Exploring Community Needs for Disaster Shelters Using Cultural Probes

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ABSTRACT

During disasters, emergency shelters play a central role in emergency management, providing both a secure environment and centralized sites for the distribution of information, material relief supplies, and access to health and human services. Despite their importance, challenges such as physical access, public awareness, and peoples' willingness to relocate limit the impact of both shelters managed by emergency responders and informal locations created by affected communities. This paper presents research conducted as part of a long-term project aimed at designing digital tools to assist communities and formal responders plan and manage emergency shelters. Working with partners in Puerto Rico, we developed and distributed cultural probes in three communities with recent experience of hurricanes and earthquakes to better understand the needs and resources of disaster affected people related to shelter. This approach yielded novel insights that challenge and expand traditional views of emergency shelters and identified several areas where HCI research and design can contribute to the sector.

CCS CONCEPTS

• **Groups and Organization Interfaces**; • **collaborative computing, computer-supported cooperative work; Social Issues**;

KEYWORDS

Crisis Informatics, Disasters, Emergency Shelters, Cultural Probes

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1 INTRODUCTION

This paper presents the findings of human-centered design research into emergency shelters and the sheltering needs of disaster-affected communities. Emergency shelters are a vital component of disaster response infrastructure. During disasters, they are used to provide both physical security but also act as hubs for distribution of relief goods, such as food, water, clothing, and information. Though intended as short-term physical structures, people often end up occupying them for longer than designed [67]. As a result, they merit attention from a wide range of scholarly perspectives. Research into shelter design and management in fields such as emergency response and civil engineering has yielded important findings regarding the physical design, layout, and construction of shelters, with attention to how they can be quickly mobilized during times of crisis, when resources are scarce and time is of the essence [65]. Similarly, HCI research on shelters for people displaced during emergencies has primarily emphasized physical design of shelters, offering such insights as the importance of participatory process and drawing on local knowledge and construction practices [54] [55]. Here, drawing on the lens of human-centered design, we offer a broader view of both disaster-affected peoples' needs regarding shelter and the contributions that HCI stands to make to this problem space.

We conducted this research as part of an ongoing collaboration with several disaster response agencies and community-based organizations in Puerto Rico. Puerto Rico, as a territory of the United States, experiences significant challenges with regards to the governmental autonomy necessary for effective emergency response planning [36]. This combines with other economic and infrastructure challenges in the health, transportation, and electricity sectors to make the island particularly vulnerable to the various natural hazards it faces [24]. Hurricane Maria in 2017, for example, killed almost 3,000 people and caused around $90 billion dollars in damages [34]. Just two years later and before the island had fully recovered, an earthquake swarm that lasted months destroyed over 8,000 houses and left many homeless as reported by Puerto Rico's Department of Housing. As is common in disasters, authorities struggled to provide shelter to impacted communities at the scale and extent needed, leaving many communities to create and manage their own ad hoc or informal emergency shelters [51].

Our research team sought to understand local needs and capacities with regards to emergency shelters and public perceptions of disaster safety, in three communities that have recently experienced both hurricanes and earthquakes. To do this, we worked with partners to develop and distribute cultural probes to individuals in each community. Cultural probes, originally popularized by Gaver et al [25], are a design research tool meant to capture rich information about participants' beliefs, daily lives, and context. This method has recently been explored in under-resourced environments [73], and we deployed them in this project based primarily on two considerations. First, given that the domain (emergency shelters) is

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relatively nascent within the field of HCI, we wanted to ensure we were using an open-ended research approach that would allow us to generate rich insights that more structured tools, such as surveys or focus groups, might miss. Second, as a result of the pandemic, in-person participatory design approaches were unfeasible, and the lack of widespread internet and mobile access in the study site made internet-based studies difficult.

Drawing on the results of our cultural probes, this paper makes three contributions. First, our findings expand the considerations of HCI research into shelters to include a range of factors beyond the design of physical structures. In addition to structure design, our respondents demonstrated desire for several other forms of support such as assistance with emotional and mental health, a sense of community, access to information, and the ability to play a role in recovery processes. Second, we position emergency shelter design and management activities from the perspective of information and coordination challenges. This allows us to connect the challenges of emergency shelter to literature in crisis informatics and suggests several areas where further HCI research may contribute to this domain. Finally, we reflect on the role of cultural probes as tools for assisting with participatory design strategies in remote and/or offline communities.

2 RELATED WORK

2.1 Crisis Informatics and Informal Community Response to Disaster

Disaster research and accounts from the field show that residents and community groups demonstrate adaptability, innovativeness, and responsiveness in the face of crisis, where strong social networks and structures are important elements in recovery after disasters [3] [38] [68] and incorporating local knowledge is thought to be able to help formal agencies improve their disaster management planning, as well as project performance, acceptance, ownership, and sustainability [18] [63]. These arguments call for disaster information and knowledge management systems that incorporate the role of residents and community groups and the time, skill, knowledge, and resources they offer [23] [67]. Meaningful support to individuals and community groups may thus require the decentering of the priorities and worldview of the disaster management community in the design of disaster information systems [61].

Crisis situations are characterized by high levels of uncertainty as result of the breakdown of physical and social infrastructures [21] [52]. Within this context, emerging technologies are often thought to support community resilience by offering means of coping with such ruptures [70]. Previous studies within crisis informatics have sought to understand the role of social media and other ICTs in these processes. Findings from this work have emphasized the importance of local knowledge [21], taking long-term perspectives on both the impacts of disasters as well as the vulnerabilities that produce them, and the need to expand the forms of technology considered by crisis informatics beyond social media [60]. Despite advances in implementations of social media and ICT within crisis response, questions remain on how to better support communities impacted by disaster. Future research needs in this area includes finding ways of building community resilience that prioritizes longevity for collective practices [60], effectively supports information seeking and sharing [70], and better addresses misinformation during disaster [22].

Importantly, crisis informatics shows that people are likely to support one another in disaster, and often develop emergent and creative ways to do so using resources at hand [45]. Previous studies have demonstrated how informal or community-based emergency response, often supported by ICTs, has been instrumental in meeting the needs of disaster-affected people [46] [70]. Yet the emergence of informal community response to disaster is never completely spontaneous [61]. Similarly, there are plans of the government and nonprofit actors that comprise formal disaster response enacted without significant improvisation [33]. The practices of disaster response thus share much in common with what interaction designers have described as bricolage, where individuals and collectives cobble together available resources in ways that respond to, but do not perfectly address, problems at hand [39]. HCI research has explored the value of thinking about design processes as bricolage [66], and developed methods such as "design for appropriation [19]" and assets-based design [71] as strategies for supporting users in their own bricolage. The research presented in this paper is part of a longer-term project aimed at bringing these insights to the field of crisis informatics, and designing to support emergent, bricolage, collaboration between informal and formal responders during crises.

2.2 Emergency Shelters

In this project, we conducted design research with three communities in Puerto Rico to understand one of the most important challenges during emergency response - sheltering. In the field of emergency management, shelter is typically defined as "a habitable covered living space providing a secure and healthy living environment with privacy and dignity" [44]. Emergency shelters provide temporary respite and safety for individuals and families displaced from their place of residence either voluntarily or without choice in the event of structural damage or extreme risk to hazards. While shelter design and management are an active area of research in fields such as emergency management and architecture, here we build upon prior HCI work [54] [55] to further develop our field's approach to this problem space. This work largely focuses on the physical aspects of sheltering and raises the importance of participatory and localized design processes[54]. A recent survey of a related field, Information and Communications Technology for Development (ICTD), found that research into shelter design focused primarily on high tech solutions and experiments within resource-rich environments [54]. We contribute to this literature by taking a broader view of individual and community needs regarding shelter, conducting this research in a relatively lower resource environment, and not centering technological approaches.

