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Improving the Children's Intravenous Therapy Experience

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Abstract

Chronic illnesses significantly impact children, necessitating frequent intravenous (IV) therapy interventions. This study explores the extensive implications for children aged 4 to 10, investigating their vulnerability to pain and negative emotions. These challenges extend beyond pediatric patients to healthcare professionals and parents. The primary objective is to thoroughly examine and propose effective solutions, employing a user-centered design approach and utilizing comprehensive methods such as secondary research, best practice analysis, interviews, questionnaires, and observation. Conducted across three hospitals, the investigation explores the requirements for improving children's intravenous therapy experience by interviewing and questionnaires with parents and nurses. Results show a 60/40 gender split (girls/boys), with 60% facing recurrent injections. Findings emphasize parents' prioritization of children's physical and psychological safety, while nurses highlight the importance of child-friendly medical devices for distracting children from IV therapy discomfort. Observations consistently reveal children's preference for colorful and interactive medical devices as effective tools for alleviating discomfort. The research recommends designing pediatric IV therapy devices with vibrant colors, interactive sounds, games, and the possibility of walking during the procedure to engage and entertain children, emphasizing the need for innovative solutions grounded in children's preferences. This approach targets unaddressed pain consequences during interventions, aiming to advance the overall well-being of this vulnerable demographic.

Keywords

Children Intravenous Therapy, User-Centered Design, Pain Management, Healthcare Innovation.

Introduction

IV therapy, delivering fluids or medications directly into veins, is vital for medical treatment (Rivera et al., 2005). Despite its benefits, especially in children, the intrusive nature of IV treatment can cause pain and discomfort, impacting mental health. Medical procedures, particularly those with needles, are among children's most feared experiences in hospitals (Broome et al., 1990), leading to adverse effects on emotional well-being (Cummings et al., 1996).

Recognizing the importance of pain management in pediatric care is crucial. Inadequate pain management during procedures has lasting consequences on children's development (Kennedy et al., 2008; Young, 2005), negatively affecting mental and physical well-being, increasing stress, impairing coping, and heightening fear among family members. Procedural pain can have enduring effects on immune function, neurophysiology, healthcare behaviors, and attitudes (Young, 2005), contributing to substantial societal costs. Factors like young age, frequency, and memory of painful experiences influence these outcomes (Anand et al., 2001; Taddio et al., 2002). Despite these findings, healthcare professionals often overlook and inadequately address children's pain, indicating a persistent lack of prioritization in this area (Carlson et al., 2000).

Challenges in Children IV Therapy

In pediatric IV therapy, around 50% of young patients face significant pain linked to injection fear (Fradet et al., 1990; Gupta et al., 2006). This fear contributes to 50-80% of children experiencing pain during hospitalization (Taddio et al., 1999). Children perceive venipuncture as intensely painful, causing heightened distress (Carlson et al., 2000). Nurses are concerned about children's behavioral responses during procedures, potentially leading to restraint and worsening future reactions (Van Cleve et al., 1996). Difficulties in achieving peripheral intravenous cannulation are predicted by a score considering factors like age, vein visibility, gestational age, and skin shade (O'Neill et al., 2012; Yen et al., 2008). Pediatric pain management is complex, particularly when relying on self-reporting. Recognizing pain as a vital sign in pediatrics is challenging, with societal costs influenced by factors like age and the frequency of painful experiences (Anand et al., 2001; Taddio et al., 2002).

