic urotherapy group training at the Wilhelmina Children's hospital of the University Medical Center Utrecht, participated. This purposive sampling strategy was chosen because these children, with experiences ranging from first-line to third-line urotherapy, can be considered experts in the field (Cash et al., 2022). Throughout the sessions, children actively participated in a variety of creative exercises within groups of 3 to 4 children (Figure 2). These included crafting collages to express their personal experiences with urotherapy. They also provided feedback on both existing and novel urotherapy products through pen and paper exercises. Furthermore, they created a digital training buddy within an app to guide them through urotherapy. Data collection reached saturation after 7 focus groups, each lasting 1.5-2 hours, indicating no new findings emerged within individual groups or overall. With the explicit consent of all participants and their parents, all sessions were recorded. The institutional review board committee classified the study as exempt of the Medical Research Involving Human Subjects Act (ID 22U-0479). The study was approved by the division management of the University Medical Center Utrecht, who conducted an independent quality check to verify compliance with legislation and regulations.

Incorporating Evidence Based Design into our design process involved ensuring that key elements of urotherapy, as outlined in established guidelines, were included. Central to this was the integration of the bladder diary, recognized as a core element in urotherapy practices (Chang et al., 2017; Maternik et



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al., 2015; Schäfer et al., 2018). The bladder diary was given a prominent place within the ecosystem to align with evidence-based principles and best practices.
The design activities encompassed sketching, prototyping, 3D modeling, and rendering to visualize the concept. We continuously integrated user feedback, ensuring that children's perspectives played a central role in shaping and refining the urotherapy ecosystem.

**Figure 2. Variety of creative exercises in focus group and co-creation sessions with children following in-clinic urotherapy group training**

# 3. Concept design

## 3.1. Urotherapy ecosystem of interconnected products

The traditional urotherapy products are typically stand-alone solutions without strong connections between them. This can result in a fragmented training process, potentially affecting its effectiveness. Additionally, these traditional products often lack internet connectivity, preventing healthcare professionals from remotely monitoring treatment outcome and progress. However, given the rise of digital-health and remote monitoring technology, there is a significant opportunity to create a urotherapy ecosystem of interlinked products supporting urotherapy at home with remote follow-up. In addition, insights from the focus group discussions underscored the children's perception of existing products as technologically outdated. They provided valuable input and expressed their interest in more technologically advanced solutions, including the integration of interconnected products. They expressed a preference for smarter technology while also emphasizing their desire not to become overly dependent on it. The fundamental design principle of our urotherapy ecosystem involves integrating various training products to create a unified and coherent approach to urotherapy. In this ecosystem, several key components align with the essential elements defined by the bladder diary, including a smart drinking bottle, a context-aware reminder watch, a home uroflowmeter, a smartphone app and a cloud-based clinician portal (Figure 3). This establishes an automated bladder diary that automatically collects data through connected measuring devices and an app.
The smart drinking bottle is designed to quantify fluid intake using capacitance technology, whereas the home uroflowmeter is engineered to quantify urinary output and bladder emptying using gravimetric technology. The context-aware reminder watch establishes a connection between the drinking bottle and the uroflowmeter, symbolizing the child's bladder and linking the two. It takes into account the child's fluid intake and bladder capacity to provide suggestions for when the bladder might reach its full capacity and is ready to be emptied. Thus, it operates as a context-aware reminder watch, shifting from the fixed time intervals of a timer watch to a more personalized approach. Importantly, as children value their independence, this reminder operates gently, with the primary intention of encouraging the child to be extra attentive to their bladder signals. This is particularly important as many children may become distracted during their daily activities and require assistance to regain their ability to sense when their bladder is full. Finally, the smartphone app and cloud-based clinician portal offer comprehensive insights into the objectively measured parameters, enhancing the narrative shared with the child both at home and in the hospital.



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The interconnected nature of these products is facilitated through Bluetooth communication, and via the smartphone app, the system can connect to the cloud for database management and more advanced data processing. This integration results in a system of interconnected products that provides a holistic perspective on urotherapy, offering children a comprehensive, educational, and informative experience.