In accordance with the United States Federal Emergency Management Agency (FEMA)'s National Response Framework, formal government managed emergency shelters are planned under Emergency Support Function #6 (ESF-6): Mass Care, Emergency Assistance, Temporary Housing, and Human Services [65]. These services are typically coordinated through state and local emergency management agencies, often with main responsibilities landing on the department of housing or social services. These agencies

take the lead on running and staffing emergency shelters. However, there are various reasons why these shelters are not fully utilized, including distance or transportation limitations, lack of trust in government or formal emergency 0response agencies, inadequate conditions, and that people feel safer in their own communities [37]. People are often reluctant to leave their homes for a variety of reasons including perception of risk, access to resources, and household composition. For example, people may not trust the government to provide adequate services in a shelter, would rather stay with friends and family, feel they need to protect their property, or have determined they would be safer to shelter-in-place. Public investments in shelters are limited and people in rural areas often face challenges of distance, transportation, or inadequate conditions on arrival.

Challenges with formal sheltering operations have led many people to take sheltering operations into their own hands, particularly in non-urban settings. In recent disasters in Puerto Rico, community-based organizations or emergent citizen groups without prior planning or training in sheltering often took the lead. Similarly, after Hurricane Katrina, many faith-based organizations stepped in to provide sheltering services and have often been formally engaged in shelter planning and operations [48]. This raises many coordination and information challenges. Shelter operations are complex and require significant planning prior to disaster to ensure shelter clients are appropriately cared for during a crisis. This planning must incorporate issues as diverse as staffing, sanitation, potable water, safety and security, unaccompanied minors, child protection, accommodations for people with disabilities, access, or functional needs, mental health, and the ability to assist in navigating transitional housing services, and other formal government provided relief options [65]. Given the diversity of challenges raised by shelter design and management, we began this project by seeking to understand more about people's views of shelters, past experiences, views about safety in their community, and other factors that may influence sheltering behavior.

2.3 Cultural Probes

Given the constraints imposed by physical distancing and uneven and unequal access to electricity and technology, many standard approaches used to facilitate participation in disaster management such as in-person workshops, design charrettes, or online crowdsourcing techniques were not possible or insufficient at this time of this study. Furthermore, due to the complexity and context specificity of sheltering decision-making and shelter planning, we were concerned that highly constrained methods of data collection, such as surveys via SMS or interactive voice response (IVR), would be insufficient to capture the depth of information necessary. To respond to this challenge, in this project we experimented with a design research method, known as a "cultural probe" to approach the research questions of this project.

Cultural probes are used by design researchers to collect rich information about the perspectives, daily lives, and desires of diverse participants [25] [74]. Cultural probes take many forms but they generally consist of packets of paper materials and exercises that are mailed or delivered to participants. Depending on the probe, participants have several days to a few weeks to complete the activities and return the materials. Probes take many forms, depending on the research goals, participants often draw pictures, provide written responses to short prompts, or draw maps or take photos of particular aspects of their environment. In some cases, designers ask participants to produce creative or artistic responses [26]. They have been used in diverse design settings, including campus sustainability planning, childhood education [74], and international development [73]. There are significant debates within the design community around the evaluation of probe results, in particular if the findings are used as research methods, as opposed to inputs into individual design processes [10]. Given the cultural probes ability to capture rich data on the lived experiences of an individual in their environment, we believe it will provide unique perspectives to understand how the community environment is perceived, daily lives lived, and priorities of those who may require more specialized services in a shelter.

Data from cultural probes is notoriously difficult to interpret in ways that align with epistemic commitments of other areas of the social sciences [10] [26]. Gaver, often credited for popularizing the approach, has noted that probes are not meant to deliver "a list of facts" about participants and wondered in 2004 if the data that probes return was "impossible" to evaluate in a manner that would be legible to other disciplines [26]. However since the time of writing, connections between ethnography and design research has increased [20] [27], and probe methodology has been taken up in more practical and instrumental ways than Gaver initially envisioned [12] [74]. Nevertheless, interpretation of probe data remains inherently subjective, and requires significant reflexivity on the part of researchers [73].

3 RESEARCH SITE

This study was conducted in rural communities in the southwest of Puerto Rico, a region adversely affected by the consequences of the recent natural hazards while already facing its own set of pre-existing challenges. Located in the northeast Caribbean, Puerto Rico is home to 3.2 million people and is exposed to a range of natural hazards including hurricanes, earthquakes, tsunamis, landslides, subsidence, and flooding [47]. In September 2017, category-5 Hurricanes Irma and Maria made landfall in Puerto Rico, causing catastrophic damage to homes and critical infrastructure [57]. At the end of 2019, before people could recover from the impacts of these hurricanes, a swarm of earthquakes occurred and caused major damage. At the start of 2020, before the arrival of the COVID-19, Puerto Rico suffered another swarm of earthquakes global pandemic [6]. These cascading disasters exposed the widening gaps in providing mass care and sheltering for those affected, exacerbated by a pre-existing housing crisis [28].

Puerto Rico's socio-economic situation is shaped and exacerbated by the relationship the commonwealth has with the United States of America. This relationship has led to recent policies such as the privatization of health and other sectors, reduction of social rights and investments in collective well-being, and led to the neglect of social and physical infrastructure [36]. The United States federal government has imposed restrictions upon Puerto Rico in areas

from government affairs to education, transportation, communication, foreign trade, and public health. This relationship makes Puerto Rico highly reliant on external aid and funding, resulting in inadequate responses during recent disasters [53]. Puerto Rico relies on the support of the United States Federal Emergency Management Agency (FEMA) during emergencies, but recent disasters have exposed the problems resulting from the limited aid the territory receives, as well as lack of local control over consumer goods, commercial trade and resource allocation as per the US federal law PROMESA (Puerto Rico Oversight, Management, and Economic Stability Act) [53].

The COVID-19 pandemic aggravated the existing obstacles faced by Puerto Ricans. Puerto Rico's population skews elderly, with 21.0% being 65 or older in age, resulting in a sizable portion of the population being categorized as vulnerable and high-risk during the COVID-19 pandemic. The pandemic outbreak worsened the ongoing crises in Puerto Rico by creating "parallel pandemics" that exacerbated socioeconomic and health inequalities faced by its most vulnerable residents [24]. These challenges, along with poor and inconsistent accessibility of transportation, cellular, and internet networks create a challenging scenario for emergency management. In recent disasters, residents and community-based organizations across the island stepped to provide assistance to affected people [51]. For example, when the most recent earthquakes forced residents into the streets out of fear and necessity, community-led efforts were fundamental to ensuring that displaced people received adequate shelter, food, access to medical care, and other forms of assistance [1]. Though citizens always play a role in crisis response [33], in Puerto Rico, high degrees of vulnerability combined with weaknesses in emergency management capacities have meant that community organizations and emergent networks of individuals are central actors during disasters [29]. Therefore, our research considers shelter planning, design, and management from the perspective of the plans of formal actors as well as the ad hoc and informal shelters that affected communities devise for themselves when necessary.

4 RESEARCH METHODS

This study used cultural probes to gather rich information about participants' lived experience during previous disasters and facets of the local context or environment that may support (or hinder) sheltering activity during storms in Puerto Rico. The study was conducted remotely under the constraints imposed by the pandemic and physical distancing and approved by university ethics review. Drawing on formative research including key informant interviews with humanitarian organizations in Puerto Rico and collaborative design workshops with disaster affected communities [*anonymized for review*], we created a 25-page cultural probe package consisting of 11 activities that cover a range of issues related to shelter planning and disaster management. Activities were chosen to represent outcomes which were important to both participants and researchers. The final activities were also selected to allow for completion in a total of approximately five hours. Example activities included a community mapping exercise, photography and diary tasks, and social network diagramming. The full version of the probe package is available, in English, in the Supplementary materials. The cultural probes were designed to take five to ten hours to complete over the course of one week.

