"It's like living a different life, going to the moon": Rethinking Space and Activity in the Context of COVID-19

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Abstract

The COVID-19 pandemic and preventive measures such as social distancing massively affected individuals' activities in different spaces. For example, social spaces such as restaurants, parks, and movie theaters are closed. To understand how adapted practices have changed the meanings and use of different spaces in the context of the pandemic, we conducted semi-structured interviews with 30 individuals living alone in a Midwestern state of the USA, focusing on changes in activities and spaces where these activities used to take place. Our findings revealed that non-technological (e.g., making slight adjustments, finding alternatives) and technological (e.g., transitioning to the virtual sphere) adaptation strategies changed the relationships between space and activity while reshuffling and decoupling activities from their usual spaces during the pandemic. Based on the findings, we propose a framework illustrating different space-activity dimensions to reflect the evolved relationships between space and activity. The framework will facilitate exploring associated challenges and opportunities for potential research and design of technology for adapted activities decoupled from the physical spaces. Towards that goal, we present design implications for future socio-technical systems to support adapting space and activities in the context of COVID-19.

Keywords: COVID-19, older adults, younger adults, framework, adaptation, space, activity, living alone

1 Introduction

> "I tried to buy bread, two or three times. There was no bread, not even the crappy bread. There was just nothing. So I decided to make my own bread. And I'll probably continue to do that. I would never have made my own bread. It's like living a different life, going to the moon." (P13, 2020)

COVID-19 is an unprecedented global public health crisis that has caused almost 4 million deaths globally (Worldometer, 2020), reduced global economic output by $90 trillion (Weiss et al, 2020), and dramatically altered the lives of billions of people worldwide. The personal, economic, and societal impacts of both the coronavirus and the mitigation measures (e.g., lockdowns, social distancing) taken to combat its spread are severe (Chakraborty and Maity, 2020). These circumstances result in a unique situation that has disrupted major aspects of human life, including social interactions, travel, work, education, religious services, volunteer activities, and caregiving (Center, 2020a).

Disrupted social activities led to isolation, loneliness, anxiety, and depression among different social groups, but those who live alone might have been affected disproportionately (Armitage and Nellums, 2020; File and Marlay, 2021; Brooks et al, 2020). People living alone tend to be more socially active and resourceful, with more diversity in their network, especially socializing and exchanging social support with friends, neighbors, siblings, and parents (Hooyman and Kiyak, 2008; Sarkisian and Gerstel, 2016). Hence, social distancing measures and lockdowns that limit or prohibit interactions with people outside of one's households have robbed solo-living individuals of the opportunities of in-person social interactions.

Globally, households are shrinking while more and more people are living alone (Klinenberg, 2013; Chandler et al, 2004; Demey et al, 2013; Jamieson and Simpson, 2013). According to the United States Census Bureau, around 37 million (15%) American adults age 18 and over live alone as of early 2021 (Bureau, 2021). There is a global trend towards solo-living among older adults age 65 and above (Nations, 2017; Center, 2020b). According to Pew Research, around 14.7 million (28%) older adults live alone in the USA (Ausubel, 2020). The rising trend of solo-living households is also evident among global south countries, such as India, Pakistan, Japan, Nepal, Myanmar (Ortiz-Ospina, 2021). Thus, we should explicitly consider the lifestyles of this major solo-living population while designing preventive measures for successfully managing the current and possible future pandemics. Most prior studies have explored the resilience and well-being of solo-living individuals as opposed to changes in their daily routines and activities in times of crisis (Fingerman et al, 2021; Bu et al, 2020; File and Marlay, 2021; Kamin et al, 2021). We need to build a holistic understanding of how solo-living individuals have adapted their regular activities (e.g., social visits, work, education, religious services, volunteer activities) in different spaces in response to a major event, like the pandemic. In this study, we endeavor to highlight the lifestyles and activities of the solo-living population in the USA during the COVID-19 pandemic.

While activities and spaces have traditionally been tightly coupled (Brown and Perry, 2002), COVID-19 has decoupled activities from their physical spaces. A few studies have explored how individuals, regardless of living arrangement, have changed specific activities, such as eating and food purchasing behavior (Zhao et al, 2020; Khubchandani et al, 2022), work (Kramer and Kramer, 2020; Newbold et al, 2022; Cho et al, 2022), education (Chen et al, 2021), etc., to address COVID-19 disruptions. Most of these changes have impacted the physical spaces where the activities have been performed. Spaces have been used in unprecedented ways; for example, people transitioned to attending funerals and memorials online from their homes instead of churches at the time of this study (Kühle and Larsen, 2021). Further, specific spaces, especially public spaces (e.g., restaurants, parks, theatres, etc.) posed risk of contagion (SAFE, 2021). Thus, the traditional meanings of home and public spaces have been impacted due to COVID-19. A more holistic understanding is needed to know how the relationships between space and activity have changed, how individuals have reconfigured activities and physical spaces, how the meanings and use of spaces have changed, what tensions have arisen due to these changes, and what the potential design opportunities are for adapted activities and spaces that might be beneficial in resolving tensions around changes.

In this paper, we investigate the following research question: How have the relationships between activities and their associated spaces evolved in response to the COVID-19 pandemic? To answer the question, we conducted semi-structured interviews with 30 individuals living alone in the Midwest of the USA. We recruited 15 older (aged 65 and over) and 15 younger (aged between 18 and 30) adults. The largest share of individuals who live alone belongs to these two age groups (Fry, 2017), thus, they are able to reflect lived experiences of the population living alone across different life stages.

