Design Opportunities to Facilitate Tangible Play and Promote Healthy Nutrition in Low-resource Healthcare Settings in Peru

Co-designing Low-fidelity Prototypes with Caregivers and Healthcare Workers

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ABSTRACT

Complementary feeding is crucial to promote healthy nutrition in infant and young children (IYC) and prevent malnutrition. Mothers, families, and healthcare professionals (HCPs) are crucial in helping IYC develop healthy eating habits. However, limited access to adequate nutritional information and health services impacts children's nutrition, especially in low-resource settings. Technology opens up opportunities to address these challenges and potentially improve IYC feeding practices. Taking a co-design approach, we conducted low-fidelity prototyping workshops with caregivers and HCPs to explore the potential of tangible interfaces to facilitate play and promote healthy nutrition for IYC in two low-resource healthcare settings in Peru. Participants envisioned diverse tangible objects and interactions that could augment the waiting spaces of the healthcare centres, encouraging play and enhancing children's and caregivers' experiences, while promoting healthy nutrition and dietary diversity. We outline design opportunities to facilitate tangible play, shared playful experiences, and promote healthy nutrition in low-resource healthcare settings.

CCS CONCEPTS

• **Human-centered computing** → **Participatory design**.

KEYWORDS

Low-fidelity Prototyping, Co-design, Play, Complementary Feeding, Global South, TUI, Low-resource Healthcare Settings, Peru

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1 INTRODUCTION

Childhood malnutrition (e.g., undernutrition, micronutrient deficiencies, overweight and obesity) remains a global health problem, especially in low-resource settings in the Global South (GS) [113]. The coexistence of undernutrition and overnutrition, also called the double burden of malnutrition, is impacting Latin American countries more than other regions in the world due to the rapid transition from being predominantly underweight to an overweight population [41]. In particular, Peru has shown the highest prevalence of double burden on malnutrition in mothers and children under five years old [24, 105], which can impact children's development increasing the risk of developing diet-related non-communicable diseases later in life [41, 113]. The World Health Organization estimated that by 2020 45% of deaths of children under five were related to nutritional factors that could have been prevented [112].

To address these challenges, it is essential to promote and support age-appropriate infant and young child feeding (IYCF) practices early in life to help prevent malnutrition [101]. Thus, it is necessary to introduce complementary foods after six months of age as breast milk is not enough to cover all the important nutrients for child development [81]. The caregivers (parents and their families) play a crucial role in developing young children's healthy eating habits and improving childhood nutrition [79]. In addition, healthcare professionals can support and improve caregivers' nutritional knowledge about healthy eating for young children [73, 88]. However,

many children are still poorly fed worldwide [111], and the zero or low consumption of vegetables and fruits among children aged 6-23 months is worrisome [5]. Caregivers face multiple challenges around time for food preparation and acquisition [84], unhealthy food preferences [86], and limited knowledge about healthy diets for young children [74]. All of these are exacerbated in low-resource settings due to the lack of infrastructure, resources, and trained staff, which impacts the provision of nutritional counselling [30, 109].

Given the current trends to use Information and Communication Technologies (ICTs) to address maternal and child health challenges [78, 83] and contribute towards the Sustainable Development Goals, previous research has explored how ICTs can offer opportunities to meet children's development needs by monitoring children's growth [59], promoting healthy snacking [95], and enhancing caregiver's nutritional knowledge [3, 107] to potentially improve IYCF practices [29]. Leveraging the crucial role of play in childhood development [98] and the potential benefits of tactile play to encourage healthy nutrition [22, 23], previous research has explored the use of tangible user interfaces (TUIs) to facilitate a more playful mealtime experience for preschool children and their families [67], and to support playful eating by using tableware devices to improve children's daily eating habits [55]. While many of these digital health interventions have the potential to enhance IYCF practices, most of them were implemented in high-resource settings or have been designed for children older than two years old. Yet, it is crucial that infants and young children under two develop familiarity with healthy foods while they are still curious and developing their relation to food in environments that are shaped by caregivers [8].

Taking a participatory approach to healthcare technology design [20, 57] and leveraging previous co-design work in low-resource settings in the context of maternal and child health [21, 106, 110], we further explore how play [21] and tangible user interfaces [107] can be used to promote healthy nutrition and contribute to the early development of food literacy in children [8] under two years old. In this paper, we present the lessons learned from co-design workshops with caregivers and healthcare professionals where we use low-fidelity prototyping (simple materialization of a design, usually with low-cost materials to allow participants to explore and interact with them [97]) to explore the potential use of tangible artifacts to promote play and healthy nutrition in two low-resource healthcare settings in Peru. The use of participatory co-design methods in Latin American or Peru is limited [6, 61, 62, 87], especially in the healthcare context [13, 89]. Considering that children under two are unable to participate in the design process as they mostly depend on their caregivers, we engage with caregivers and healthcare professionals as proxy-users [25, 34, 51, 70, 99] due to their important role in the development of children's eating habits. Based on the co-created low-fidelity prototypes, we outline different design opportunities for tangible interfaces to facilitate play and enhance children's and caregivers' experiences in the waiting areas of low-resource healthcare settings while promoting healthy nutrition.