Our partner organizations in Puerto Rico translated and distributed the cultural probe packages and recollected them once they were complete. In addition to the paper activities guide, each packet included a disposable camera, pen, colored pencils, and a pencil sharpener. A local phone number was provided in case participants had questions or concerns about the activities enclosed. Overall, all 30 packets that we distributed were completed, or 10 respondents per community. Participants included those who identified as Male (n=11) and Female (n=19). Participants by age group included 18-30 (n=2), 31-49 (n=13), 50-64 (n=8), and 65+ (n=7). Participants by subpopulation included caregivers of children (n=8), caregivers of the elderly (n=9), dual caregivers (n=1), and elderly living alone (n=7). Recruitment was managed by our local partners and aimed at gathering a diversity of perspectives, rather than being demographically representative of the communities that we studied. Participants were compensated for their time.

Our authoring team is composed of two crisis informatics researchers, a human-centered designer, and a disaster and public health researcher. We also received significant research support from a community psychologist and an anthropologist who are based full-time in Puerto Rico who assisted in community coordination, relationship management, and ensuring all interactions and content were culturally appropriate. Together, we examined the 700 pages of probe results using inductive thematic analysis [14]. After reviewing the data individually and performing inductive coding, we met twice as a group to discuss potential themes, allowing opportunity for further reflection and iteration on our individual analyses. These discussions served as aids to our own reflexivity, in particular given the different relationships to, and levels of familiarity with, our study site. At the second meeting we agreed upon an initial set of themes to orient our analysis. We then drafted summaries for each theme, which became the basis for the Findings section of this paper. Physical distance constraints due to the COVID-19 pandemic as well as the subjective nature of interpreting cultural probe data posed unique challenges for the research team (discussed in Section 7).

5 FINDINGS

Gaver et al. [25] explain how cultural probes are not meant to be analyzed but rather reflected upon for speculative designs. Rather than producing a 'list of facts' [26], cultural probes are useful tools for understanding people's daily lives and routines. Our findings below take advantage of the interdisciplinary and differently situated knowledge of the research team to elicit themes from the cultural probes that portray the diverse needs and capacities of disaster-affected communities. Overall, our research demonstrates the need to consider emergency shelters from more broadly than as physical structures for temporary occupation by disaster-affected people. Though participants did raise many suggestions about the physical design, layout, and management of shelters, we focus here on several topics that have received less attention in the research and practice regarding emergency sheltering.

Activity Number	Activity title	Activity Description
1	Superpowers and special resources	What would you say are your superpowers and other resources that you could bring to your community before, during or after a disaster?
2	Support network	Identify people or organizations you would turn to skills, resources, and information needed to get through an emergency
3	Words of support	Write a note of support thinking of a person who is in a difficult situation. In addition, include tips that you consider useful to overcome a difficult moment.
4	Care routine	Design a "routine board" that lists the activities or care tasks that you put into practice to meet the needs of the person(s) you care for.
5	Emergency items	Take photos and provide explanation of items that you would bring with you so that you could take care of yourself and your family in a shelter.
6	Menu designs	Design a menu for you, your family and close friends. Imagine that they are meeting to celebrate a special occasion.
7	Sources of information and trust	List sources of information that are most significant to you in keeping you up to date with news, important events and the latest details of what is happening in your community.
8	Short story	Write a short story or personal account about a natural event that has had the most impact on you, how you adapted, and what you would share with other people in your community.
10	Community map	Draw a map of your community where you include and identify a location for a shelter, your home, and local landmarks of your community.
11	Shelter designs	Imagine that a shelter would be the safest refuge for you during a disaster. Draw and describe the most important features and services your shelter should have.

5.1 Mental and emotional health

Disasters are immensely stressful for impacted [35]. Though this is widely accepted, official disaster management planning often under-resources or outright ignores mental health issues [8]. Providing psychological support, in various forms, as part of emergency shelter management can help in coping in the aftermath as well as build community resilience to future disasters. We identified three categories of mental and emotional support themes raised by participants in their responses to the cultural probes: self-care practices, support through religion, and support through community.

First, participants frequently mentioned the importance of various forms of self-care practices in supporting the mental health of shelter users. For example, in Activity 3, participants were asked to write short letters of support to an imagined person impacted by a future disaster. Many letters advised healthy physical habits to help cope with the stressful situations such as "eat well, exercise, go for a walk, sleep, go to bed and wake up at the same time," and meditative practices such as "relaxation exercises: breathe deeply in through the nose, exhale from the mouth". Within this theme, the mention of nature was quite common, with multiple participants advocating for outdoor activities to overcome hardship (once the immediate threat of the disaster had subsided). One participant recommended to "visit the beach and relax with the waves of the sea" while another suggested "listening to music, getting in contact with nature and quiet places". Some participants advocated for art and craft-based activities as an effective coping mechanism with suggestions of decorating the shelter with drawings of nature and other art, and listening and playing music. Shelter designs from participants included nature through a recreational lens with suggestions of having shared outdoor spaces and community gardens, as well as harnessing natural resources such as solar power and rainwater collection systems.

Second, religious themes were prevalent in responses to prompts pertaining to emotional and community well-being. Sentiments of community support were communicated through religion as one participant stated within the letters of support exercise (Activity 3) that, "God and I are here for you". In Activity 3, 'prayers' and 'trust in god' were recurringly brought up as psychological support systems. Multiple participants also identified churches as viable places for refuge as a shelter in disaster. Figure 1 shows how churches were recognized as important community centers and depicted as potential shelter locations within the community mapping exercise (Activity 10) from multiple participants. In the social network mapping exercise, religious figures were identified as critical resources for mental health and emotional support, as well as leadership during disaster. One participant stated that they look up to the pastor for 'advice' and for 'managing their fear'. Other participants brought up the wider community of fellow church attendees as sources of 'spiritual aid and support'.

Lastly, connections to, and feelings of, community was raised by many respondents. Friends, family, and members of the community were identified as resources for emotional support and solidarity. Many participants discussed the importance of shelters hosting or supporting communal activities such as playing games, sports, eating and praying. Participants suggested community centers as possible shelter locations in Activity 11, and, as shown in Figure 2, almost all drawings of shelter designs from the probe included communal spaces with designated areas for entertainment, TVs, play etc. highlighting the tightly knit social fabric of the communities that partook in the cultural probes. The social fabric also extended