Pharmacological and Non-Pharmacological Pain Management Techniques

Enhancing pediatric intravenous therapy demands a holistic approach, blending pharmacological and non-pharmacological strategies. Pharmacologically, methods like Transcutaneous Electrical Nerve Stimulation (TENS), painkillers, and anesthetics play a role. Non-pharmacological techniques, including emotional support and various cognitive methods, are vital for pain relief and empowering pediatric patients (Mazur et al., 2013; Uman et al., 2006). Distraction, emphasized by (Vessey et al., 1994), is a widely accepted and effective non-pharmacological intervention involving visual, vocal, touch-motion, and purposive forms, with audio-visual distraction, such as cartoon techniques, notably reducing anxiety in school-age children (Kaur et al., 2014; Vessey et al., 1994). Complementary non-pharmacological interventions outlined by (Cohen et al., 2006) include relaxation techniques, hypnosis, modeling, desensitization, and stress management (Cohen et al., 2006). These evidence-based approaches, supported by (Uman et al., 2006; Mazur et al., 2013; Vessey et al., 1994; Cohen et al., 2006; Kaur et al., 2014), provide effective tools for children, underscoring the importance of a comprehensive approach to enhance the overall intravenous therapy experience. Recent computer technology advancements, especially virtual reality (VR), have revolutionized pain management during therapeutic procedures (Chau et al., 2020; Furness et al., 2019). VR, providing an immersive multisensory experience, serves as an effective pain distraction (Ma & Zheng, 2011; Matsangidou et al., 2017), surpassing traditional methods, as evidenced by neurobiological studies (Gold et al., 2007; Hoffman et al., 2004; 2006).

In addition, the application of artificial intelligence (AI) in pain assessment and treatment shows promise for improving patient outcomes and optimizing healthcare resources. A thorough review of AI-driven interventions in pain management will offer valuable insights for future research (Zhang et al., 2023).

User-Centered Design

In designing medical products, especially in healthcare, understanding users' needs is crucial. Effectiveness, safety, and clinical efficacy are vital, necessitating an ergonomic approach for patient safety, improved outcomes, and user satisfaction (Gloyd, 2003; Gosbee, 2002; Leape, 1994; Martin et al., 2008; 2012; Sawyer et al., 1996). Meeting user requirements is particularly crucial for devices managing chronic diseases, with inclusive design, especially involving children, offering explicit benefits (Druin, 1999). Specialized pediatric devices face challenges in adaptation due to smaller sizes, growth, and extended usage. Insufficient safety data, smaller sample sizes, and financial concerns impede pediatric device development (Espinoza et al., 2022; Gold et al., 2007; Jenkins et al., 2017; Lee et al., 2021). This study aims to enhance pediatric IV therapy through a comprehensive approach, integrating pharmacological and non-pharmacological strategies with user-centered medical device design. Research focuses on identifying pain points and desires in children, nurses, and parents during IV therapy, exploring holistic approaches, and leveraging user-centered design for enhanced experiences.

Research Methodologies

The study revolves around a user-centered design process, employing a human-centric approach to tackle challenges in children's IV therapy. Prioritizing the distinct needs of end-users-children, nurses, and parents-ensures tailored solutions. The initial stages involved a literature review, and visits to three public hospitals in Tehran, chosen for their demographic diversity, widespread usage by the general public, and a high prevalence of chronic diseases. Hospital selection was guided by limitations in permits and entry restrictions, ensuring a comprehensive representation. For data collection, we employed semi-structured interviews, questionnaires, and observations to ensure validity. Direct interviews and questionnaires with children were impractical due to age-related, psychological, and health constraints. Therefore, user research was conducted with parents and nurses while observing children actively undergoing IV therapy. To enhance data validity and reliability, the research was conducted in hospitals with participants actively undergoing IV therapy and participant conditions were carefully considered to ensure a comfortable research environment. The holistic approach incorporated the Analytic Hierarchy Process (AHP) for data analysis, contributing to pediatric IV therapy and broader healthcare user-centered design. The methodology aims to enhance both specific and general contexts, emphasizing the systematic application of AHP for data analysis and prioritization.

Result

This section combines insights from semi-structured interviews and a comprehensive questionnaire with parents and nurses, addressing challenges in pediatric intravenous (IV) therapy across functional, ergonomic, and aesthetic dimensions. The proposed user-centered design solutions emphasize improvements in functionality, ergonomics, and aesthetics to enhance the overall pediatric IV therapy experience.

Parents' Interview Result

The semi-structured interviews, predominantly conducted through observations and discussions with parents and caregivers, involved 12 participants (n=12). Data saturation was achieved, and subsequent interviews were discontinued upon reaching redundancy in the gathered information.