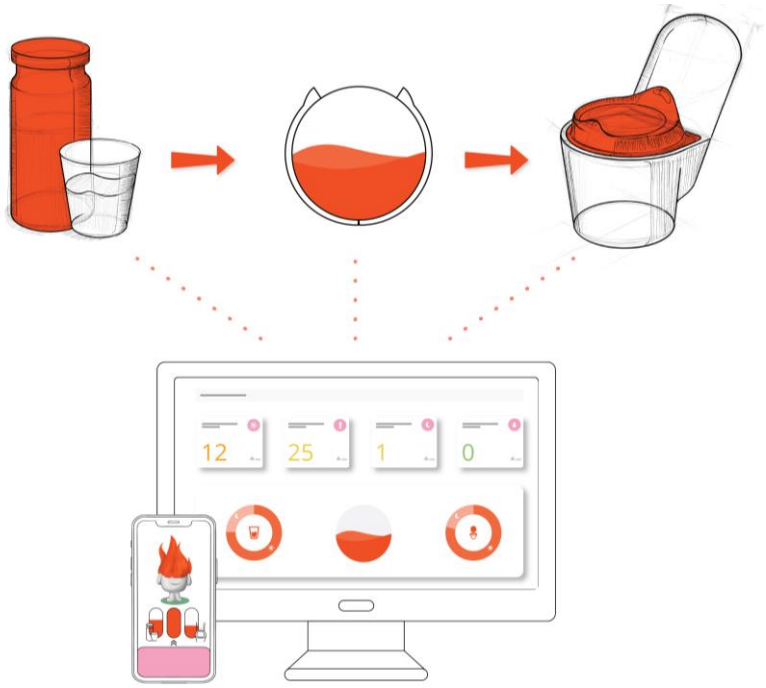


**Figure 3. Urotherapy ecosystem of interconnected products: smart drinking bottle, context-aware reminder watch, home uroflowmeter, smartphone app and cloud-based clinician portal**

## 3.2. Reduce stigma by focusing on drinking

During the focus group sessions, children raised concerns about the traditional urotherapy products drawing unwanted attention. To mitigate the stigma associated with the urotherapy products, we implemented design interventions, as outlined by Vaes (Vaes, 2014). One such intervention involves pairing the stigmatized product with a widely accepted one and exploring their potential interaction. An example is the integration of a hearing aid (stigmatized) into eyeglasses (widely accepted). In our case, we employed this approach by creating an interaction between a uroflowmeter and a widely accepted everyday item—the drinking bottle (Figure 4). Our goal is to shift the focus of urotherapy products from urination to drinking. By highlighting the role of drinking and using it as the cornerstone of urotherapy, we introduce a novel and innovative way of approaching urotherapy with the potential to reduce stigma. Additionally, this approach allowed us to address urotherapy in a more holistic manner, highlighting the significance of appropriate drinking behavior and its impact on urinating, an aspect often overlooked. Sometimes, simply changing a child's drinking habits—ensuring an adequate fluid intake throughout the day and avoiding bladder-irritating drinks—can significantly alleviate symptoms. In order to further reduce stigma and create a product that is appealing and acceptable to children, the design of the bottle incorporates a colorful and playful aesthetic.

Unlike most traditional urotherapy products, many children in the focus group found the timer watch acceptable because of its familiar and stigma-free design. Therefore, in our ecosystem, we maintained the design of a watch for the context-aware reminder tool and aligned it with the playful aesthetic of the drinking bottle. However, we enabled a physical connection to the bottle, allowing children the flexibility to use the bottle either as a combined fluid intake tracker and reminder tool or as two separate products connected via Bluetooth (Figure 4). Finally, the home uroflowmeter is essential for measuring urine output and bladder emptying function. Its design takes a more subtle position compared to the other components. However, it introduces a significant enhancement in terms of user comfort. Unlike traditional uroflowmeters, it can be comfortably placed on a standard toilet, creating a more natural and



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comfortable voiding process. The design maintains a somewhat medical appearance with its white color but retains a consumer health product aesthetic, conveying a sense of reliability while avoiding the overly clinical look associated with traditional uroflowmeters.