2 RELATED WORK

2.1 Engaging with Low-Resource Communities: Challenges for Participation

Researchers in the Human-Computer Interaction (HCI) community have a long tradition of engaging with different stakeholders through cooperative approaches that have been proposed to increase their involvement throughout the design process [60, 92]. Indeed, Sanders [91] stated that it is necessary to believe that everyone has something to offer to the design process. However, articulating participants' thoughts, experiences, and ideas can be difficult due to, for example, participants' lack of motivation, their health condition, and limited understanding of technology [2], among other socioeconomic, cultural and technical factors that could hinder participation, especially in low-resource settings in the Global South [21, 47, 106, 107]. Thus, there is a need for more inclusive approaches to design in this context [27], where participatory methods must be flexible and adapted [47] to increase and support the development of the capacity to participate, especially when including marginalised voices [15]. To address this, as a means of supporting stakeholder involvement [35, 46, 94], HCI researchers have created different design tools to facilitate and enhance participation [93], such as probes, toolkits, and prototypes to be used throughout the different phases of the design process. In particular, a cooperative design approach [12] promotes the active involvement of stakeholders through the creation of low-fidelity prototypes.

2.2 Low-Fidelity Prototypes and Design Materials To Encourage Participation

The use of low-fidelity prototyping has served as a unique tool to enable participation in the design of technology [100], supporting the development of design ideas [4]. Prototypes can work as a means to inspire, explore, learn, articulate, visualise and evaluate (new) design ideas, concepts, and scenarios [93, 114], and support collaboration between multiple stakeholders [56]. Indeed, low-fidelity prototypes support the navigation of the design space [66], enable exploration (e.g., seeking or filtering new design ideas or concepts), and foster active learning (e.g., gaining new knowledge) [16] through the interaction or co-creation of prototypes. Low-fidelity prototypes can support the exploration of near or speculative futures [94], which is particularly beneficial when designing technology to explore its potential and people's perspectives before implementation. Furthermore, materialising the ideas through prototypes can not only help to articulate ideas, but also to uncover invisible complexities [43], challenging designers' assumptions and enriching the design process [66].

Participatory design approaches in healthcare also pose additional demands in participation as diverse stakeholders with often conflicting perspectives need to be involved [20]. Socio-technical and cultural barriers exist, especially in low-resource settings, such as diverse community power dynamics [26], lack of self-confidence for creative activities [47, 80], and lack of infrastructures that can impact users' participation in the Global South [47]. To support prototyping activities, tangible, low-cost and everyday materials, such as paper and post-its notes, have been used to facilitate stakeholder involvement [11]. For example, Cho et al. [19] used clay,

sticks, plastic bowls, and so on to explore how nurses, children and guardians visualised playing spaces for hospitalised children. In particular, paper, cardboard and craft materials have supported the participation of caregivers and healthcare professionals in low-fidelity prototyping workshops in low-resource settings to sketch, visualize, and envision their co-produced design ideas in the context of maternal and child health [72, 106, 110].

2.3 Technology for Children's Play & Nutrition

Play is essential to support children's cognitive, socio-emotional, and physical development [98]. Prior work has explored the use of play to familiarise children with healthy eating by improving children's food literacy or enhancing their lunchtime experience to help overcome picky eating behaviours using tangible user interfaces [55, 67]. For example, to motivate a child to eat, Lo et al. [67] designed an interactive tray that incorporates an embedded screen to show different characters running in a racing game while the child eats. Furthermore, mobile technology with playful elements has been used to increase the acceptance of vegetables in 3-6 year old children using the principles of repeated exposure [33]. In addition, a wall projection has been used to support play in the hospital setting (e.g., playroom, waiting room) through an interactive virtual underwater world aiming to reduce stress and boredom for children aged 2-16 years [63]. Yet, there is limited work on designing technologies aimed at IYC that encourage play and healthy nutrition in low-resource healthcare settings.

While designing tangible interfaces for children, many studies have excluded children under four years old because early technology exposure is often not adequate for them [7]. However, it is evident that children are exposed to technology at younger ages [58], which highlights the need for developing age-appropriate technology for IYC [9, 44]. For example, Honauer et al. [44] developed an interactive soft book to facilitate the development of sensory-motor skills in children under two years old involving proxy-users (e.g., caregivers) only during the evaluation. The design of tangible and playful objects should consider children's preferences for parallel play and simple interaction [108]. However, many projects have been designed for high-income countries, with few exceptions from the GS [37], making it difficult their use in low-resource settings.

3 METHODS

3.1 Research context

The study described in this paper is part of a larger multidisciplinary research project that started in 2019 aiming to tackle the double burden of malnutrition in children aged 6-23 months in peri-urban communities in Peru. In the summer of 2022, we started a co-design phase, engaging with healthcare workers and caregivers through a series of co-design workshops in low-income areas in two Peruvian regions: Manchay (Lima) in the coastal region and in the city of Huánuco (Huánuco district) in the Andean highlands.