We found that the relationships between space and activity evolved while the adaptation practices reconfigured, reshuffled, and decoupled most activities from their usual spaces in response to the pandemic. Adaptation strategies included (1) doing the same activity with small adjustments, (2) finding alternatives to existing activities, and (3) transitioning activities to the virtual sphere. In addition, the evolved relationship resulted in tensions around changes, such as the changing nature of social interactions, altered meanings of spaces in the home, and complexities of multimodal communication.

Our work reports on the findings that capture the nature of the evolved relationships between space and activity across multiple types of activities (i.e., personal, social, and professional activities) in public and private spaces in the context of the pandemic. Findings of this study contribute to the Human-Computer Interaction (HCI) and Computer-Supported Cooperative Work (CSCW) research in three ways. **First**, our work provides an empirical understanding of how relationships between activity and their associated spaces evolved in response to different adaptation strategies in the context of the pandemic: (1) making slight modifications to the existing activities

allowed continue with the same activities in the same spaces where they used to take place before the pandemic, (2) finding alternatives changed both activity and its associated space, and (3) transitioning activities to virtual spheres decoupled activities from their usual spaces in the context of the pandemic. In addition, we uncover tensions around adaptations, such as the changing nature of social interactions, home spaces, and the complexity of multimodal communication, created by the changes in the relationships between space and activity. The findings extend and complement the literature of crisis and collapse informatics (Pine et al, 2021; Soden and Palen, 2018) that focus on the role of technology in preparing, responding, and recovering from a crisis. **Second**, we develop a framework (Fig. 2) to illustrate the various dimensions of activity and space that have evolved due to changes in the relationships between them. The framework can be used to inform future research and design of socio-technical systems, with a focus on supporting adaptations. The framework complements prior work on the meaning of space (Dourish, 2006; Dourish and Bell, 2007), spatial practices (Certeau, 1984), and space-oriented design (Silberberg et al, 2013; Kao, 2021) by facilitating reflection on what activities decoupled from physical spaces mean for designing socio-technical systems to support activities. **Finally**, this work proposes design implications for future socio-technical systems to support individuals and communities in adapting activities and the associated spaces in the context of a pandemic, such as COVID-19.

2 Background

We build our understanding on prior work on space, particularly on the perception of different spaces, as well as on adaptation in times of crisis.

2.1 Space and HCI

Human-Computer Interaction (HCI) researchers have discussed space as a fundamental property of the three-dimensional world in which people live and interact. Prior work on space primarily has focused on conceptualizing the notion of space (Harrison and Dourish, 1996; Dourish, 2006; Low, 2009; Harrison and Tatar, 2008) and explored various interpretations of space and its relationships with place. Space is often defined as geometrical arrangements which mediate movement and interaction (Harrison and Dourish, 1996; Cresswell, 2004). When humans invest culturally shaped meaning and values through interactions with a space and form attachments with it, then it becomes a *place* (Ujang and Zakariya, 2015; Dourish and Bell, 2007; Harrison and Dourish, 1996; Turner and Turner, 2006). In their seminal paper *Re-placeing space*, Harrison and Dourish (Harrison and Dourish, 1996) differentiated between the concept of space and place: spaces are where "placeness could arise" and placeness is "created and sustained by patterns of use." Brown et al. (Brown and Perry, 2002) conceptualized place and space through the lens of activity. They suggested activity, space, and place are tightly coupled where

activities mediate between space and place. The conceptualization of coupled space and activity is significant to this study. This coupling has been affected due to the pandemic, as people have redistributed spaces and activities, changing the meaning of space, i.e., place. In this paper, we will not delve into the conceptual differences between space and place [1]. We are interested in understanding how individuals reconfigured space and activity while they adapted activities in spaces.

Ten years after their seminal paper *Re-place-ing space*, Dourish et al. revisited the notion of space and spatiality (Dourish, 2006). He envisioned space as a collective product created through shared practices and meaning-making. He highlighted technology and collaboration as critical elements for producing space. While technological developments offered opportunities to re-imagine everyday spaces, existing research focused on exploring how the concept of spaces evolved through technologically mediated spatial approaches (Benford et al, 1998; Jones et al, 2004). Benford et al. classified shared spaces according to the extent to which a group of users can access virtual objects from their local space (e.g., physical and virtual reality) and the extent to which a space is produced either synthetically or based on the physical world (e.g., augmented reality and telepresence) (Benford et al, 1998). When shared spaces integrate two spaces, i.e., physical and virtual, it is referred to as *mixed realities* (Benford et al, 1998). A musician simultaneously performing live in a physical theater and engaging with online audiences in a collaborative virtual environment creates a mixed reality experience by superimposing a synthetic environment onto the associated physical world. Thus, mixed reality promotes a new way to think about spaces according to their degree of spatiality (Dourish, 2006; Benford et al, 1998). Jones et al. introduced the P3 framework linking people to people to geographical places to facilitate designs for mixed spaces (Jones et al, 2004).

In addition, there exists research exploring alternative aspects of everyday spaces for certain lifestyle values (Cheon and Su, 2018; Smith, 2008). For instance, Cheon et al. (Cheon and Su, 2018) described how emerging lifestyles and practices of minimalists informed alternative aspects of space through the concept of *empty space*. The notion of alternative aspects of space is important to this current study as we examine the adaptation of older and younger adults' activities in public and private spaces during the pandemic situation.