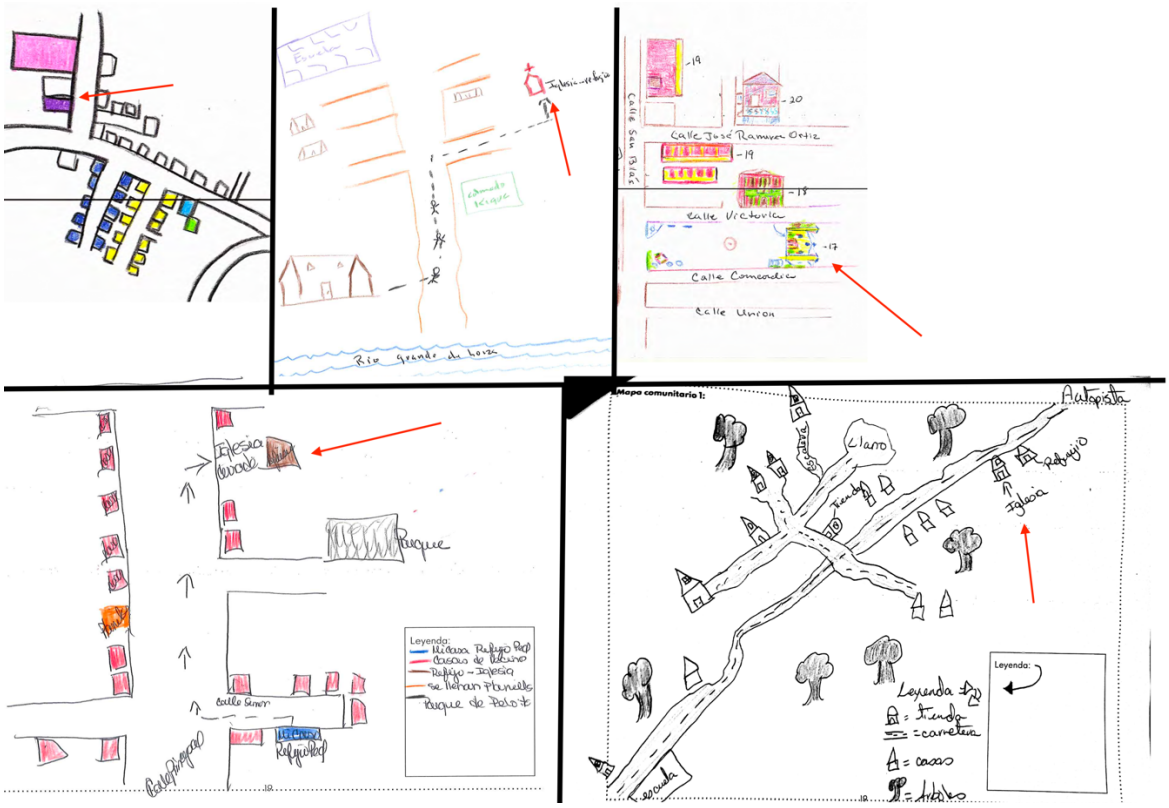


Figure 1: Responses to Activity 10 – Community Map. Notations to identify churches added by research team.

past the participants' immediate locality. In multiple activities, participants also brought up the importance of being able to connect to people outside the disaster affected areas, and in particular, being able to reach out to friends or family in the mainland United States.

5.2 Skills, knowledge, and resources of communities

Our findings reinforce the need for shelter management planning to treat members of the public as skilled, knowledgeable, and resourceful during moments of crisis [13]. This supports prior disaster research that has demonstrated that people often behave rationally and creatively as they cope with the impacts of a crisis [62]. For example, in Activity 10 we asked participants to draw main features of their community including their home and other important infrastructure, locate hazardous areas, and identify potential shelter locations. The resulting maps, as shown in Figure 3, demonstrate intimate knowledge of local environments, including shared understanding of past hazards across many of the maps, general agreement about possible sites for shelters, and other details that may not be obvious or accessible to formal emergency responders arriving in the communities from other places. These findings thus help to reinforce the importance of local knowledge and community participation in disaster management, and emergency shelter planning in particular [55].

In addition to their own knowledge, our respondents also prioritized seeking out other reliable information about disaster impacts and recovery processes [45]. Activity 5 in our cultural probe asked participants to take photos of household items they would pack in their emergency kits to bring with them if they were forced to leave their home and write short descriptions of the purpose of each item. Every kit included the participants' mobile phone for communication and information seeking needs. In Activity 7 (Figure 4), participants were asked about where they turned for information in disasters. Here, local social networks were the most cited source of information during a crisis, with emphasis on friends and family being a source of news. Community groups were also brought up as reliable sources of information with one participant mentioning "women groups" and "community members". Interestingly, only a few participants mentioned social media as an information source, though one participant mentioned the necessity of a computer in a disaster shelter. We hypothesize that the age profile of the participants, rural nature of the chosen communities, and limited connectivity to the internet during prior disasters may to some extent explain this finding. Overall, we found that participants were thoughtful of information sources and had a deep local understanding of ways to receive credible information.

In addition, responses to the cultural probes highlighted the role of community in providing skills and resources through material and financial support. For example, in Activity 2 (Figure 5), where participants mapped their support network, it was frequently mentioned

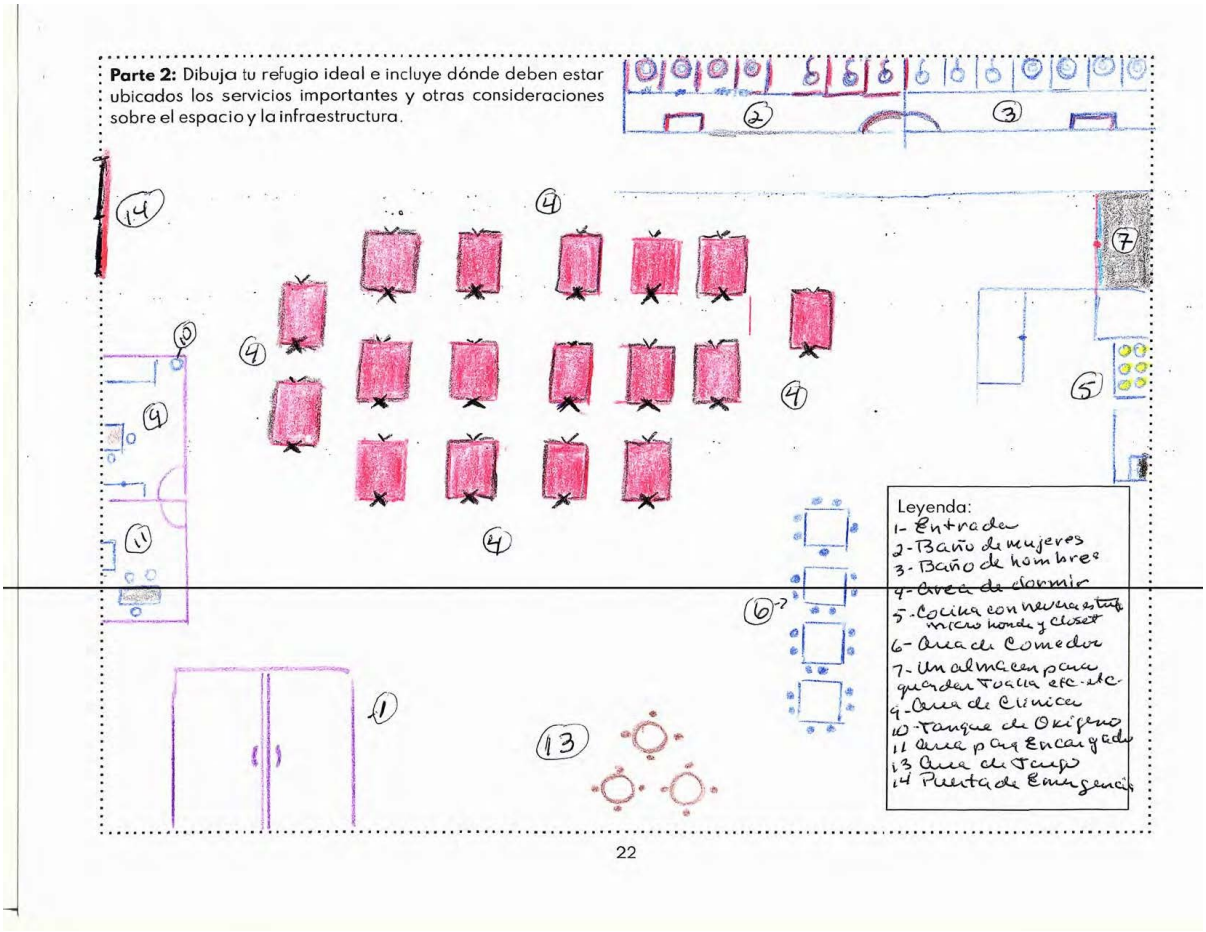


Figure 2: Sample Response to Activity 11 – Design Your Ideal Shelter. Participant shelter drawing showcasing communal space allowing for a variety of activities.

that they looked to friends, family, and neighbors for assistance in running errands such as picking up medicines or looking after vulnerable groups such as children and elderly relatives. Participants listed community members whose skills would be beneficial in a disaster, such as friends working for the police force, nurses, and people with organizational skills for shelter management. Participants also identified connections from their own networks who were familiar with the processes needed for a community to function during a crisis, such as, being able to repair/fix infrastructure, where to go in emergencies, ability to function heavy machinery to clean up debris, fix blocked or damaged roads, or remove downed trees. Others mentioned the need for assistance with transportation identifying individuals from the community from who they could borrow cars or ask for rides. Few participants recognized members of the community who had access to generators for electricity needs. These findings illustrate that such communities, though adversely affected by crisis, are quite aware of who to communicate with for particular skills and resources.