3.1.1 Manchay, Pachacamac District. Manchay is situated in the Pachacamac district in the province and department of Lima in Peru. The Pachacamac district has one of the highest percentages of illiteracy in the metropolitan area of Lima [28] and around 30.6% of children aged 6 to 35 months in this district have anaemia [28]. Manchay is a peripheral area located between hills and sandy areas with few paved roads. It is zoned as a low- and middle-low-income settlement with a household income between S/863.72 - S/1,073.00 and less than S/863.71 per month ($1 = S/3.71) [17]. The provision of healthcare services, such as childhood immunisation, nutritional counselling and growth monitoring, takes place primarily in the healthcare centres by a diverse group of healthcare professionals (HCPs), including nutritionists and nurses.

3.1.2 Huánuco, Huánuco District. Huánuco is a city located in the district and department with the same name in the central-north of Peru. The district has one of the highest percentages of illiteracy in the country [49]. In 2022, the Huánuco district reported a concerning 51.8% prevalence of anaemia among children aged 6 to 35 months [50]. In 2020, the average income per house was S/1235 monthly, approximately $ 325.60 [1]. However, in 2022, between 36.7% to 40.9% of people in the district faced monetary poverty to meet the household basic critical needs [48]. In contrast with Manchay's healthcare centre, Huánuco has a more homogeneous group of healthcare professionals (HCPs), with nurses being the most predominant healthcare provider/personnel.

3.2 Positionality and Ethical Considerations

Our positionality is driven by acknowledging that our experiences and backgrounds contribute to our world perspective and how this shapes our work [14, 75, 96]. The larger project team included a cross-cultural and interdisciplinary group of researchers (seven from Peru and nine from UK/France) with backgrounds in public health, nutrition, social sciences, and human-computer interaction (HCI). In this paper, seven out of the eight authors are women. Three of the authors are based in a research institution in Peru and four are based in academic institutions in the UK (two of them with Latin American backgrounds) and one author is based in a French research institution. Three Peruvian co-authors and two co-authors based in the UK are native Spanish speakers, and all authors speak English. While all members of the team belong to an upper-middle socio-economic class, our team has extensive expertise, individually and collectively, conducting participatory research in the context of maternal and child health in low-resource communities and multi-linguistic settings (urban and rural) in Latin America and around the Global South. Our position has indeed shaped the way we framed the overall project and analysis of the co-produced materials and we have followed the best practices to continuously involve community participants in our activities before, during and after the project. The interdisciplinary project team collaborated actively and meaningfully throughout the research process.

The workshops received ethical approval from the Ethical Review Committee of the Instituto de Investigación Nutricional (IIN) Peru (388-2019/CIEI-IIN), Loughborough University (C19-87) and confirmed by Cardiff University. Additionally, written informed consent was obtained from all participants. Caregivers attended the workshops with their children. To facilitate caregiver's participation, the research team set up an area in the workshop room where babies and toddlers could play or rest, supervised by researchers and health promoters that were not participants. Participants received fruit and water during the sessions. They were compensated with

transport costs and a plastic water jar, and their children received the wooden puzzles they played with during the workshops.

3.3 Pre-workshop Activities

Based on insights from previous co-design workshops (idea generation workshops, future workshops [80], and storyboarding workshops) in Huánuco and Manchay, the first author created tangible materials to explore how to encourage play in the healthcare settings and how play can promote healthy nutrition. These materials also aimed to support the participation and familiarization of tangible materials for the low-fidelity prototyping workshops. We used the materials as prompts in the workshops and included a puzzle with fruit images, a plate with a variety of food that participants could decide what to put on, and a craft foam strip where participants had to move the food elements to "encourage the child to eat" (see Figure 1a and 1b).

3.4 Participants and Recruitment

In each research setting, we purposefully selected the principal health centre and one subsidiary health centre to invite participants in the surroundings to our co-design workshops. We extended invitations to caregivers, HCPs and health promoters (HPs) within the jurisdiction of four health centres (two in Manchay and two in Huánuco; see Table 1). In collaboration with the heads of the health centres, we recruited three HCPs: two nurses with one year of experience and one nutritionist with 25 years of experience from Huánuco; and two HCPs: one nurse with 24 years of experience and one nutritionist with 25 years of experience from Manchay, who participated during their regular working hours. In addition, we recruited five health promoters: three in Huánuco and two in Manchay (all with more than 9 years of experience), who conduct regular visits to caregivers to monitor the progress and the growth of caregivers' infants during the first year. Four of them were also invited to the workshop as participants. Furthermore, nine caregivers (mean=28.25 years, SD = 6.96) in Huánuco and five in Manchay (mean=31.6 years, SD=7.40) participated in the workshops. Most of the participants (six caregivers and two HPs in Huánuco; two caregivers, one HP and two HCPs in Manchay) attended previous co-design workshops. Three caregivers and three HCPs in Huánuco and three caregivers and one HP in Manchay were new participants.