**Figure 4. Stigma-free design approach: emphasis on drinking, featuring a familiar and widely accepted drinking bottle and watch with appealing, colorful, and playful aesthetics, along with a uroflowmeter designed for standard toilet placement to integrate into the home environment**

## 3.3. Engage through rich and meaningful interactions

In our efforts to enhance the experience of paediatric patients undergoing urotherapy, we recognize the need to go beyond the mere collection and visualisation of data. Instead, our focus is on creating an engaging and meaningful interaction that offers guidance, motivation and support. To achieve this, we have adopted the design approach explored by Van Campenhout et al., which integrates the flexibility of the digital world with the richness of the physical environment (Van Campenhout et al., 2020, 2023). Utilizing the child's digital drinking and voiding data, we aim to customize product interactions, coupling on-screen animations to expressive, physical actions. As the child drinks from the bottle, the liquid transitions through on-screen animations, flowing from the bottle's display to the watch's display (Figure 5). In this approach, inspired by Van Campenhout et al., the displays not only show information but also serve as carriers of matter. As mentioned earlier, the watch predicts when the bladder approaches its full capacity, illustrated through on-screen animations that mimic the bladder's filling phase (Figure 5). In addition to serving as a context-aware reminder tool, this interactive process also functions as an educational tool, helping children in gaining a better understanding of this aspect of their physiology.

**Figure 5. On-screen animations illustrate liquid flow from the drinking bottle to the context-aware reminder watch, mimicking the bladder's filling phase**



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The next phase is the voiding phase, during which the bladder is emptied under voluntary control. In child-friendly explanations, the voiding phase is often illustrated using the metaphor of 'opening and closing the gate'. When a child decides to urinate, they figuratively 'open the gate' by consciously relaxing the urinary sphincter and pelvic floor muscles. Conversely, when a child wishes to retain urine, they 'close the gate' by voluntarily contracting the sphincter and pelvic floor muscles, effectively preventing involuntary urine loss. To bring this gate metaphor to life through embodied interaction (Dourish, 2001), we brainstormed and prototyped various expressive physical movements, such as pressing, pulling, twisting, lifting, and pinching (Figure 6).