On the whole, these findings affirm and provide detailed illustration of prior research that underscores the importance of strong localized expertise in shelter design [55] and overall community resilience to disaster [2]. While local NGOs and community leaders are looked up to in crisis situations as sources of information as well as for resource aid and distribution. Our findings rather highlight the immeasurable capacity the community itself has and the skills, knowledge and resources it can provide after disaster. These blur the strict dichotomy between formal responders and community members, so often a challenge in emergency management situations where first responders are not part of the community and point to a potentially significant source of local resilience in the locations we studied. Effective shelter planning, and emergency management practice overall, should therefore account for how local communities share skills, knowledge, information and resources. We put forward that these local community assets (skills, knowledge, information, and resources) as well as practices of sharing these assets should be prioritized by and called upon by formal responders during shelter planning and their management.

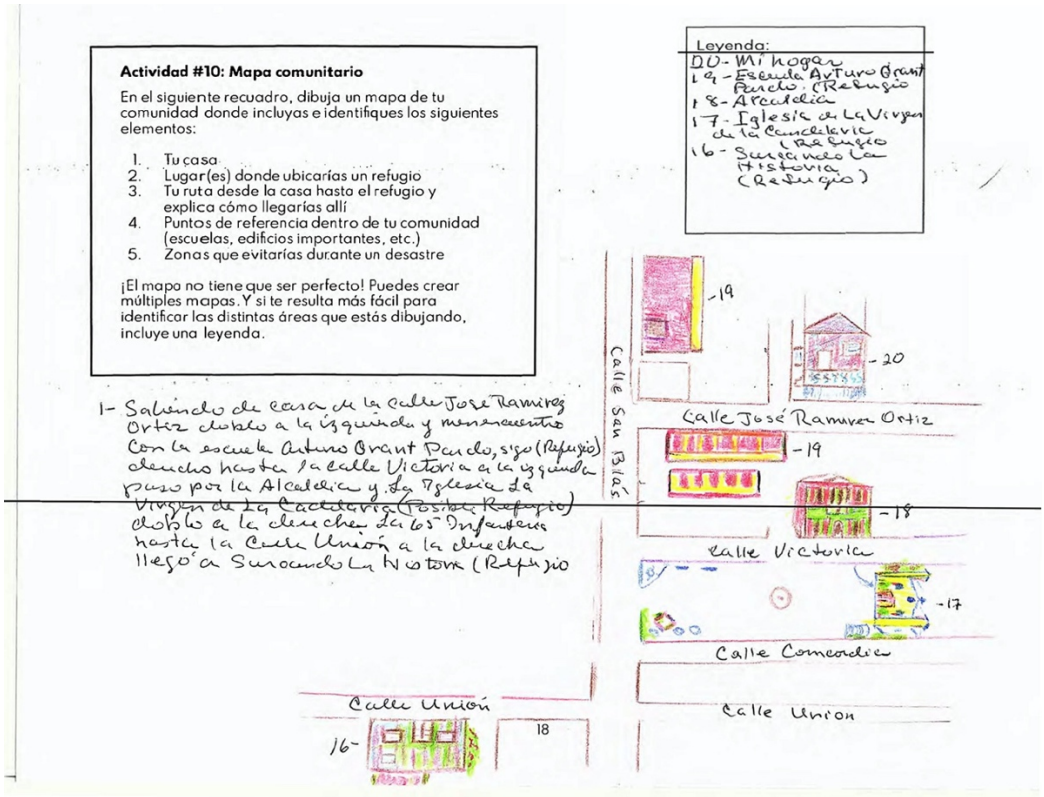


Figure 3: Sample Response to Activity 10 – Community Map. Participant drawing of the community, highlighting areas of potential shelter locations and demonstrating intimate knowledge of the locality.

5.3 Staying busy and being able to help

Though disaster response and shelter planning often assume passive populations, participants expressed the importance of staying busy through engagement with the community as a means of coping with the stress of a disaster across their responses to many of the activities. In various ways, they highlighted that being able to maintain a routine through daily habits and recreational activities help in bringing back balance and order to the lives affected by crisis. For example, in the letters of support activity, one participant mentioned the importance of having a daily schedule, while others recommended recreational activities like 'arts, crafts and games.' Shelter designs drawn by participants as part of Activity 11 often included spaces to do 'exercises, walk and yoga' and outdoor recreation areas. Few participants included productive activities such as growing vegetables in a garden and environmental education workshops in their shelter designs (Figure 6). Similarly, within Activity 4 (Figure 7), where participants listed out their daily routine as caretakers, we found daily schedules filled with productive activities such as cooking, exercise, household chores and giving company to the elderly and children. Our findings highlight that shelter designs should incorporate the means for people to stay engaged through either recreation and/or productive activities.
Relatedly, participants expressed the importance of being involved in recovery processes, and helping others, as an especially valuable means of keeping busy. In the words of support letters (Activity 3), one participant recommended "help others to feel useful", while another suggested that individuals "join a community relief organization." Shelter designs in Activity 11 were thought of more than just spaces for physical facilities with most designs containing designated areas for psycho-social support. Designs from multiple participants included means for cultural programming and continuing education. Here, involving members of the community in shelter planning and management would seem to support both broader resilience goals, but also support a sense of agency amongst people impacted by disasters by giving them the opportunity to contribute. Such sentiments support the arguments of seeing disaster affected communities more than incapable disaster victims but rather productive and essential assets to the crisis response.

5.4 There is no "typical" disaster evacuee

One striking aspect of the probe results was the great diversity of individual needs, capacities, and past experiences during disaster. For example, participants' evacuation kits (Activity 5) contained a wide range of medicines, equipment, and tools necessary to sustain daily activities. People's daily routines (Activity 4) were full of both friends and family members in need of different forms of care, while people's social networks (Activity 2) had many skilled professionals and individuals with prior experience in disaster recovery. In their shelter designs, (Activity 11) participants expressed varied preferences and desires on how they would like to spend their time