3.5 Low-fidelity Prototyping Workshops

In September 2022, we conducted two low-fidelity prototyping workshops to explore the material and tangible dimensions of potential artifacts that can support play and promote nutrition in low-resource healthcare settings through sketching, hands-on activities, and cooperative prototyping.

Table 1: Participants per Workshop

Place	Healthcare Workers	Caregivers
Huánuco	6 (1 nutritionist, 2 nurses, 2 health promoters (HP))	9 mothers
Manchay	4 (1 nutritionist, 1 nurse, 2 HP)	5 mothers

3.5.1 Introduction and an overview of previous workshops. A facilitator welcomed the participants and introduced the research team and participants using an icebreaker activity, asking them to share their experiences in previous workshops and integrating new participants. A second facilitator briefly explained the ongoing co-design process since June 2022. First, the main challenges identified at the beginning of the project regarding the double burden of malnutrition were recalled including the high consumption of unhealthy food and savoury snacks in mothers and IYC, as well as issues with nutritional counselling [85, 89]. Second, the facilitator also provided a brief explanation of the previous co-design workshops (ideation, future, and storyboard workshops) [80, 89] and summarised the ways caregivers and HCPs prioritised the challenges, brainstormed and shared ideas of possible solutions to address them. Last, the facilitator explained how caregivers and HCPs in the previous workshops have highlighted the importance of creating playful interventions to convey information about healthy food for them and their children in the healthcare centres.

3.5.2 Hands-on activity. In each location, facilitators divided participants into two groups, balancing the groups between HCPs and caregivers, e.g. where possible aiming for the same number of participants per group and integrating 1 HCP or 1 health promoter for every 1 or 2 caregivers. Then, the facilitator introduced the created tangible materials presented above (see Section 3.3 and Figure 1a) as material probes [54] to trigger discussion and invited each group to explore them by touching and playing with them while expressing their thoughts. The aim was to support the dialogue among participants, and critique the ideas and materials.

Next, participants were asked what they thought was missing in the tangible prototyping materials, who they imagined could use or play with them, and how caregivers could be involved with their children during the playtime. To support the low-fidelity prototyping activity in the Huánuco workshop, we provided participants with markers and A0 sheets and asked them to draw their ideas. Based on the co-created sketches and the tangible forms of materials and interactions depicted in the Huánuco workshop, for the next workshop in Manchay, we provided participants with additional 3D materials to further enhance the prototyping activities (see Figure 1c). Participants were encouraged to explore and emphasise the tangible, physical and material attributes of their prototypes, depicting how they envision different forms of play at the healthcare centres to promote healthy nutrition.

3.5.3 Closing the workshop. In the end, the groups presented their co-created sketches and/or low-fidelity prototypes and reflected on their experiences from the workshops. Overall, caregivers found the workshop to be a positive experience since it facilitated their participation, acquisition and exchange of knowledge among caregivers and HCPs, and how the workshops promoted a healthy diet for their children. For HCPs, it was a moment to reflect on the caregivers' contribution to the discussions, recognising the importance of the caregiver's experiences, knowledge, involvement and participation considering their key role in children's nutrition.

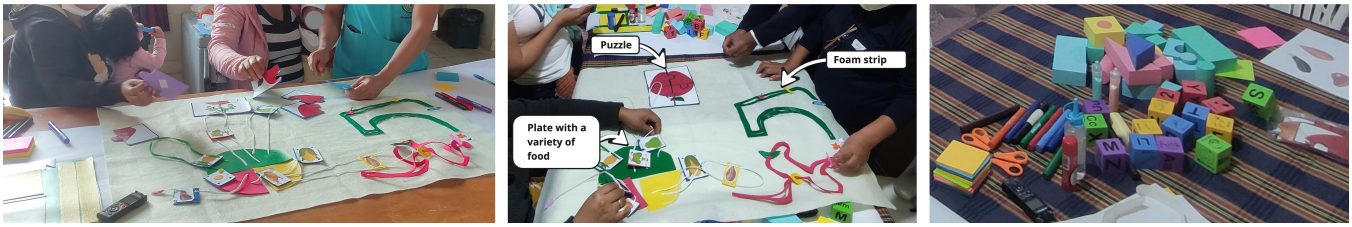

Figure 1: Tangible materials used during the prototyping workshops: caregivers, HPs and HCPs interacting with materials in: a) Huánuco, and b) Manchay; and c) additional 3D materials for hands-on activities.