Table 1: *Parental Insights on Children's IV Therapy: Interview Findings.*

Key areas	Parents' insights
Functional Issues	Concerns arise from serum pack depletion, potentially causing delays in nurse attendance.
	Complications may arise from multiple unsuccessful attempts at venipuncture.
	The child's movements may dislodge the angiocath on their hand, posing a risk.
Ergonomic Issues	Children exhibit anxious behavior post-discharge.
	Movement restrictions during injections.
	Lack of conviction leads to children's non-cooperation in the treatment process.
	Potential fear from the blood returning to the IV tube.
	Children experience pain and restlessness.
	Parents feel worry, depression, and disappointment.
Aesthetic Issues	IV therapy set lacks familiar and cartoon motifs.
	Use of narrative engagement to divert a child's attention during the procedure.
	Integration of vibrant, child-friendly colors.
	Measures to captivate and entertain the child during the injection process.

Nurses' Interview Result

The semi-structured interviews with nurses aim to elucidate challenges in delivering pediatric intravenous (IV) therapy. The interviews, primarily facilitated through observations and discussions, included 8 participants (n=8). Data saturation was successfully attained, leading to the cessation of further interviews once redundancy in the collected information was observed.

Table 2: *Nurses' Insights on Children's IV Therapy: Interview Findings.*

Key areas	Nurses' insights
Functional Issues	Lack of automatic flow cutoff on serum depletion causes recurrent parent notifications.
	Parental worry during injections disrupts nursing procedures.
	An unclear degree of serum pack requires a clear solution.
	Need for functional solutions to ease venipuncture in children.
Ergonomic Issues	Parents need comprehensive info on children's health and IV therapy from nurses.
	Educational brochures for parents about IV therapy procedures are essential.
	Emotional support for parents and children should be provided by nurses.
Aesthetic Issues	Hospitals should create child-friendly medical devices for easier injections.
	Toy-filled, colorful playrooms and medical devices enhance children's entertainment.

Parents' Questionnaire Result

The survey with 50 parents of ill children revealed a gender distribution of 60% girls and 40% boys. Approximately 60% reported recurrent injections, with 20% undergoing over five instances of intravenous injections. The age distribution included 40% early elementary school children, 20% preschoolers, 25% in later elementary stages, and 15% in the initial phase of middle school. Behavioral responses during IV therapy showed that around 50% of children cautiously accepted treatment, often expecting a gift as an incentive. Notably, a significant proportion expressed a desire to move around during IV injections, with 20% seeking movement within less than 15 minutes, 30% after 15-30 minutes, and another 30% after one hour. Extracted issues from interviews were categorized into functional, ergonomic, and aesthetic groups and the Likert questions gauged parental views on the importance of these issues, revealing that venipuncture procedure, children's psychological distress, and unattractive/unentertaining medical device appearance were identified as the most crucial factors in each category, respectively.