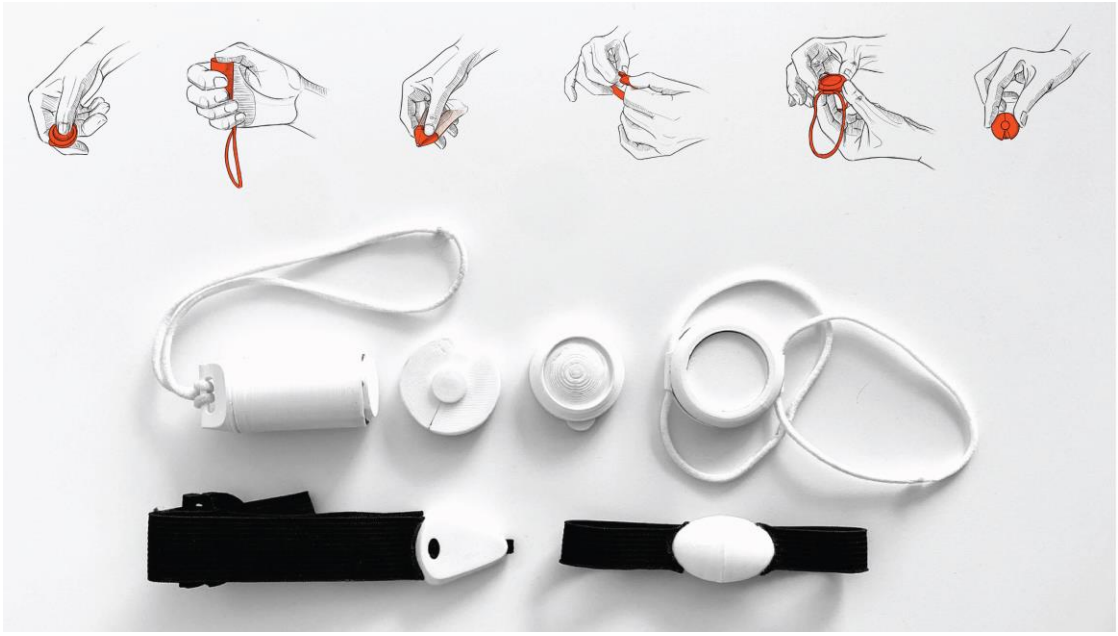

**Figure 6. Embodied interaction: prototyping physical movements (pressing, pulling, twisting, lifting, pinching) for the voiding phase metaphor of 'opening and closing the gate'**

After careful consideration and testing, we settled on the pinching motion. This pinching action causes the opening of the gate, representing the urinary sphincter, and triggers an on-screen interaction. An animation displayed on the watch showcases the gradual emptying of the virtual bladder. The deliberate slowness of this interaction is intentional, as children often hurry through the voiding phase, leading to incomplete bladder emptying. When combined with the uroflowmeter, this interaction can be personalized according to the flow rate and voided volume, further enhancing engagement and education. Educational materials, such as a child-friendly information booklet with images and a cardboard model of the lower urinary tract, complement this interactive learning process, offering a comprehensive view of the bladder, kidneys, and pelvic floor muscles in their anatomical context (Figure 7). Overall, our approach to creating rich and meaningful interactions, coupling the digital world with the physical environment, aims to engage, educate and train the child.

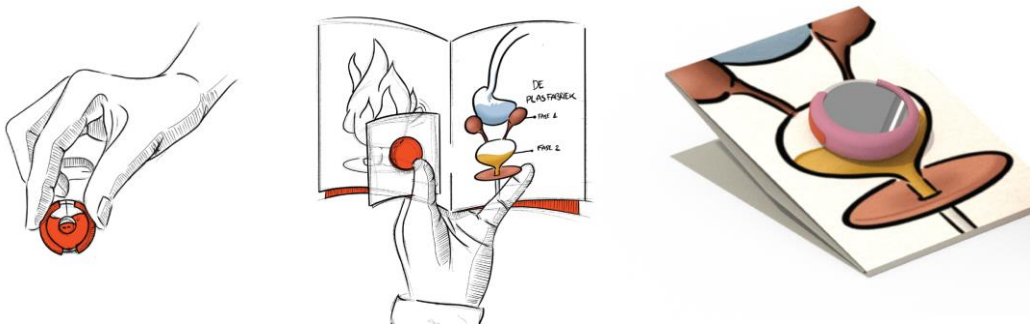


**Figure 7. Educational material explaining the rich and meaningful interactions in the broader context of the urinary tract to support the interactive learning process**



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### 3.4. A digital training buddy for urotherapy support

In the focus group sessions, children expressed their dislike for constant reminders from parents or teachers to use the toilet, often ignoring it as an act of rebellion. On the contrary, they highly valued support from peers or buddies. Inspired by this insight, they brainstormed creative ideas for urotherapy support, introducing concepts like a training buddy and elements of gamification. Some children suggested that if a digital training buddy recommended a toilet visit, they would be more inclined to listen than to an adult. Building on this concept, the children sketched ideas for a training buddy within the app (Figure 8). Several preferences emerged from their drawings: the buddy should be animated in a way that captivates children's imagination, potentially taking the form of an animal or fictional character. The buddy should feature various states indicating the need to drink, visit the toilet, or respond to an accident—a concept reminiscent of the popular Japanese Tamagotchi, a digital pet with evolving stages based on user care. For the uroflowmetry component, the children proposed an animated uroflow curve, where the buddy could be seen climbing a mountain or riding a wave, symbolizing their uroflow curve. Most importantly, the training buddy should be supportive, motivating, and act as a companion throughout their urotherapy journey.