3.6 Data Analysis

The first author captured the sketches and pictures of low-fidelity prototypes, notes and descriptions from the workshops in Huánuco and Manchay in virtual post-its notes (approx. 150 Post-it notes) on Miro, an online collaborative board tool. To analyse the data, the first author used affinity diagram [38, 68], clustering the notes and exploring the virtual wall in Miro, and identified some types of interaction, materials, and properties portrayed in the sketches. Then, the audio recordings of the workshops (110 min. in Huánuco and 130 min. in Manchay) were transcribed and analysed with a deductive analysis of the transcripts based on the information from the affinity diagram. The first author identified and tagged new and previous codes in the data (e.g., food classification in play/toys, iron-rich food, play on the floor, etc.). The first author grouped the codes into themes and discussed them with the last author before sending them out for comments to the rest of the team. All the data collected was analysed in Spanish and translated to English for reporting in the next section.

4 FINDINGS

The results illustrate how caregivers and HCPs were able to envision the potential development of playful and tangible interactions in their low-resource healthcare centres. In addition, the co-produced low-fidelity prototypes and sketches depicted how participants portrayed and associated them with various local foods, supporting playful interactions to encourage children's familiarisation with and exposure to healthy food.

4.1 Augmenting the Health Centre Waiting Area to Facilitate Interactive Play

From earlier workshops, we found that caregivers spent most of their time in the waiting area and wished to improve its physical and social environment to improve their waiting experience at the healthcare centre. Caregivers and HCPs co-created sketches and low-fidelity prototypes that, together with their discussions, portrayed how the properties of the floor, wall, and physical objects in the healthcare environment could support playful activities for children while waiting for medical appointments. Participants also mentioned that caregivers can be encouraged to be involved in playful activities with their children during the waiting time in the healthcare centre.

4.1.1 Considering the practical properties of the floor and their potential to support playful interactions. During the workshop, caregivers and HCPs explored how to enhance the design of the waiting area to create a more ludic environment considering the spatial constraints of the healthcare centres (e.g., lack of space). Participants suggested leveraging the practical properties of the floor as it is a common surface that can support children's everyday learning and play, especially for babies who are crawling or starting to walk as part of their early development. For example, a caregiver commented:

> *"I put [the baby] on the floor, and I [walk away]... and I say come, and she sits down, and first, she looks at me and then comes [...] or [I use] a little toy, a doll or something [to get her attention]"* (Huánuco Caregiver01).

From the generated low-fidelity prototypes, we also found that caregivers sketched cushioned materials on the floor to prevent accidents. For example, a caregiver mentioned: *"Here I'm going to draw a mattress, in case children throw themselves [to the floor and get hurt]..."* (Huánuco Caregiver 02). From the discussions, HCPs agreed and mentioned that foam mats can be flexible materials to be used on the floor to support playing: *"Mats of fruits... for children, but able to disassemble"* (Huánuco Nurse 01). In addition, in the generated prototypes, participants also portrayed different ways to encourage children to move around, as one participant commented: *"For those [children] who are walking, who feel like going up and down, there would be play blocks [on the floor] for them to go up and down"* (Huánuco Caregiver 02).

Our participants sketched popular/common games on the floor, such as hopscotch, and visually represented food elements on them (Figure 2a). Participants also mentioned that older children that accompany their caregivers to the healthcare centre and younger siblings could benefit from augmenting the floor of the healthcare centre with playful and interactive objects.

4.1.2 Using the wall to support playful interactions while standing or walking. Our participants also emphasised the potential for using the walls of the healthcare centre to promote children's playful activities, especially for children who are starting to walk and can use the wall surface to assist them. For instance, a caregiver stated:

> *"Also like [the wall] but wrapped because normally we wait in the chair, right? That is close to the wall so the baby can be standing and the baby can be playing. For example, we normally queue in a chair, on a bench that*

a) b) c)

Figure 2: Sketches and low-fidelity prototypes created by participants depicting: a) a hopscotch with food elements, b) playing to find out what food the child likes, c) a low-fidelity prototype to play "What do I want to eat today?".

> *is attached near the wall, so while the baby is there, sometimes he can't stand sitting for long... so he can stand up and grab the things [on the wall]"* (Manchay, Caregiver 01).

Participants' prototypes also portrayed food elements as pieces on the wall to encourage children to move them to create a healthy meal (see Figure 3). However, it is important to add some covering to the wall *"e.g., plastic... so they don't take it away"* (Manchay Caregiver 01) as well as *"ensure the pieces do not fall on the floor"* (Manchay Nutritionist) as a caregiver mentioned that *"children put things in their mouths"* (Huánuco Caregiver 04).

Figure 3: Low-fidelity prototype "Making the menu for lunch" by placing food elements in the plate to make a healthy meal.

4.1.3 Enhancing tangible play using physical objects. While discussing how to support playing in the healthcare centre, caregivers mentioned how they use physical objects to entertain children under two years old. Participants explained that while waiting for the medical appointment, they held their children in their arms to prevent them from crawling or walking. Hence, caregivers consider that it is necessary to give the infant an object to hold and play with; otherwise, children want to go down and crawl. From the generated sketches and prototypes, participants portrayed different physical objects such as shape sorting cubes, stacking toys, or dice with food representations. A caregiver mentioned that the shapes and food could encourage *"children to arrange the pieces where each food belongs"* (Manchay Caregiver 01) like a form of classification. Three of the six co-produced sketches in Huánuco resembled shape-sorting cubes, and two of them portrayed food elements (e.g., fruits and vegetables). Participants also illustrated other individual toys representing nutrition-related items like grapes, fish and pineapples.