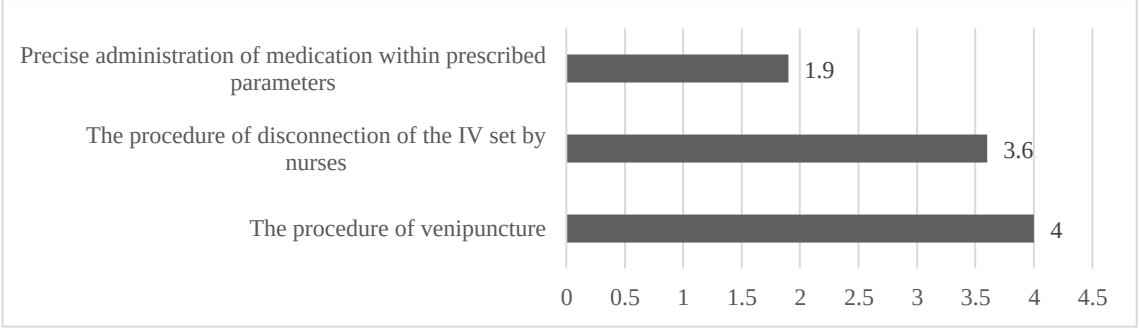

Figure 1: *Parental Insights - Functional Issues.*

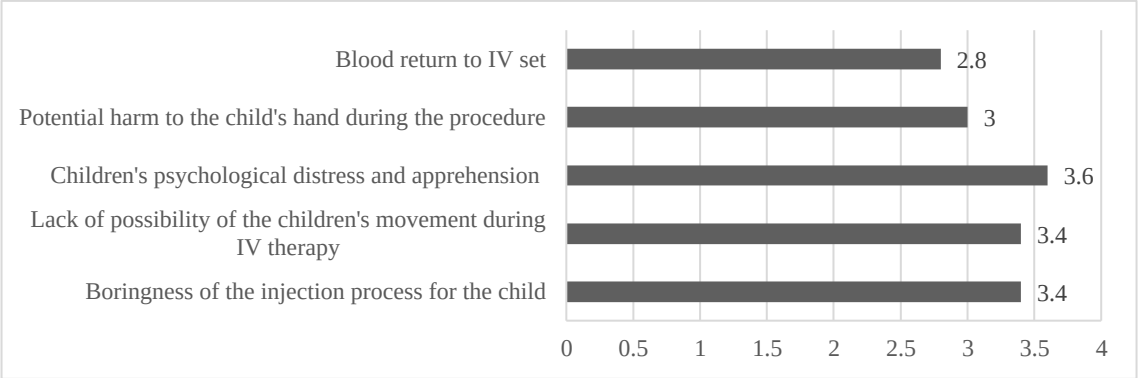

Figure 2: *Parental Insights - Ergonomic Issues.*

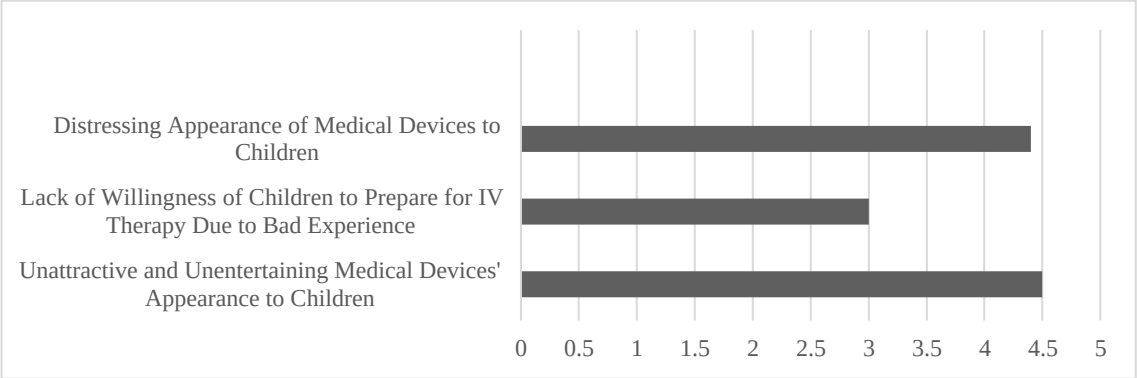

Figure 3: *Parental Insights - Aesthetics Issues.*

Nurses' Questionnaire Result

The survey with 100 nurses across three hospitals revealed a gender distribution of 70% women and 30% men. Approximately 80% reported having more than one year of job experience. In chronic disease IV therapies, 80% of injections took 2-3 hours, with 20% exceeding 5 hours. Nurses identified distraction (35%) as the most effective technique for alleviating pain and stress during children's injections, followed by indoctrination (30%) and playing (25%). Only 10% recognized transcutaneous electrical nerve stimulation (TENS), indicating a consensus on the efficacy of distraction techniques. In extended IV therapies, 35% of nurses viewed children's stress, anxiety, and fear as the primary concern. Pain during injection, children's reluctance to move, and parents' frequent questions and worry were selected by 15%, 15%, and 10% of nurses, respectively. Issues identified in interviews were categorized as functional, ergonomic, and aesthetic. Likert questions assessed their importance, highlighting concerns like children's fear and reactions, nurses' sadness witnessing children's anxiety, and the absence of appealing distraction tools as the highest-ranking issues in each category.