**Figure 8. Children's drawings of a digital training buddy within the app**

Building on the idea of a digital training buddy, we aimed to strengthen the link between the products in our ecosystem while incorporating elements of gaming. Our goal was to create an interactive and informative storyline within the app, similar to the experience of a Tamagotchi, using the child's real voiding and drinking data. Inspired by the children's drawings, we created a fictional character with fiery hair to serve as a training buddy (Figure 9). The choice of fire as hair was influenced by the clear relationship between fire and water, offering a symbolic way to represent different states.

**Figure 9. The digital training buddy: a fictional character with fiery hair, symbolically representing different states using fire and water**

We tried to enrich the products in our ecosystem with a sense of being 'alive' through the training buddy. This was done to establish an emotionally charged interface between the user and the product. Following Leube et al.'s assessment of product characteristics associated with animacy, we incorporated four key characteristics using the training buddy: sensation, adaptability, energy, and regeneration (Leube et al., 2016). Sensation refers to the product's capacity to 'sense' the user's proximity, while adaptability reflects its ability to adjust to its environment. Energy encompasses the product's acquisition of energy, while regeneration represents the product's ability to heal or repair. To incorporate sensation, the buddy dynamically follows the child across various interactions, be it in the bottle, the watch, the uroflowmeter



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component or in the app. Its adaptability is evident as the buddy's appearance adjusts to the specific product it occupies (Figure 10). In the app, the fire buddy takes the form of a detailed and animated character, brought to life on the smartphone screen. Inside the bottle, it metamorphoses into a flame through an individually addressable LED array, serving as a visual guide for the recommended liquid level at various times of the day. On the watch with an MIP screen simulating the bladder, the buddy gazes through a window as if he is inside a submarine.

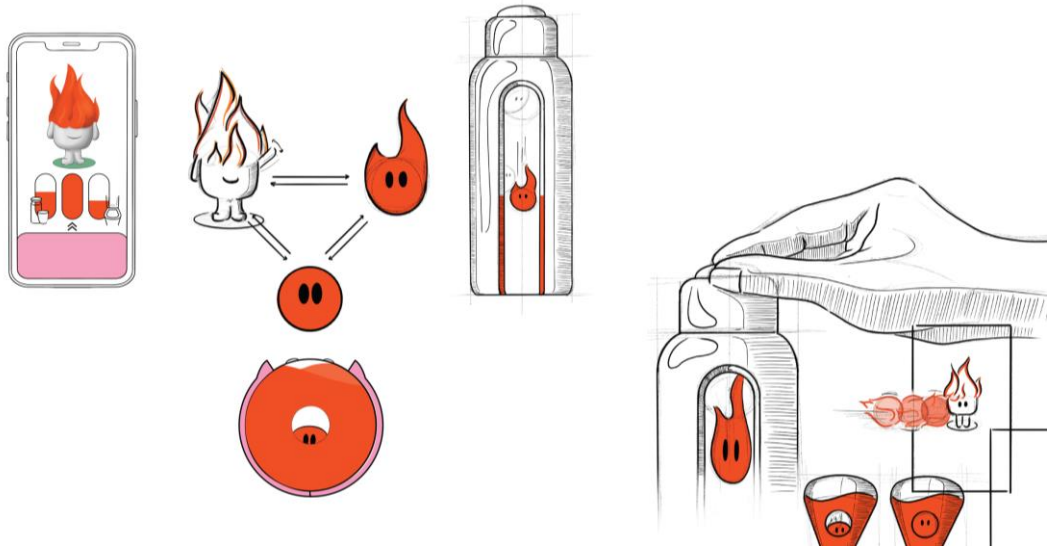

**Figure 10. The digital training buddy follows the child across the various products, adapting its form across the products: animated character in the app, flame in the bottle and eyes gazing through a submarine window in the watch**