In particular, participants portrayed physical objects that can augment existing surfaces (e.g., wall, floor, or table) and support tangible interactions. For instance, one pair of participants (Manchay Caregiver 02 and Manchay HP 01) designed a prototype to learn about the child's food preferences that could be placed on the floor or a table and the child would have to move the pieces with the food they like (see Figure 2b). Participants also pointed out that physical objects could get lost and suggested sticking the objects on the surfaces to prevent children from taking them to their houses. A HCP commented: *"little children sometimes unconsciously take [objects to home]"* (Manchay Nutritionist).

In addition, participants explored the potential integration of other modalities like having sounds in objects such as *"toys with sound"* (Huánuco Caregiver 02) and *"musical games like bells to catch [children's] attention"* (Huánuco Nurse 01). Participants also depicted rattles and bells on the sketches, as they are one of the most common toys for children under one year.

4.1.4 Encouraging caregivers' involvement in playful activities with children. All participants highlighted possible ways caregivers could be involved during the playtime of their children. For example, a HCP, when explaining their sketching, illustrated how caregivers could be involved:

> *"Then the little one comes, throws [the dice] and says... "mommy, look, I took this out, it's the pear", [the mom would say] "look for what the pear is, son", the boy takes out the little pieces and then, in the company of his mother, he can also be putting together [the pieces]"* (Huánuco Nurse 02).

In addition, some prototypes refer to how the caregivers may pay attention to the children's play while waiting for the medical appointment anticipating their next meal.

> *"The mothers are very focused on the children's play. As soon as they are at home, they will cook the food that the children rolled on the dice"* (annotation on the co-created prototype from Manchay Caregiver 03 and Manchay Nurse).

Furthermore, participants referred to their older children to engage in playful activities as well, as they mentioned that younger children usually imitate what their older siblings do. For instance, a caregiver mentioned: *"My girl saw that her 3-year-old brother grabbed the rattle, he has a whistle, there he started to play and there she also started doing it the same way, she imitates what others do [...] they are imitators of everything"* (Huánuco Caregiver 01).

4.2 Promoting Healthy Nutrition and Food Diversity at the Healthcare Centre

Participants' discussions, sketches and low-fidelity prototypes illustrate the potential of tangible and interactive food elements to support children's and caregivers' familiarization with healthy food and enhance awareness of a balanced diet and food diversity.

4.2.1 Enhancing children's and caregivers' familiarization and exposure to healthy food. In most of the low-fidelity prototypes, participants represented food in different ways. For example, three stacking toys displayed fruits, vegetables and animal source foods (ASF) where each ring of the toy represented a food element (e.g., liver, mango, etc.) (see Figure 2a). According to participants, the design should have a clear classification to avoid confusing children about the types of food and help caregivers identify the food to feed their children.

> *"This game is about differentiating the [food] group. Children can arrange the pieces where each food piece belongs. The benefit for both children and adults is that they can learn to differentiate what is protein, what is carbohydrate, what can I give them [children], which can nourish them more or less. What are important to eat. For example, my baby rejects some things; that's why I prefer him to eat the liver before the rice or certain things first before... With this game, we create like this, being able to identify more than anything."* (Manchay Caregiver 01)

Prototypes, in general, portrayed vegetables, fruits, and ASF in groups. When participants identified elements they wanted to use but were not in the provided materials, they drew them to visualize local food elements (e.g., guinea pig and "zapallo", a Peruvian pumpkin) and iron-rich food, such as liver, eggs and blood, etc. For example, a health promoter suggested: *"it could be [to help] children to identify [the food], a puzzle with foods rich in iron"* (Huánuco HP 01). Furthermore, participants highlighted the importance to portray food that children are unfamiliar with or dislike but that they should consume. For instance, another health promoter explicitly stated *"you can draw the things [the child] doesn't like, so you can encourage him to eat...[the child] will learn to eat"* (Manchay HP 01).

4.2.2 Providing awareness of a balanced diet and food diversity. While in Huánuco only one sketch portrayed a plate showing a balanced diet including fish, lettuce and lentils, in Manchay 3 out of 4 prototypes were related to making a dish (*"What do I want to eat today?"*, see Figure 2c; *"Making the menu for lunch"*, see Figure 3; and *"What will we eat today?"*, see Figure 4) in the healthcare centre. This exemplifies how playing at the healthcare centre could anticipate and influence the decision of what food to prepare at home. In two of them, the child has to choose tangible food elements and put them in a line or on a plate. In the third prototype, children have to roll five dice, each representing a different food group (fruits, vegetables, cereals, ASF, carbohydrates) with up to 6 food elements, to decide what meal they would eat today.