According to Oldenburg et al. (Oldenburg, 1997), there are three types of spaces 1) home space, 2) workplace and 3) third place (i.e., informal public gathering places). People create their own meaning for spaces through their movements and activities in those spaces (Certeau, 1984). Home is defined as a space imbued with a sense of belonging, desire, and intimacy (Baldwin and McCracken, 2014). Home is a more personal and informal space that is not limited to daily activities at the house but also acts as a domestic and social zone fostering social relationships (Blunt, 2005). HCI studies set the

[1] For clarity, the term *space* will be used through out the rest of the paper.

home apart from the workplace and highlighted it as a place for technologies to support social connection and ludic engagement (Gaver, 2002; Kirk et al, 2010; Voida and Mynatt, 2005). Existing research also explored designing and assessing technological interventions embedded in the home (Crabtree and Rodden, 2004; Kozubaev et al, 2019), including interventions focused on overall space (Semsioglu et al, 2018) or specific areas (e.g., kitchen, closet, drawers, etc.) in the home (Paay et al, 2015). The emergence of smart technologies in the home space has blurred the boundary between private and social (Frissen, 2000; Woodruff et al, 2007). Aipperspach et al. (Aipperspach et al, 2008) presented the concept of *heterogeneous home* to establish different types of spatial boundaries at home; for example, boundaries between technology-rich and technology-free spaces. Beyond the traditional aspects of home, researchers have explored home space through the lens of religious practices (Wyche and Grinter, 2009), privacy issues (Radics and Gracanin, 2011; Garg et al, 2014), home entertainment (Ogonowski et al, 2013), and emergency situations (Erete, 2013). Desjardins et al. (Desjardins et al, 2015) identified seven broad perspective of domestic research, including *social routines*, *smart homes and automation*, *contested values*, *home as a site for interpretation*, and *speculative visions of the home*. Here, the perspective of *contested values* uncovers alternative configurations of home space that go beyond the common assumptions about the home. This perspective is relevant in our study as we examine activity patterns of individuals while they are confined to spaces, especially homes, in response to social distancing and stay-at-home orders.

On the other hand, the workplace is considered a more formal environment. In contrast with home space, people have different sets of values and practices associated with the workplace (Gaver, 2002). Existing research on the workplace primarily has focused on traditional workplaces, such as offices, factories, hospitals, laboratories, etc. (Schmidt and Bannon, 1992; Trace, 2011). CSCW and HCI research has primarily focused on exploring the roles that tools, artifacts, and technologies play within the workplace (Heath et al, 2000; Schmidt, 2009; Kao and Schmandt, 2015). For instance, Kao et al. designed a tangible artifact, MugShots, which enacts as a 'social catalyst' to trigger conversation and facilitate social interactions at the workplace (Kao and Schmandt, 2015). The emergence of information and communication technologies (ICTs) have enabled different ways of working outside a traditional workplace, such as working from home (Ciolfi et al, 2020; Messenger and Gschwind, 2016). Another body of existing literature explored nomadic work practices, such as working from anywhere/anytime (Perry et al, 2001; Ciolfi and De Carvalho, 2014; Choudhury et al, 2021; Su and Mark, 2008). For instance, Su et al. noted nomadic workers carry their resources to set up their temporary workspace anywhere and anytime (Su and Mark, 2008). In addition, prior research has noted how work practices, such as working from home, have blurred the boundary between home and work (Nippert-Eng, 2008; Harper, 2006). When domestic and work life becomes intertwined, individuals face difficulty maintaining and negotiating the boundary between family and work

lives, struggle to manage their productivity, and experience higher levels of stress (Cox et al, 2014; Ciolfi et al, 2020). To improve work performance, manage stress, and maintain work-life balance, people often create work-home boundaries (Salazar, 2001; Thomson, 2013). For instance, Salazar et al. uncovered relational and situational boundaries based on how individuals negotiated the time and space needed to work with other household members and how they maintained or blurred the boundary between work and home (Salazar, 2001). In addition, existing research demonstrated that categories of work-home boundaries can be physical, temporal, psychological, social, and digital (Cecchinato et al, 2017; Thomson, 2013). The concept of *blurred boundary* is relevant in our study as we investigate how activities of the social world that once were physically and temporally separated are no longer demarcated by physical spaces in response to the pandemic.

Lastly, the 'third place' describes other spaces beyond home and workplace (e.g., parks, neighborhoods, recreation centers) (Oldenburg, 1997). People perceive these spaces as informal and sources of community interactions. Urban studies in HCI have explored people's experiences and interactions with different artifacts deployed in public spaces (Schieck et al, 2007; Bennett et al, 2021). People's interactions with different technology in public spaces influence their perceptions about those spaces (Kao, 2021). The concept of public communal space, third place, is crucial for individuals living alone, because the sociability of people living alone more heavily relies on their everyday life flows in public places and events (Roseneil and Budgeon, 2004). They are more inclined to socialize with strangers in public space to feel connected amid social distancing (O'Connor, 2020). We believe technology could foster the changing ecosystem of social interactions in public space. To better support the design of such technologies, we need to unpack how solo-living individuals' relationships with public spaces have adapted in response to the pandemic.

Existing literature in HCI and CSCW posit that individuals' activities and spaces are tightly coupled and their interactions define the meanings of spaces. However, the COVID-19 pandemic and resulting disease mitigation measures have impacted individuals' relationships, interactions, movements, and activities in different spaces. In addition, spaces have posed threats in new ways, especially when other people are present. As a community, we need to understand the impact of COVID-19 on the use, perception, meaning, and design of space. We need to rethink the concept of space and its entanglement with activities when adapted activities decouple from their physical spaces in response to the pandemic. Therefore, in this paper, we explore individuals' adaptations to various activities in different spaces during the pandemic.