Energy and regeneration manifest in the buddy's various states based on the child's drinking and voiding data (Figure 11). When the child drinks adequately, the fire buddy is content and well-hydrated, displaying a well-controlled flame. If the child forgets to drink, the buddy expresses sadness and dehydration, and its flame begins to diminish. Conversely, as the child drinks sufficiently and the bladder reaches full capacity, the fire intensifies, and the buddy signals the child to go to the toilet to regulate the flame and restore control. Upon urination, as the gate opens and the bladder empties, the buddy reverts to its content state. When connected to the uroflowmeter, the buddy uses its hot air and a bag to form a hot air balloon, floating in alignment with the child's uroflow curve. In case of an accident, when the bladder empties involuntarily, the fire buddy briefly loses its fiery hair, signalling urine leakage, but swiftly regenerates to resume with newfound fire and energy.

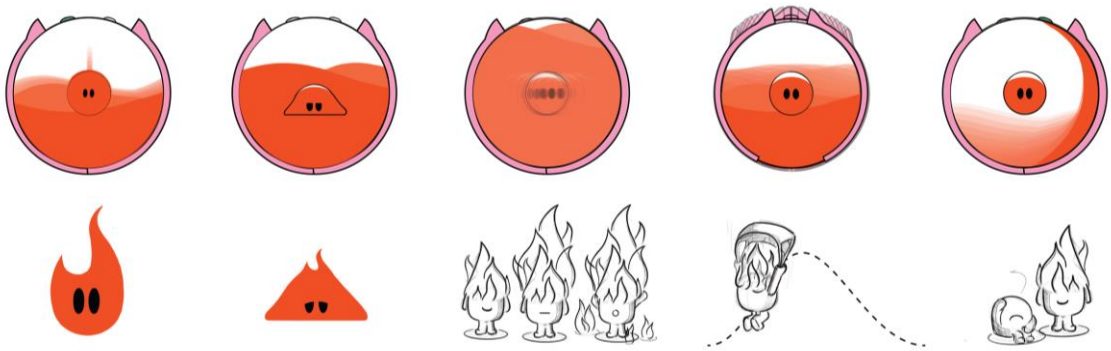

**Figure 11. Buddy's various states: (i) Content and well-hydrated with a well-controlled flame; (ii) Sad and dehydrated with a diminished flame; (iii) Ready to urinate with an intense fire; (iv) Urinating, using hot air and a bag to float in alignment with the uroflow curve; and (v) Urine leakage resulting in the loss of fiery hair but swift regeneration with newfound fire and energy**



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## 4. Summary and conclusion

This paper introduces a novel urotherapy ecosystem prioritizing user experience through focus groups and co-creation sessions with children aged 9-13 years undergoing in-clinic urotherapy. Evidence Based Design principles guided the integration of an automated bladder diary as a foundational element. The ecosystem offers a holistic, engaging and educational experience through interconnected products, including a smart drinking bottle, a context-aware reminder watch, a home uroflowmeter, a smartphone app, and a cloud-based clinician portal. To tackle stigma and improve user acceptance, the design shifts the focus from urination to drinking and incorporates playful aesthetics. To boost engagement and learning, the ecosystem employs embodied interaction, coupling on-screen animations to physical actions through expressive control elements. Finally, the digital training buddy, displaying various states, offers companionship, support and motivation throughout urotherapy.

While this qualitative research lacks generalizability, the children's extensive urotherapy experience suggests some transferability. However, further research is needed to assess the feasibility of the ecosystem from technological and design perspective, cost-effectiveness, and patient satisfaction. Next, a refined ecosystem could undergo comparison with conventional urotherapy products in a randomized controlled trial to assess the long-term impact on treatment outcomes. Furthermore, evaluating the applicability of this ecosystem, with its design elements for enhancing engagement and motivation, in an older demographic and exploring potential adjustments to meet their needs would be interesting.

In conclusion, this urotherapy ecosystem concept represents an innovative, comprehensive and engaging approach to pediatric urotherapy. Overall, we believe this concept illustrates the potential of a holistic and user-centered design approach, integrating diverse design methodologies. We believe that this design approach, which we see as relevant to the broader field of healthcare design, aims to improve treatment outcomes and overall patient experience.

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