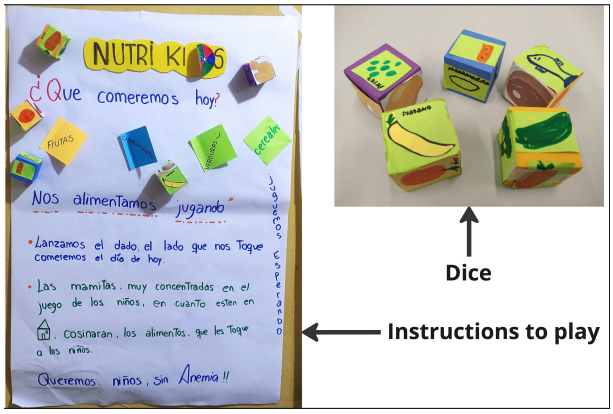

Figure 4: Low-fidelity prototype encouraging to play with dice to decide what to eat today.

5 DISCUSSION

While technology-enabled innovation and participatory approaches are creating opportunities for global health research and practice [43], there is still little innovation (e.g., limited tangible user interfaces) and participation of communities in the design of digital health interventions for maternal and child health, especially in low-resource settings [102, 107]. Based on our findings, we outline design opportunities to enhance the physical environment of the healthcare setting to promote healthy eating through playful and tangible interactive low-cost technologies in low-resource healthcare settings.

5.1 Augmenting the Waiting Area with Interactive Objects to Support Active Play

Playing is a natural way to explore the world and can be crucial for developing children's cognitive, socio-emotional, and physical abilities [98], especially for children under two years old. With the increasingly interactive ubiquitous devices, children have already been exposed to technology at early ages, especially to mobile devices [58]. Careful consideration should be given to the potential risks of using emerging technologies (e.g., too much screen time too soon) at early ages and the potential impact on child development [39] and their caregivers [104]. Therefore, there is a need to carefully design age-appropriate technology to support children's early

development [44]. Tangible user interfaces offer alternatives across different development stages [108], supporting children's learning [7] and play [44] during the first years of life. Although most of studies have focused on children over four years old, tangible user interfaces have the potential to engage young children in physical activities suitable for active play [31]. In our study, participants explored how enhancing the physical environment (e.g., walls, floors and objects) of the healthcare centres could offer opportunities to enhance children's experiences by amplifying activities for children under two years to support interactive play, complementing prior work [7].

5.1.1 Augmenting the surfaces of the waiting area with cushioned materials to promote active play. Previous research with adults [76] has shown the potential use of cushioned materials to enhance playful and vigorous interactions, such as hitting or boxing, encouraging movement and physical activity. For children, previous research has suggested that slides, swings, forts and climbing structures can help to promote active play in children between 3 and 5 years old [103]. For children younger than two, our study highlights the potential use of cushioned materials such as mattresses or mat foam materials to enhance the spatial design of low-resource healthcare settings with playful interactions while also preventing children's injuries (e.g., if a child falls on the floor). Furthermore, enhancing cushioned climbing structures [103] digitally or with projections to attract children's attention, and with sensors to capture children's direct input, could encourage active play and foster development of their motor skills. In addition, supporting playful interactions in the waiting areas of the healthcare centres can also be helpful to improve the overall spatial user experience [53] for caregivers by entertaining their children while waiting [65], reducing the perception of the waiting time [10, 82], and lessen the potential stress that the medical environment can bring [63].

5.1.2 Providing flexible, low-cost, and modular design of tangible interfaces for space-constrained healthcare settings. Although previous research [18, 69] has explored modular playful technologies, they have not been designed for children under two years old. In our workshops, participants showed how assembling and disassembling features are important to consider for infants and toddlers in the design of tangible user interfaces that could fit in low-resource healthcare settings with limited spatial capacity (e.g., waiting areas). Aligned with [69], our study highlights the opportunities that modular design could offer. It not only could support a variety of playful activities, but also the flexibility to adapt low-cost tangible user interfaces to the spatial constraints of the healthcare centres could help to improve the spatial appreciation [53] ("the process of aesthetic appreciation and the users' judgments of the physical setting" [52]) of the caregivers by re-purposing and enhancing the physical design of the waiting areas.

5.1.3 Enhancing social-physical interactions through play. In the context of a public space, such as the waiting area of healthcare centres, encouraging social-physical play between children [19] could be achieved by augmentation of familiar objects. In our study, most of the sketches and prototypes from our participants portrayed familiar objects (e.g., toys, mats, rattle), highlighting their potential use across various surfaces (e.g., wall, floor, table). Although social-physical play is particularly recommended for older children, based on our findings, we identified that the waiting area is a meeting point for children of different ages. Participants suggested that the physical objects can also be augmented with lights or sounds as prompts to facilitate or initiate interactions between younger children and (stranger) children or older siblings accompanying caregivers and young children for medical appointments. Here, it is important to keep the interaction as simple as possible and restrict the number of feedback modalities for younger children, as well as balancing the complexity for older children [108]. Although previous work [42] has enhanced objects to promote social-physical interaction for outdoor play, we consider that augmenting the waiting area to promote indoor play, regardless of the limited space at the healthcare centres, can also foster caregivers' social-physical play with their children and others in the waiting area. In addition, a few of our participants mentioned the possibility of children (unconsciously) taking the augmented objects to their homes, as well as they can bring them to their mouths. As these objects could be dirty, it is important to consider their hygiene. If hygiene is a concern, future research could investigate using anti-bacterial materials or implementing different strategies to keep hygiene in playful objects and spaces [19] in low-resource healthcare centres.