2.2 Adaptation to Crisis

Individuals change their behaviors in response to a crisis to maintain psychological homeostasis (Lei et al, 2014). Adaptations may include a range of behaviors, such as coping, goal-setting, problem-solving, and other attempts

to fulfill human needs during a crisis. Crises can be personal, where an individual needs to adapt to major changes in their life circumstances, health and social status, or social and physical environments (Massimi and Baecker, 2011; Kempen et al, 1999); whereas both individuals and communities have to adapt to societal crises, such as public health crises (e.g., COVID-19, Zika) (Hartley and Perencevich, 2020; Gui et al, 2017), environmental crises (e.g., natural disasters, climate change) (Patterson, 2015), inequality and marginalization (King and Carberry, 2020), economic crises (Kirman, 2010), and political crises (Offe, 1976).

Technology plays a vital role in preparing, responding, and recovering from crises. Existing research in HCI and CSCW has investigated the role and potential effects of information technology in dealing with changes induced by crises (Eriksson and Pargman, 2018; Tomlinson et al, 2013; Massimi et al, 2012; Bica et al, 2019, 2020). For example, Shahid et al. (Shahid et al, 2020) have examined the social media interactions of people in developing countries during a public health crisis to understand irregularities and challenges faced by individuals. They also investigated how government agencies and healthcare institutions can use social media data to inform policies during a crisis. So far, this body of literature has investigated the roles of technology in supporting communities and individuals in crises with common characteristics.

The COVID-19 pandemic is distinctive from other widely-studied crises, such as natural disasters (e.g., earthquake, hurricane, etc.) and public health crisis (e.g., dengue, Zika virus, etc.). Natural disasters are localized and caused disruptions for a short period (Bica et al, 2019). Prior public health crises were disruptive for the medium-term and restricted to a geographical region and demographic group. However, COVID-19 spread globally, created unique conflicts between physical safety and other values (e.g., in-person social interactions), and caused long-term disruptions. The impact of the pandemic has been profound in every aspect of our lives (Corbera et al, 2020). Disease mitigation and protective measures such as social distancing, self-quarantining, and restrictions on the use of public places have disrupted usual activities.

Researchers have studied how the unique context and characteristics of the COVID-19 pandemic make it more challenging for individuals and community to adapt to the crisis (de Haas et al, 2020; Das et al, 2021; Zhao et al, 2020; Kramer and Kramer, 2020; Chen et al, 2021; Sin et al, 2021; Heshmat and Neustaedter, 2021). Research studies focused on social activities have highlighted that individuals, particularly older adults, expanded their technology use to combat loneliness during the lockdowns (Sin et al, 2021). Although individuals initially enthusiastically experimented with pandemic-driven tools (e.g., video-conferencing tools, contact tracing applications, etc.), major impediments to long-term adoption of these technologies have been reported in the literature (Sin et al, 2021; Alharbi et al, 2021; Heshmat and Neustaedter, 2021). Heshmat et al. (Heshmat and Neustaedter, 2021) have pointed out that individuals experienced *technology detachment* due to the

lack of the desired level of control, participation, shared atmosphere, and physicality.

In addition, existing research has explored pandemic-invoked changes and adaptations in professional activities, such as work and education (Das et al, 2021; Teevan et al, 2021; Miller et al, 2021; Cho et al, 2022; Newbold et al, 2022). Although remote work is not a new concept, the rapid and mandatory shift of a significant portion of the workforce to work from home during the pandemic introduced additional challenges for workers because the change was abrupt, and many people were not prepared for the transition. Existing research investigated how the rapid transitions to work from home blurred the boundary between home and workspace and how they impacted individuals' well-being, work practices, and productivity (Cho et al, 2022; Guillou et al, 2020; Kaur et al, 2020). Individuals who lacked prior experience working from home had to reconfigure their home space to create a working setup, redefine their perspectives of home, navigate relationships among household members, and renegotiate boundaries between work and their personal/family life. Cho et al. showed that individuals enacted six types of boundaries such as spatial, temporal, psychological, sensory, social, and digital, to maintain, modify, and reconstruct their home's sense of place as a living space and a working/studying space during the pandemic (Cho et al, 2022). To support technology design for remote work in domestic settings, Newbold et al. investigated how workers adapted their routine and everyday practices to cope uncertainties of working from home (Newbold et al, 2022). Based on their findings, they proposed the New Normal framework that captures individuals' mentalities in response to the transition of work during the pandemic. According to the framework, individuals wait for the return of their old normal, develop a new normal of working from home, and anticipate a new future of work.

Existing research also explored how local communities adopted activities in third places (e.g., coffee shops, gyms, bars, parks, churches, etc.) to provide support with reduced physical contact in response to the crisis (Jo et al, 2021; Knearem et al, 2022; Roberts, 2020). Jo et al. (Jo et al, 2021) explored local communities' efforts to set up virtual spaces to complement physical third places in the era of social distancing. They highlighted how emotion sharing and interaction with others in virtual public places become more significant in more prolonged disasters, the pandemic. Researchers need to reimagine public spaces and explore opportunities beyond digital placemaking to accommodate meaningful social interactions in public places (Hespanhol, 2022).

COVID-19 is one of several crises that the world will face in this century. We have long been aware of other global threats (e.g., climate change, institutional collapse, etc.) (Brozus, 2020). As a community, we need to think about how we can design supportive technology for future global crises that can be easily adapted and deployed when the time comes. Towards that goal, in this paper, we unpack how individuals' relationships with home and public places have adapted in response to the pandemic and how technology could foster the adaptations.