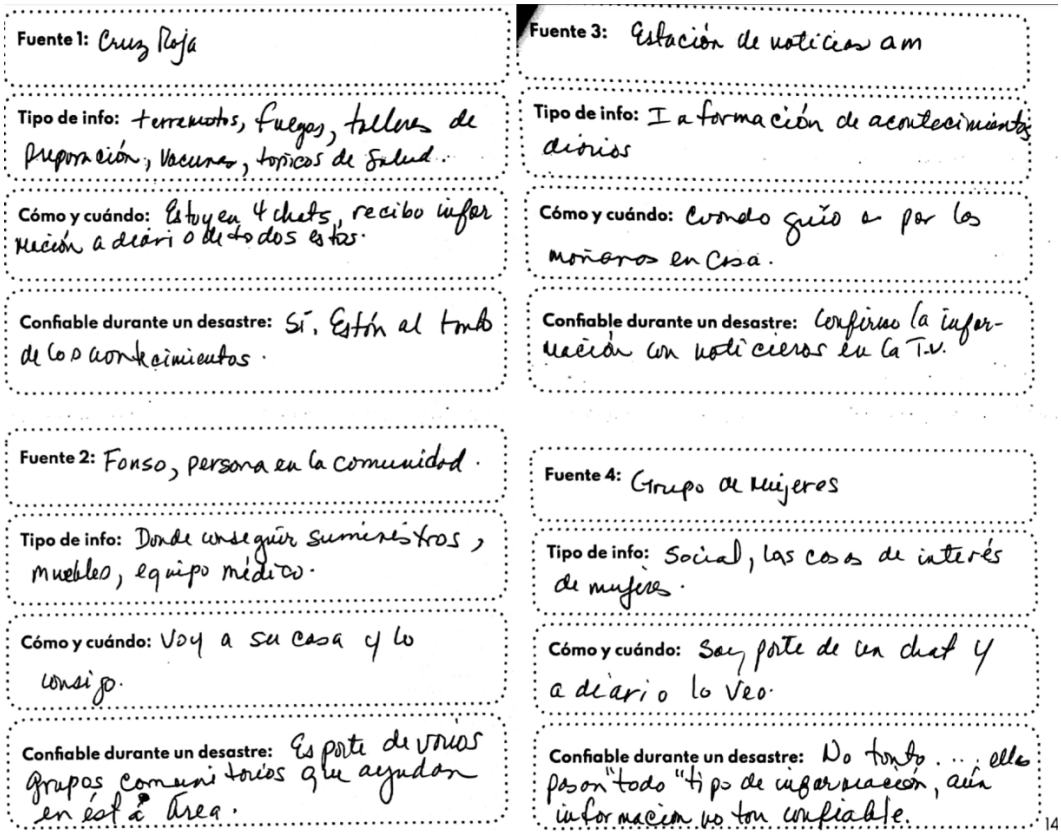


Figure 4: Sample Response to Activity 7 – Sources of Information and Trust. Participant listed local Red Cross, a women's group, local media, and personal connections in the community.

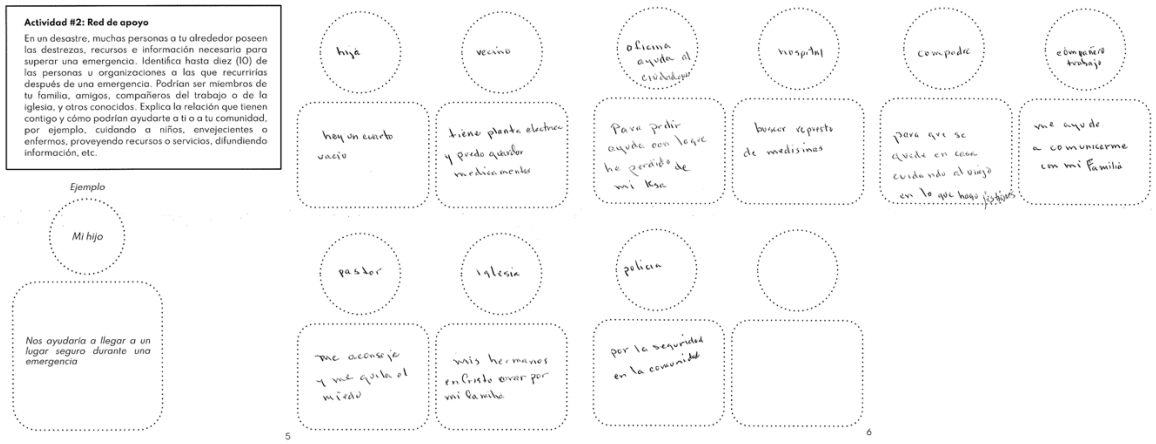


Figure 5: Sample Response to Activity 2 – Describe your support network. Participant mentioning family, friends, and community members as part of their support network in times of crisis.

within and around a disaster shelter. Each design included an assortment of elements consisting of basic shelter needs, comfort, the contextual environment, communal space, support for vulnerable groups, accessibility, education, and entertainment. Figure 8 presents this diversity found in the shelter designs from selected participants. This meta-finding points to one of the more significant challenges to shelter planning and management, whether formal or community-based. Efforts to standardize shelter plans for an

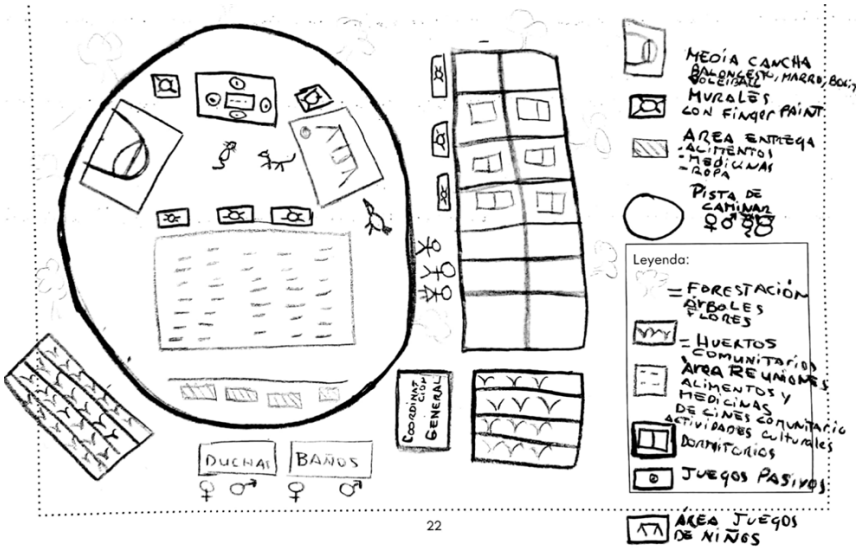
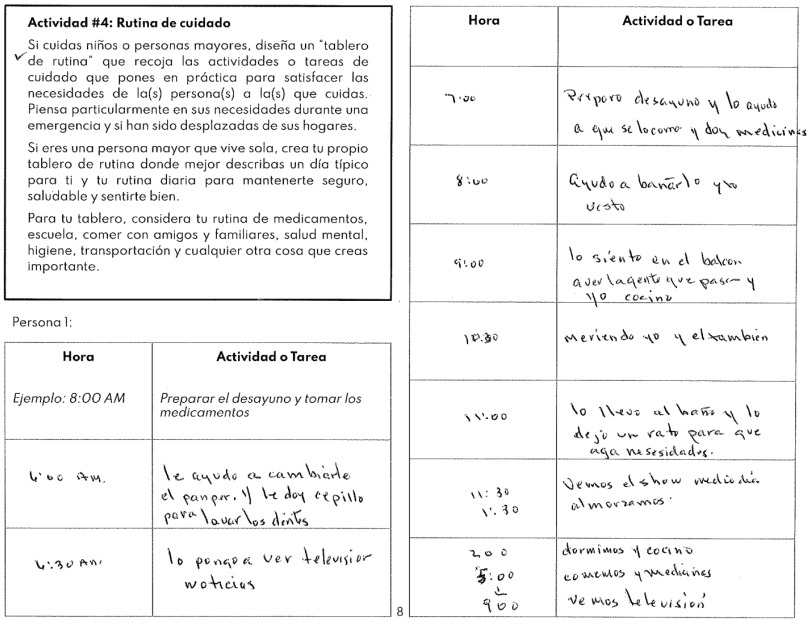


Figure 6: Sample Response to Activity 11 - Shelter design with outdoor spaces for gardening.



Actividad #4: Rutina de cuidado

Si cuidas niños o personas mayores, diseña un "tablero de rutina" que recoja las actividades o tareas de cuidado que pones en práctica para satisfacer las necesidades de la(s) persona(s) a la(s) que cuidas. Piensa particularmente en sus necesidades durante una emergencia y si han sido desplazadas de sus hogares.

Si eres una persona mayor que vive sola, crea tu propio tablero de rutina donde mejor describas un día típico para ti y tu rutina diaria para mantenerte seguro, saludable y sentirte bien.

Para tu tablero, considera tu rutina de medicamentos, escuela, comer con amigos y familiares, salud mental, higiene, transportación y cualquier otra cosa que creas importante.