5.2 Promoting Healthy Nutrition and Food Diversity in the Waiting Area

Based on our findings, we identified the potential of tangible user interfaces to facilitate children's and caregiver's exposure to physical representations of healthy and diverse food, and to support learning through shared experiences.

5.2.1 Facilitating repeated exposure of healthy and diverse food representations using tangible user interfaces. Repeated exposure and multisensory experiences can help develop healthy food preferences [77]. For instance, Heath et al. [40] demonstrated that repeated exposure through pictures in books increases infants' interest in fruits and vegetables, and can facilitate their acceptance [40]. In our study, we found that most of the co-created sketches and prototypes included tangible representations of diverse food elements including local food products, and beyond fruits and vegetables [45]. This could facilitate not only the familiarisation with healthy food appearance, but also promote healthy food preferences to different food groups and according to the local food environment. While prior work has used tablets to increase vegetable acceptance in children [33], our study highlights the opportunities for tangible user interfaces to leverage repeated exposure techniques to increase the awareness of the benefits of a balanced diet and food diversity to enhance caregiver's knowledge and engagement with IYC healthy nutrition. For example, participants emphasized the importance of including foods children dislike to facilitate their acceptance and consumption. Therefore, this can be an opportunity to convey information to caregivers by taking advantage of their peripheral attention while their children play during the waiting time.

5.2.2 Supporting learning through shared playful experiences. Caregivers emphasized how they could be involved during playtime at the waiting areas of the healthcare centres by sharing the playful experience with their children because children under two years old

are often less autonomous. In addition, participants also mentioned the potential role of older children in supporting caregiving tasks and how tangible users interfaces (e.g., by augmenting the physical environment of the healthcare centre) could also be suitable for them. Considering older siblings' influence in early childhood development and eating behaviors [90], future work could investigate how tangible user interfaces could support and foster the role of siblings in promoting healthy nutrition by facilitating shared playful experiences with younger siblings, within and outside the healthcare centres. Here, our study highlights the opportunities for tangible user interfaces to support shared playful experiences [36] and potential for whole mind-body learning in a three-dimensional world – something a two-dimensional screen-based interfaces could not do [64]. In particular, the results point towards the potential benefits of tangible user interfaces in fostering positive peer-to-peer, sibling and parent-child relationships towards healthy child development and nutrition.

5.3 Strengths and Limitations

One of the main strengths, but also a limitation, is that our target audience is children under two years old and their caregivers. Since infants and toddlers have limited autonomy, they usually depend on their caregivers for assistance and it is not possible to interview or involve children under two in workshops. Thus, the active involvement of caregivers, HPs and HCPs as proxy co-designers was critical as they directly influence the children's development and are the experts in relation to children's eating habits. In addition, they are the principal users of the waiting area of the healthcare centre. As such, any technology deployment may affect their and the children's experience. However, involving HPs, HCPs and caregivers can also be challenging due to the situated power dynamics present in the context that might not be explicitly recognised or known by the facilitators [26], which could impact the co-design process [32]. In our study, we acknowledge that, as facilitators, we may (unconsciously) influence the HCPs and caregivers' participation since we were external actors in their day-to-day environment [71]. To mitigate our influence, we encouraged open participation for both caregivers and HCPs. We also attempted to balanced their interaction in group work (e.g., grouping 1 HCP with 2 caregivers) to avoid caregivers feeling intimidated by another group of participants. As a result, both caregivers and HCPs valued their participation in the workshops, and caregivers commented that the workshops encouraged them to speak in public (within the small groups or the entire workshop participants) and provided a means to enhance their nutrition knowledge. HCPs also recognised the value of caregivers' knowledge and experiences. Furthermore, some HCPs saw the workshops as important for improving caregivers' awareness about feeding and nutrition, while others perceived the activities as beneficial for themselves as a way to interact and meet caregivers in different settings and to learn from each other.

6 CONCLUSION

We have presented a number of design opportunities for Tangible User Interfaces for low-resource healthcare settings coming from our engagement with both caregivers and HCPs in two different regions of Peru. Co-sketching, the low-fidelity prototypes, and design materials were helpful to support user participation during the workshops, facilitate discussions, and explore the potential of tangible materials and playful interactions in low-resource settings. Based on the presented design opportunities, future work could explore the design and implementation of low-cost tangible prototypes that could support play to enhance caregiver's and children's experiences in the waiting areas and promote healthy nutrition and food diversity, as well as evaluate their acceptability and usability in low-resource healthcare settings in situ.

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