3 Method

To gain a high-level understanding of the pandemic-invoked changes in space-activity relationships across multiple types of activities and spaces, we conducted a qualitative study with individuals living alone in a Midwestern state in the USA. The study protocol was approved by the university institutional review board (IRB).

3.1 Study context: The COVID-19 Pandemic

We conducted the study in a single state located in the Midwest region of the USA during the COVID-19 pandemic, specifically in the summer of 2020. In 2020, the novel and contagious COVID-19 evolved from an isolated disease in the Wuhan region of China into a global pandemic (Staff, 2021). With the alarming rate of spread around the world, the U.S. Center for Disease Control and Prevention (CDC) confirmed the first COVID case in the USA in January 2020 (Staff, 2021). Countries around the world took drastic measures to combat the outbreak of the virus, such as lockdowns, limiting all non-essential travel, etc. In the USA, the government declared a National Emergency in Feb 2020 and initiated federal and state-level plans ranging from *shelter in place* to *stay at home* orders. The state in this study was typical of many states, shifting to a five-stage plan imposing restrictions on business organizations, non-essential work activities, public places, and people's movements (Evans, 2020; Mosby, 2020). Public places, such as parks, activity centers, bars, restaurants, etc., were closed while non-essential work activities were shifted to home. People were allowed to go for walks, grocery shopping, and healthcare visits. However, older adults and immune-compromised people were advised to stay at home.

The study was conducted between June and July 2020. The state-level restrictions were gradually relaxed (in some cases lifted). During this time activity centers, restaurants, bars, and clubs were allowed to function at partial or full capacity (Mosby, 2020). People started to venture out cautiously following social distancing guidelines, while face coverings/masks were mandated in public places (indoor and outdoor) by the county government. Fig. 1 shows a timeline of key events and disease mitigation measures taken by the state and county government between February and July 2020.

We conducted the study over two months. There is a possibility that different temporal stages and restriction levels might affect participants' lived experiences of the pandemic. Further, the COVID-19 pandemic was in its infancy at the time of this study, and thus an individual's lived experiences might still evolve due to measures, such as vaccinations, which did not start to become available to the public until January 2021. In this paper, we provide findings from a particular time window of this prolonged crisis, which might have long-term consequences for individuals' lives.

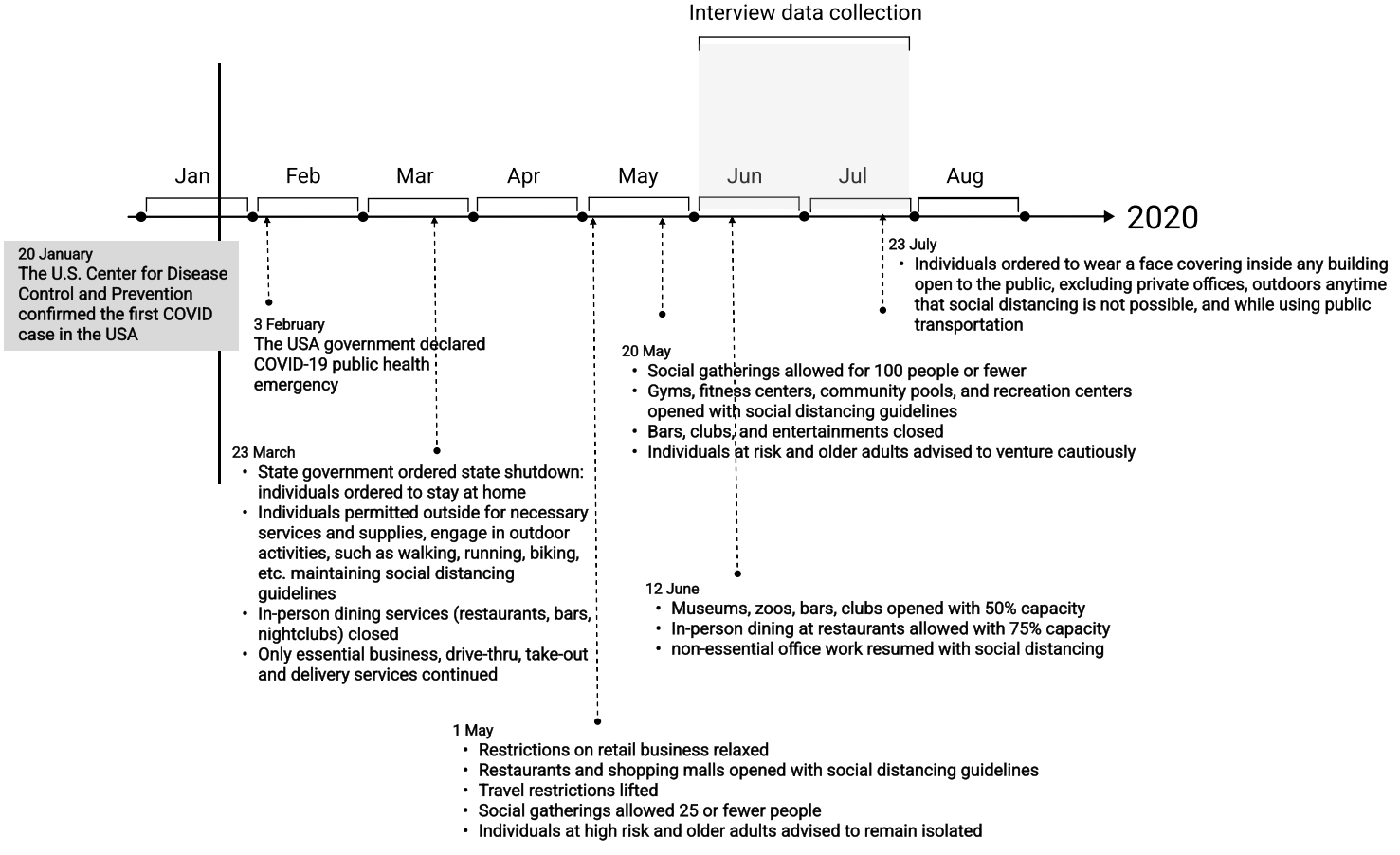

Fig. 1: Context of our study with a timeline of key events of the COVID-19 pandemic in the U.S. state where the study took place