Persona 1:

Hora	Actividad o Tarea
Ejemplo: 8:00 AM	*Preparar el desayuno y tomar los medicamentos*
6:00 a.m.	le ayudo a cambiarle el pampar. y le doy cepillo para lavarlos dientes
6:30 a.m.	lo pongo a ver televisión noticias

Hora	Actividad o Tarea
7:00	Preparo desayuno y lo ayudo a que se locome y doy medicinas
8:00	Ayudo a bañarlo y lo viesto
9:00	lo siento en el balcon a ver la gente que pasa y yo cocino
12:30	merendo yo y el tambien
11:00	lo llevo al baño y lo dejo un rato para que aga necesidades.
11:30 1:30	Vemos el show mediodia almorzamos.
2:00 5:00 9:00	dormimos y cocino comemos y medicinas vemos televisión

8

Figure 7: Sample Response to Activity 04 – Care Routine. Participant care routine consisting of productive activities such as cooking, chores, and care for elders.

imagined universal, or idealized, user will inevitably risk failing to meet the needs of some individuals. More perniciously, such standardization risks the marginalization of certain people, and perhaps those from groups who are most vulnerable to disaster. Implementing solutions that attempt to encapsulate the diversity and complexity of effected populations and their relationships with each other, and the environment can be time consuming during sensitive moments of disaster relief. Responsive shelter design, discussed in Section 6.2, is a potential way forward order to meet the wide range of needs that shelter users express.

6 DISCUSSION

Based on our findings, we contribute three implications for future HCI research and design into emergency shelters.

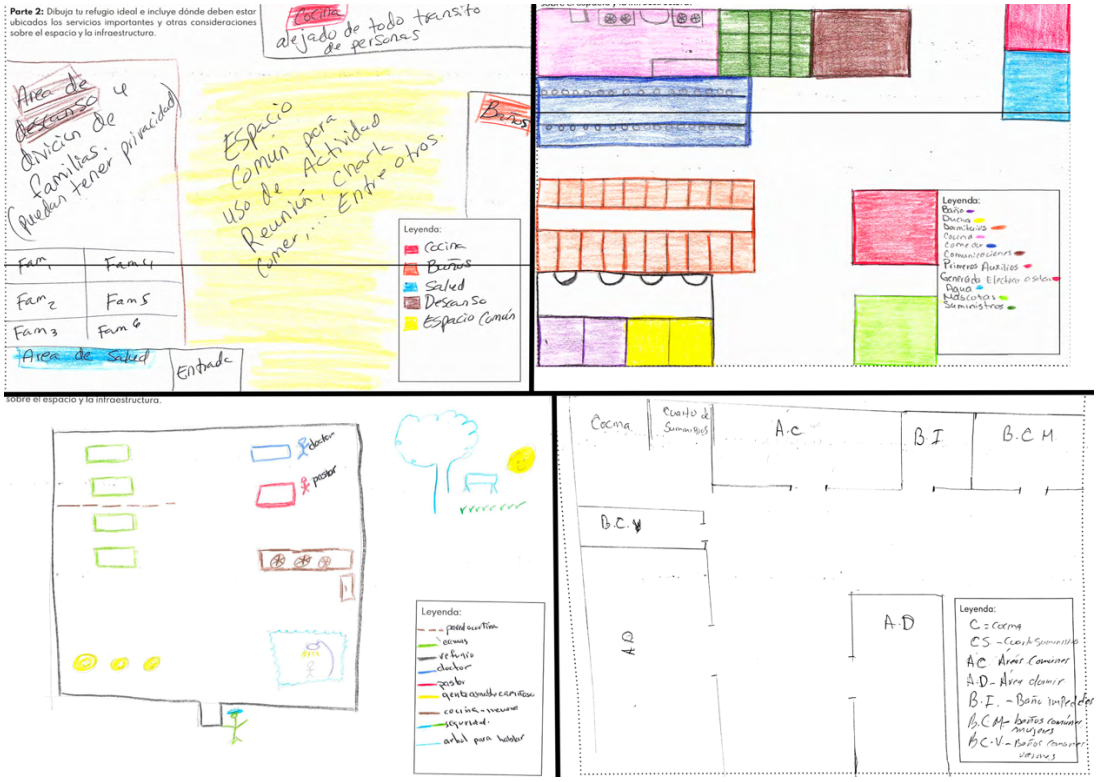


Figure 8: Sample multiple responses to Activity 11. Four separate responses to shelter designs, showcasing the diversity of requirements and needs of crisis impacted populations.

6.1 Shelter as an Information and Coordination Challenge

First, our findings demonstrate that many of the challenges of providing emergency shelter during disaster can usefully be viewed as problems of information and coordination. As with our other arguments in this paper, this view broadens the problem space of sheltering beyond an issue of identifying and maintaining an adequate physical space to house people displaced by disaster. As confirmed by our research, disaster-affected people rely on diverse and wide-ranging socio-technical infrastructures to find and share information and stay connected to friends and loved ones both within and outside of impacted areas. Infrastructures such as strong local community networks and their support mechanisms, religious buildings, local arts and culture, public spaces, and access to information, supported by the activities of people to use, maintain, and repair them in emergencies are potential targets for HCI research and design. This framing connects research on emergency shelters to core concerns in the field of crisis informatics, which has generated numerous insights into how disaster affected communities use ICTs to seek and distribute information and resources during emergencies [45].

For example, the process of acquiring, analyzing, and sharing data, well-known challenges in HCI, are needed to support decision-making around logistics, supplies, and cooperation that is crucial to effective shelter management. Shelter managers, whether formal or informal, face tremendous time pressure and uncertainty to allocate scarce resources and coordinate across disparate groups and individuals [31]. Their operations can be further impeded by damaged communication, energy, and transportation infrastructures in the wake of disasters. Furthermore, information needs also vary across different stakeholders in ways that HCI research may help to illuminate. For example, shelter managers need a variety of information to perform different tasks at different phases, including generating early warnings, identifying shelter locations, evaluation of disaster severity, and distribution of relief actions and supplies [75]. Other actors in sheltering, such as agency officers, require access to disaster situations, and knowledge about the availability of staff and resources, and philanthropic entities require assessments of communities' needs in order to target overall funding strategies. In sheltering, as in most crisis response operations [45], the need to gather, analyze, and share timely, comprehensive, and reliable information is paramount.

As our research showed, affected communities face their own information and coordination challenges in disaster, but also have significant resources and local knowledge to bring to bear. Studies have found that challenges around disaster information and knowledge management lie with risk interpretation and understanding, mentalities across scales, power structure, personal attitudes, values, and other constraints across individual, community, and agency

levels [9] [40] [63]. Due to many of these barriers, a key component of disaster information— local knowledge and practices — has not yet been adequately incorporated into the official channels of disaster management [16] [41] [42]. While the importance of local knowledge has been widely recognized and advocated in relation to disaster, particularly for the most vulnerable populations, the practical application has so far been limited[18] [41]. Sabie et al [55] identify the opportunity for HCI research to make a contribution to this agenda, including "tools to provide instruction on techniques such as site preparation, safety, weather proofing, etc, and for capturing and preserving lessons learned within each community", and note that these tools "need not necessarily be digital", but further development is necessary to meet this potential.

6.2 Designing for the whole person during disaster

Another argument that arises from these findings is the need for designers and managers of emergency shelters, formal and otherwise, to attend to the broad range of needs of impacted people. Here we draw on the dictum to *cura personalis* or "care for the whole person" in humanitarian response [54]. Beyond immediate needs related to physical health and safety, participants in our study expressed the need for, amongst other things, psychological and religious guidance, community, and a feeling of agency. This aligns with other research in crisis informatics that has identified the value of emotional support and personal relationships to disaster recovery [21] [59]. Though emergency shelters are typically intended to be used for a time period ranging from overnight to a few days, in practice affected people often spend significantly longer amounts of time in them [49]. Indeed, many "temporary" or "transitional" housing structures built during moments of crisis become permanent homes for their residents [55]. We argue that this necessitates a more comprehensive view. Despite their importance, as with any sort of assistance to impacted communities, providing these forms of care is risky and may lead to or sustain unhealthy power dynamics [21] [31]. Nor can they be separated from broader structural patterns of race, coloniality, and economic inequity [43].