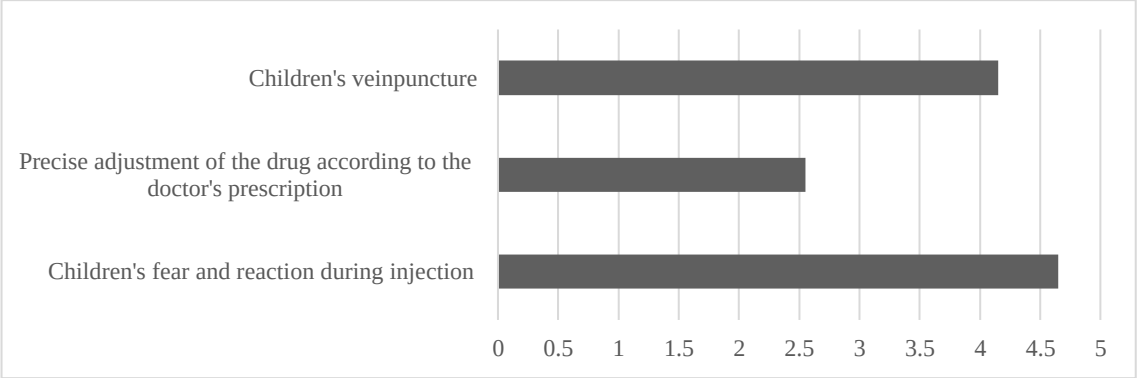

Figure 4: *Nurses' Insight-Functional Issues.*

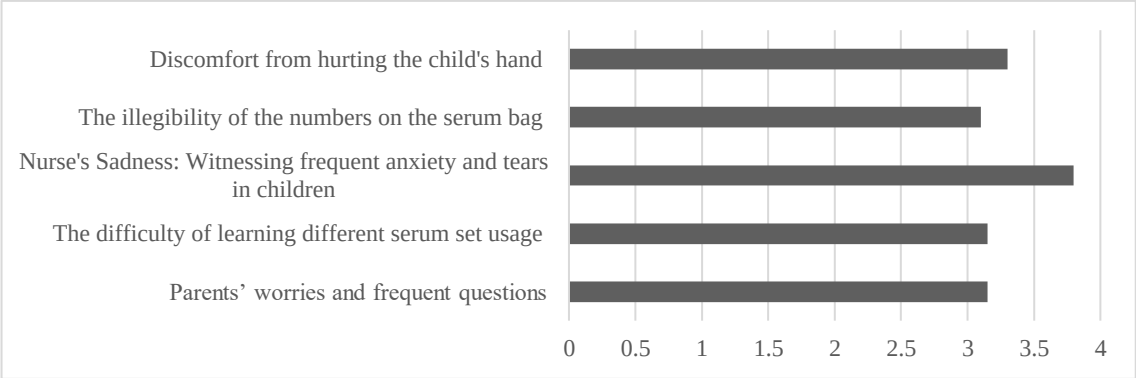

Figure 5: *Nurses' Insights - Ergonomic Issues.*

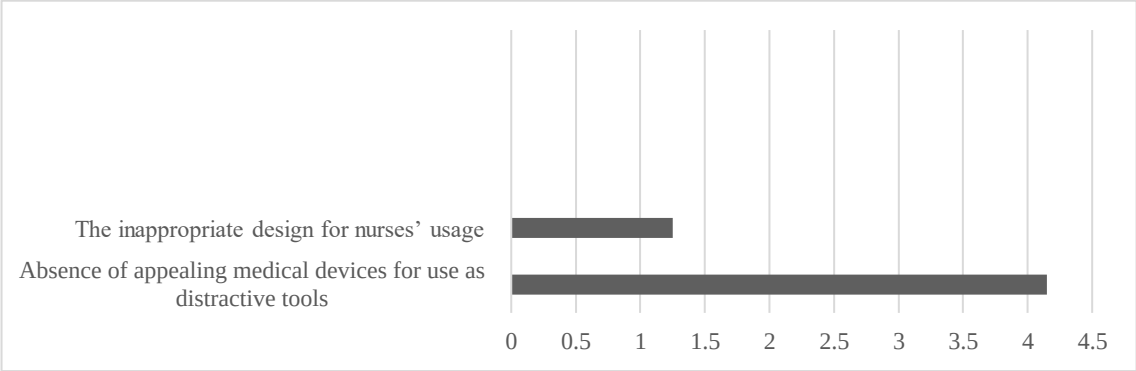

Figure 6: *Nurses' Insights - Aesthetics Issues.*

Prioritizing Users' Requirements

Participants, including parents and healthcare professionals, prioritized three criteria: safety covering vein puncture, precise dosage, blood return, injection pain relief, and alleviation of negative emotions (pre-, during, and post-injection). Identified through user research, this data underwent rigorous analysis using the Analytic Hierarchy Process (AHP).

Table 3: *Prioritization of main criteria.*

Parents' Desires	Nurses' Desires
1. Children's physical safety (vein-puncture, blood back, etc)	1. Children's stress relief (controlling aggressive responses)
2. Children's stress relief (Psychological safety)	2. Children's pain relief
3. Children's pain relief	3. Children's safety

Solutions for Enhancing the Children's IV Therapy Experience

The main ideas for addressing the challenges associated with children's IV therapy have been derived through phases of analysis and research. These criteria have been categorized into three groups (functional, ergonomic, aesthetic), and can serve as guiding principles for the improvement of the children's IV therapy experience. They are grounded in the best practices within the field of pediatric healthcare and researchers' ideations.

1. *Functional Solutions*

Precision in dosage: The IV device could facilitate precise dosing and effortless adjustments tailored to the specific needs of the child, potentially reducing treatment duration and minimizing discomfort.

Painless Needle Insertion: Implementation of technologies, such as needleless IV systems or devices using vibration or heat, could mitigate pain during needle insertion. Utilizing devices with enhanced vein-finding technology would contribute to minimizing discomfort.

Effortless Removal: Devices designed with mechanisms for painless removal could reduce discomfort when IV therapy is no longer required, alleviating the child's fear of future procedures.

Vein Visualization Technology: Incorporating advanced vein visualization technologies could assist healthcare providers in identifying suitable veins with greater precision, reducing the chances of multiple puncture attempts and associated discomfort for the child.