3.2 Procedure

3.2.1 Recruitment

To examine the range of solo-living individuals' lived experiences across the adult lifespan, we recruited 15 young adults (ages 18 - 30 years) and 15 older adults (ages 65 years and above). Individuals within these age frames have a higher tendency to live alone, whereas, people with ages in between tend to live with partners/spouses, children, etc. We predetermined the number of research participants based on the local standards for sample size within the CHI community (Caine, 2016). Our analysis showed that we reached thematic saturation (Hancock et al, 2001) (i.e., data from the last interview transcripts do not lead to new codes or findings) within this sample size. To recruit participants, we disseminated our recruitment materials (e.g., digital flyers, social media posts, etc.) to local community organizations, neighborhood mailing lists, university mailing lists, and research volunteer platforms. We also adopted snowball sampling to recruit participants who met the inclusion criteria and were interested in sharing their pandemic-related experiences. The inclusion criteria were: 1) aged 18 - 30 years or 65 years or above and 2) living alone during the pandemic. We shared the informed consent sheet with the recruited participants by email and collected their consent over emails.

3.2.2 Participants

Our participants (N=30) included individuals of different genders (22 female, 7 male, and 1 other), races (1 Black or African American, 1 Latino or Hispanic, 7 Asian, 20 white, and 1 other), and ages (average age was 26 and 74 for young and older adults respectively). Most of the young adult participants had lived alone for 3 months to 1 year. Five younger participants mentioned that they started to live alone during the pandemic as their roommates moved to different states to live with their family members. Older adult participants had lived alone in the local community for 10 or more years prior to the pandemic. Most of the participants had a Bachelor's degree or higher. Among the participants, 10 were students, 9 were involved in different part-time jobs, and 7 participants were engaged in volunteer activities before the pandemic. During the pandemic, only 3 participants were involved in full-time jobs and volunteer activities. Most participants had access to diverse technology (e.g., smartphones, laptops, desktops, tablets, game consoles, etc.) during the pandemic. Table 1 contains more detailed breakdown of information about our participants.

3.2.3 Pre-interview Online Survey

We shared a link for an online pre-study survey along with the informed consent form. The online survey contained questions about ways of purchasing groceries, food, and supplies, social engagement, volunteer, religious, and civic activities, work/education, and healthcare access during the pandemic. The

Table 1: Demographics of the participants

Id	Age	Education	Employment status before COVID-19	Employment status since COVID-19	Access to technology since COVID-19
P1	71	Bachelor's Degree	Retired	Part-time	Laptop, tablet, landline, smartphone
P2	80	Doctorate Degree	Retired, volunteer	Retired, volunteer	Laptop, tablet, smartphone, flip phone,
P3	73	Bachelor's Degree	Retired	Retired	Tablet, smartphone, Alexa
P4	74	Bachelor's Degree	Part-time, retired, volunteer	Retired	Laptop, tablet, landline, smartphone, smart TV
P5	75	Bachelor's Degree	Retired	Retired	Laptop, tablet, smartphone, MP3 player, smart TV
P6	78	Doctorate Degree	Part-time	Part-time	Desktop, tablet, landline, smartphone, e-reader
P7	79	Master's Degree	Part-time, retired, volunteer	Retired	Desktop, smartphone
P8	74	Doctorate Degree	Retired, volunteer	Retired, volunteer	Laptop, landline, smartphone, e-reader, smart TV
P9	78	Bachelor's Degree	Retired	Retired	Laptop, smartphone
P10	81	High School Diploma	Retired	Retired	Desktop, laptop, smartphone, smart TV
P11	69	Master's Degree	Part-time, volunteer	Part-time	Tablet, landline, smartphone, smart TV
P12	68	Master's Degree	Part-time, Retired	Retired	Laptop, tablet, smartphone, game console, smart TV
P13	73	Master's Degree	Retired, volunteer	Retired, volunteer	Desktop, smartphone
P14	72	Master's Degree	Retired	Retired	Desktop, laptop, smartphone, smart TV
P15	66	Master's Degree	Retied	Retired	Desktop, smartphone
P16	29	bachelor's Degree	Student	Student	Laptop, tablet, smartphone
P17	28	Master's Degree	Student	Student	Desktop, laptop, tablet, smartphone
P18	20	High School Diploma	Part-time	Student	Laptop, smartphone, e-reader, game console
P19	23	Bachelor's Degree	Part-time	Part-time	Laptop, smartphone
P20	24	Master's Degree	Student	Unemployed	Laptop, smartphone
P21	25	Master's Degree	Student	Student	Laptop, smartphone
P22	27	Master's Degree	Student, volunteer	Student	Desktop, laptop, smartphone, e-reader, game console
P23	24	bachelor's Degree	Part-time	Part-time	Laptop, smartphone, game console
P24	27	Master's Degree	Student	Full time	Laptop, tablet, smartphone, game console
P25	25	Master's Degree	Student	Student	Laptop, tablet, smartphone, game console
P26	27	Doctorate Degree	Student	Part-time	Laptop, smartphone, MP3 player
P27	28	Bachelor's Degree	Full time	Full time	Desktop, laptop, smartphone, e-reader, game console
P28	29	Master's Degree	Student	Student	Laptop, smartphone, MP3 player
P29	28	Bachelor's Degree	Student	Student	Laptop, tablet, smartphone, game console
P30	22	Bachelor's Degree	Student	Full time	Laptop, smartphone, game console

survey also included questions about demographics, access to technology, and social media usage. The survey took an average of 12 minutes to complete. After the survey completion, the first author contacted the participants to schedule a time and date for the interview.