As an example, our findings suggest the opportunity for crisis informatics to draw upon HCI research into games and leisure, both digital and analog, as a means of supporting disaster-impacted communities. Though often overlooked and easily dismissed as a trivial concern when compared to issues such as physical safety and basic resources like food and sanitation, HCI research has revealed the value of such activities in dealing with stress and trauma and building social capital [5] [7] [11]. Our study reinforced these arguments, with participants frequently raising the importance of being able to engage in play, games, arts and crafts, music, sports, and exercise as a means of diversion and personal agency. Games aid in alleviating stressful situations by being a means of escape and distraction [7]. This escape in turn creates other opportunities for engagement and social interaction and offers a productive outlet for individuals to seek and find relief from psychological stress. Games and leisure also help in inculcating a sense of agency, competence (efficacy) and autonomy, all of which are difficult to instill within a community which has just recently experienced disaster but are critical to recovery [7].

Responsive shelter design, which considers an array of specific population needs, is necessary to accommodate the varied needs of shelter users. For example, recent efforts to design "Child Friendly Spaces" in shelters have sought to provide children "a sense of safety, structure, and continuity in the midst of overwhelming experience [58]." These spaces can offer recreation, parental respite, and a distraction from the upheaval of a crisis. Designing for children is highly sensitive, and HCI research has identified a range of challenges and ethical concerns that arise when working at the intersection of children's needs and displaced communities [4] [30]. Nonetheless, buffering the impact of a disruption for children can help keep them on a positive trajectory and help prevent regressive behaviors often associated with traumatic stress. Various models exist and can be locally adapted to staffing availability, access to materials and resources, and required capacity and shelter utilization [52]. On a whole, responsive shelter design incorporates the contextual social, political and environment variables of a region in creating shelters that are adaptive to the situation and inclusive of the impacted population. Understanding the positionality of vulnerable and marginalized groups within society is therefore vital for effective responsive shelter design [13]. In addition to children, HCI research could contribute to understanding the needs of groups including the medically fragile, women, people with disabilities, access, or functional needs, those without transportation, elders, and orphans during shelter planning and management processes.

6.3 Assets-based design

Our research suggests that assets-based design may be a valuable approach for researchers and designers working with communities who are vulnerable to, or impacted by, disaster. Within recent HCI research, asset based design [71] [72] has been identified as a viable design approach for resource-scarce communities and vulnerable populations [50]. Disaster shelter environments, often confined by limited access to external resources, mirror the contexts of studies that have advocated for assets-based design. The culture-in-action theory [64], wherein cultural tools (skills, beliefs, language, stories, art etc.) are unpacked as a way for strategic action and capacity development, is the primary lens through which assets-based design identifies available capacity of a community [71]. Assets-based design proposes that "design should start from a deep understanding of people's current assets" rather than their perceived needs or limitations. This creates space for designers and their community partners to explore non-deficit-based directions for intervention and empowerment and enables designers to use existing community assets and skills as resources for interventions.

Our findings reinforce the argument that people in disaster affected areas, though struggling to recover, are nonetheless creative and resourceful, and possess a strong desire to contribute to the community and take the lead in their own recovery processes [62]. Through the cultural probes, we found significant evidence of available material, knowledge, and social networks of an affected community. Together, these resources suggest that effective shelter plans can be designed based on the existing assets of vulnerable communities. Some of the assets in our field sites in Puerto Rico included the use of technology (radio, television), skilled individuals, and presence of strong social networks that enabled personal connections

for wellbeing and immediate aid during disaster response. Assets-based design strategies could harness these resources to supplement or further enable the activities that communities already during disaster do in the form of informal or emergent response. This strategy would center and place value on existing day-to-day activities and community priorities as well as leverage existing assets and resources (physical and social infrastructure, skills, knowledge, networks, and environmental) of the community in focus [50].

Resource-constrained contexts, such as disaster-affected communities, face challenges and high costs in deploying and sustaining additive, external, interventions (needs-based design) [50], but alternatively provide a rich environment for assets-based design. The social and infrastructural constraints set in crisis affected communities, makes way for design opportunities that empower the impacted people by utilizing existing resources and cultural tools resulting in reduction of the learning curve for adoption (thereby increasing community resilience). This approach to design may particularly contribute to supporting informal emergency sheltering activities where affected communities must initially rely on their existing resources and processes while awaiting the potential arrival of external aid. As each community possesses a unique set of resources, the sorts of interventions that an assets-based design approach may suggest are not universal solutions but will instead vary from location to location [54].

7 CULTURAL PROBES AS RESEARCH TOOLS IN LOW RESOURCE ENVIRONMENTS

This project sought to use cultural probes as a way of including local knowledge into the design, planning and management of emergency shelters. In the context of complex hazards, accounting for local knowledge can help agencies improve their disaster management planning, as well as project effectiveness, acceptance, ownership, and sustainability [18]. Participatory research approaches, including cultural probes, acknowledge local communities and residents as the primary actors, providing an entry point for promoting local people's participation with "higher-level" disaster management entities that already have a comparative advantage. Therefore, though there are many challenges to the documentation and use of local knowledge in disaster management, working with communities to integrate their knowledge has the potential to serve as an effective tool for improving shelter management and building overall disaster resilience [41] [63]. While our participants were not emergency managers, or experts in shelter planning, they have experienced disasters before and have important knowledge about their communities' needs and were therefore able to provide valuable insights for shelter planning processes.

Our probes were designed to elicit findings that help to expand the design space in which shelter planners work and construct a rich understanding of participants' lived experience of thorny and personal concepts like safety, shelter, and danger. They can also illuminate issues or other ideas that may be missed through more narrowly targeted research approaches. In this case, they did seem to suggest a broader set of considerations as well as a much more capable and resourceful group of users than shelter planners typically account for. Cultural probes thus demonstrate a critical potential for other areas of work. As shown here, they have the potential to reframe difficult topics, and expand or challenge taken-for-granted problem formulations. Disaster response, along with related areas such as international development and sustainability, is full of such challenges that cultural probes may contribute to in a similar fashion.

However, the time and effort needed to evaluate cultural probe results is significant [26]. This approach also relies on different methods and sensibilities than researchers or planners would draw upon to assess more narrow or quantitative research instruments. It was unfamiliar to some members of our research team and collaborators, and so required additional attentiveness and care in both evaluating and communicating the results. Further development of the specific cultural probe we deployed may provide both communities and formal emergency response organizations with a better way to understand the desires of the people who may be in the extreme circumstance of needing shelter when no safer alternative exists. Such a process would not only help plan for more contextually appropriate sheltering processes but also create an opportunity to build trust between all stakeholders. However, partner organizations, community groups, and disaster planners would require sensitization, training, and resources to use these tools effectively. Given the constraints imposed by physical distancing due to COVID-19 and uneven and unequal access to electricity and technology, many standard approaches used to facilitate participation in design processes such as in-person workshops, design charrettes, or online crowd-sourcing techniques were either not possible or insufficient at the time of this research. Working with partners in Puerto Rico, we were able to develop a series of cultural probes that could be safely mailed or delivered to residents and community-members in the project area and collected after one week. The strength of the results suggest that similar approaches might be used to support participatory research processes in other contexts where internet or mobile connectivity is low, and communities are difficult to access. Further research is therefore warranted to explore the use of cultural probes as a method for integrating community knowledge and information for other challenges in crisis and emergency response.

8 CONCLUSION

The economic, political, and historical factors that shape Puerto Rico's vulnerability to natural hazards are shared by many parts of the world. By many measures, disaster vulnerability is growing worldwide as a result of climate change, unplanned urbanization, and rising inequality [69]. Thus, efforts to augment and improve societal capacity to cope with disaster will only increase in coming years. This research, by deploying cultural probes, connects one of the core challenges in disaster response - the provision of emergency shelters - to HCI research in crisis informatics and several other areas. Our findings contribute to recent explorations regarding the usage of cultural probes in low resource environments [73]. They also unsettle dominant conceptions of shelter planning and management and point to several areas of future work for HCI researchers seeking to support communities facing disaster.

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