Figure 7: *Conceptual design - Equipped with electronic pomp for precise dosage injection, vein visualization technology, and wheels for autonomy in movement (Designed by the writer).*

2. *Ergonomic Solutions*

Size-Adapted Equipment: The development of equipment tailored for pediatric patients, including smaller, less intimidating needles, catheters, and tubing, ensures compatibility with the child's size and weight, potentially mitigating discomfort and complications.

Wireless Monitoring: Leveraging wireless technology for remote monitoring of IV therapy parameters allows the child greater mobility while still receiving proper care, enhancing their overall experience.

Alarm systems for Safety: Intelligent IV devices with less distressing alarm systems, featuring gentle chimes or colorful lights instead of loud, disconcerting sounds, ensure the prompt communication of safety alerts to healthcare providers.

Engagement Features for Children: Incorporating elements promoting children's active involvement in their treatment, such as buttons for signaling a nurse or adjusting room lighting, enhances the child's experience.

Compact IV Pumps: Designing IV pumps to be compact and easily portable affords children greater freedom of movement during their treatment.

Interactive Displays: Integrating child-friendly interactive screens or displays on IV pumps allows children to engage in games, view videos, or select soothing images during the procedure to divert their attention.

User-Centric Controls: Implementing user-friendly and child-oriented controls on IV equipment facilitates the participation of older children in their care and adjustment of non-critical settings.

Portable IV Equipment: Creating portable IV equipment, including wearable infusion devices or smaller, battery-operated IV pumps, affords children mobility during treatment.

Noise Mitigation: Deliberating soundless or quieter IV pumps and monitors could mitigate distress stemming from noisy medical equipment. Alternatively, integrating soft and soothing sounds comforts the child during treatment.

Educational Materials: Providing age-appropriate educational materials aims to explain the IV procedure in a simple and non-threatening manner, preparing children, alleviating fears, and encouraging cooperation during the injection.

Communication Boards: Using visual communication boards featuring images and symbols facilitates the expression of needs and emotions by non-verbal children, ensuring their comfort and comprehension during IV therapy.