3.2.4 Semi-structured Interview

To adhere to the COVID-19 pandemic restrictions, we conducted semi-structured interviews remotely over Zoom (N=29) and phone (N=1). The first author conducted the interviews between mid-June through July 2020. Each interview lasted between 45 to 60 minutes. Each participant was compensated with a $10 Amazon electronic gift card. During the interview, we asked the participants about their everyday life during the stay-at-home orders, how they adapted their regular activities in the home and public spaces in response to the pandemic restrictions, what challenges they encountered due to the changes, and how they navigated changes. We used their survey responses (mentioned in section 3.2.3) to guide reflective discussion about participants' adaptation strategies for their individual and group activities. In addition, we asked the participants how much they adhered to the stay-at-home order and safety measures during the pandemic to investigate how such adherence influenced their adaptation strategies. The interview protocol is available in the supplementary material.

3.3 Analysis

We recorded and transcribed all the interviews for analysis. We analyzed the transcribed interview data through a qualitative analysis approach (Hancock et al, 2001). The first author followed an inductive coding approach during the analysis. First, the author read the interview transcript from 1-2 participants and wrote memos to familiarize herself with the data. Then, she open-coded the interview transcripts. The resulting codes were discussed with other researchers to create an initial codebook. Next, the first author coded all the interviews using the codebook and met with the research team weekly to iterate and refine the initial codes and codebook. Our initial analysis revealed changes in activity and associated space in response to the pandemic guidelines and restrictions. The researchers reviewed the codes and excerpts and organized conceptually similar codes into high-level categories, such as ways of living, social support, adaptation strategies, and tensions around change. High-level codes were iteratively reviewed, revised, and refined through several synchronous meetings within the research team. In this paper, we presented the results of this analysis to answer the research question (i.e., evolving nature of space and activity adaptations).

4 Findings

Our findings revealed that pandemic-invoked adaptive practices altered the relationship between activities (e.g., individual and co-located activities)

and their associated physical spaces (e.g., public and private spaces) while decoupling and reshuffling most activities from their usual spaces. Adaptive practices include (1) non-technological adaptation (i.e., adapting existing activities while making small adjustments, adopting alternative activities instead of routine activities) and (2) technological adaptation (i.e., transitioning activities from in-person to a virtual sphere). In addition, the evolved space-activity relationship resulted in tensions around changes in the context of the pandemic.

The changes in the space-activity relationships were salient across participants of the two age groups (e.g., older and younger participants). We did not encounter significant age-specific differences among participants' adaptation strategies and emerged tensions around adaptation. However, older participants were more concerned about protecting themselves against the virus due to age-related complications. Whereas younger adults were not concerned with their own risks of catching COVID-19 because of their youth and not having any major health issues but still adhered to bans and recommendations to help contain the virus.

In the section, first, we describe how the space-activity relationships have evolved through pandemic-invoked adaptations of various individual and co-located activities in private and public spaces (Table 2); we then discuss tensions around those changes.

4.1 Individual Activities in Private and Public Spaces

We define *individual* activities as activities that participants performed alone at home and in public spaces (Table 2). Our analysis demonstrated that participants leaned towards non-technological adaptations for most individual activities (e.g., food purchase and eating activities, exercise and physical activities). Whereas technological solutions (i.e., transitioning from in-person to online) were often adapted for selected individual activities, such as food purchasing, among those who strictly adhered to self-isolation measures. For instance, 90% (N=27) participants continued in-person grocery shopping while making minor adjustments to their pre-pandemic practices, whereas only 20% (N=6) participants opted for online grocery ordering.

4.1.1 Non-Technological Adaptation: Adapting Existing Activities and Adopting Alternative Activities

Non-technological adaptation included adapting existing activities (i.e., making small changes) and adopting alternative activities (i.e., replacing or dropping the activities). We found that participants made minor adjustments to individual activities, such as performing permissible activities to adhere to bans (e.g., walking on trails with no people), taking more protective measures to avoid risk factors (e.g., making fewer trips to the grocery stores), etc. Such adaptations allowed participants to continue the same activity in the same spaces where these activities used to take place. When they could not adapt

Table 2: Different types of pre-pandemic activities in public and private spaces with definitions and examples

Activities	Definition	Examples of activities in private spaces	Examples of activities in public spaces
Individual	Activities that participants performed alone in private (i.e., home) and public (i.e., outdoor) spaces	• Food purchase (e.g., grocery and meal delivery) • Eating activities (e.g., cooking) • Exercise and physical activities (e.g., home exercises, stretching, etc.)	• Food purchase (e.g., in-person grocery shopping) • Eating activities (e.g., dining at restaurants) • Exercise & physical activities (e.g., walking, running, swimming, etc.)
Co-located	Social interactions and activities that participants did with others while being in the same space and sharing facilities	• Social visits with others (e.g., gatherings, birthdays, etc.) • Entertainment activities (e.g., board games, card games, etc.)	• Social visits with others (e.g., festivals, social events, etc.) • Work/education activities • Religious activities (e.g., sermons, funerals, etc.) • Volunteer & civic activities • Exercise & physical activities at activity centers • Entertainment activities (e.g., travels, theaters, concerts, etc.)

to their regular activities, participants either found alternatives (e.g., cooking more at home instead of dining out at restaurants) or altogether dropped those activities (e.g., swimming). As a result, participants ended up changing both the activity and the associated space.