Child Life Specialists: Utilizing the expertise of child life specialists, who can provide emotional support to children before and during IV therapy through play therapy techniques, alleviates fear and anxiety.

Emotional Support: Recognizing the positive impact of empathetic and well-trained healthcare professionals and the presence of parents or guardians during IV therapy in ameliorating children's stress.

Cognitive Techniques: Applying cognitive techniques, such as mental distraction, body relaxation, stimulation, and skin stimulation, helps managing the child's pain.

Figure 8: *Conceptual design - Wireless monitoring and a mobile alarm system for nurses can offer parents peace of mind, minimize disruptions for nurses, and promote greater autonomy for children (Designed by the writer).*

3. *Aesthetic Solutions*

Child-Friendly Aesthetics: Enhancing the visual appeal of IV equipment through vibrant and playful designs that are non-threatening to children can create a more inviting environment.

Child-Engaged Equipment: Involving children in the design process or soliciting feedback from them to enhance IV therapy equipment can foster the development of more child-friendly and acceptable devices.

Age-Appropriate Distractions: Employing age-appropriate distractions, such as engaging stories or visual aids, to divert the child's attention away from the vein puncture procedure aims to reduce anxiety and discomfort.

Transparency in Components: Utilizing materials that afford children visibility into the flow of IV fluids could aid their comprehension of the process and potentially reduce anxiety.

Therapeutic Playrooms: Conceiving pediatric treatment areas incorporating dedicated playrooms where children can engage in creative and calming activities before and after the procedure aims to mitigate anxiety and fear.

Figure 9: *Conceptual design - Proposes an affordable solution to distract children from pain and stress, offering autonomy in movement, and providing a friendly treatment experience (Designed by the writer).*

Discussion and Conclusion

Only a limited number of medical devices are specifically designed, tested, developed and promoted for children. Typically, adult devices are repurposed and utilized off-label in pediatric settings. Pediatric devices, constituting only one-quarter of those for adults, face challenges in adaptation due to smaller sizes, growth, and longer usage in children. Initiatives like the Pediatric Device Consortia Program, Early Feasibility Studies, and the System of Hospitals for Innovation in Pediatrics – Medical Devices show promise, yet comprehensive progress hinges on collaborative efforts across industry, academia, advocacy groups, healthcare providers, investors, payors, regulators, and Congress (Espinoza et al., 2022).

This study contributes significantly to the existing knowledge by addressing a critical gap in understanding the challenges and requirements of pediatric IV therapy in the Iranian healthcare context. The identified themes and patterns provide a foundational framework for future user-centered product development.

Challenges encompass functional, ergonomic, and aesthetic dimensions, portraying a multifaceted landscape within pediatric IV therapy that aligns directly with our research question, illuminating the pain points experienced by children, nurses, and parents during IV therapy.

Moreover, the study enhances existing literature by offering a nuanced understanding of the factors influencing pediatric IV therapy experiences. Stress relief and pain relief emerge as primary requirements, fostering not only the psychological well-being of children but also enabling healthcare professionals during IV therapy. Distraction surfaces as the most effective and favored non-pharmacological method for pain and stress relief, suggesting the potential for child-friendly medical device designs to engage and entertain children during procedures, diverting their attention from pain and stress. Looking ahead, a comprehensive examination of AI-driven interventions in pain management and recent advances in computer technology, notably virtual reality (VR), provides valuable insights for future research to be employed in developing distraction and pain management solutions.

By emphasizing interdisciplinary collaboration and human-centric design, this research aims to propel healthcare advancements for young patients. The findings underscore the necessity for tailored IV set designs, considering the psychological and physical attributes of children, thus offering a novel approach to enhancing the overall pediatric IV therapy experience. The next phase of this research involves detailed design, evaluation, and industrial production of these ideas, addressing financial, regulatory, and strategic barriers. Addressing the study limitations, bureaucratic processes presented challenges in accessing children's wards, thereby restricting the application of user research in the field. Furthermore, the extraction of data relied on observations and discussions with parents and nurses due to the specific conditions of the sick children, as well as their age and mental states.

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