Food Purchase: Most participants (N=27, 90%) continued in-person grocery shopping because the activity was permitted by the government (Fig. 1) and it provided participants an outlet during the pandemic restrictions. For instance, P22 described that trips to grocery stores were an escape from the confinement of social distancing and stay-at-home orders, which was also a facilitator to mental well-being:

> "I am living alone and doing very restricted tasks, you know, I'm not working. And it's been helpful for my mental well-being, to go outside and to take trips, like the grocery store. I find driving to the stores relaxing, something to look forward to is helpful." (P22)

We found that most participants preferred to have the freedom of making decisions about their groceries rather than others (e.g., family members,

friends, Instacart shoppers, pickup services, etc.,) deciding for them. For instance, P5 described that she was not comfortable with someone else making decisions about her groceries:

> "I like a lot of fresh fruit so when I go to get specifically grapes, I always pick the big ones because I know they taste better. Groceries are different because there are things that I like and things that I don't like. I don't want to leave that up to someone else." (P5)

Although participants continued in-person grocery shopping, they adapted these activities to reduce risk exposure and time spent around unknown people in public spaces. Participants adjusted their grocery shopping frequency (e.g., getting groceries less often than usual), timing (e.g., going to stores during specific hours), and shopping styles (e.g., avoiding walking down the aisles). In essence, they were able to keep the activity in the same space while making slight modifications. For instance, P27 mentioned that he reduced the number of trips to grocery stores:

> "I usually go like about once a week (before the pandemic), but at the beginning when things were rough I probably went only once every two or three weeks." (P27)

Eating Behaviors: Participants made changes in their existing cooking and dietary habits to be healthier while they were stuck at home. Most participants started cooking more at home because they had free time during the lockdown. They adapted to a healthier diet during the pandemic to manage their weight. For instance, P12 adapted to healthier food habits to avoid gaining weight during the quarantine:

> "when you're living alone, [...] sometimes you're bored and you eat things. I try to eat better now, and eating more salads and vegetables. Before I have lots of weight. Now I've lost some of that." (P12)

Participants described cooking and eating at home when they were not allowed to dine out at public spaces, such as restaurants, during the stay-at-home orders (Fig. 1). Even after the pandemic restrictions were relaxed to allow in-person dining or outdoor dining at restaurants (Fig. 1), most participants still chose to eat at home instead of dining out in public spaces for safety purposes. As a result, participants had to change the activities and spaces where these activities used to take place. For instance, P27 started cooking meals more at home instead of getting them from restaurants because most local restaurants were closed due to a lack of customers:

> "Normally, I would go out and buy lunch. Obviously I don't (now). During the height of lockdown nowhere was open, like literally nowhere. [...] A lot of places just were completely closed because there were no more people hanging around. [...] So I started cooking more at home." (P27)

Exercise & Physical Activities: Disease mitigation measures disrupted participants' regular physical activities. Participants were able to continue only a few existing physical activities (e.g., walking and running outdoors) that were still permissible and safe (Fig. 1). Although participants continued walking

activities, they made slight adjustments to walking to adhere to social distancing restrictions (e.g., walking on wider trails instead of parks, walking on trails with no people, revisiting places around their homes, etc.). In addition, participants developed their own hacks to continue exercising by themselves. For instance, P8 started walking with her friend's dog to keep herself motivated during the quarantine period:

> "I added [my friend's] dog to my daily walking and it kept me going. It was hard at the beginning because all of a sudden there are things that you can't do and there are places that are no longer open, you just have to adjust to it. I think I just did that fairly well." (P8)

Most fitness and activity centers were closed to comply with the pandemic restrictions. Participants adopted permissible and safe alternative home exercises (e.g., stretching, working out with exercise videos, buying exercise equipment, etc.). In essence, this adoption strategy allows the participants to change the activity and the space in which they used to do it. For instance, P16 adopted home exercises instead of his regular CrossFit because the gym was closed:

> "I used to do CrossFit at the gym. My gym isn't open right now [...] during the pandemic, I started my home workout more regularly at the exact time. I assigned a time that I should work out at that time." (P16)

Additionally, participants considered healthier eating habits as an alternative to the lack of their regular outdoor exercises and workouts. For instance, P30 mentioned eating healthier food since the pandemic, as he was not continuing his usual physical activity of walking to class:

> "I was stuck inside and I don't work out. My workout basically was just me walking to class, walking to campus. But since everything switch to online. I am not getting my daily work out anymore. So I was like, well, let me try to eat healthier." (P30)

In summary, our participants made small-scale adjustments to their food purchase practices and physical activities to mitigate risk exposures. They often adopted alternative activities when they could not continue their regular activities in the usual spaces where these activities used to take place. For instance, participants adapted to healthier dietary habits to stay fit while staying at home during the pandemic.

4.1.2 Technological Adaptation: Transitioning to Virtual Sphere

We found that participants' existing technological activities, such as Internet use, social media usage, etc., were affected during the pandemic. For instance, most participants (N=24, 73%) reported an increase in their use of the Internet since the pandemic. They also reported that their frequency of using digital communication mediums, such as emails, text messages, and social media, increased as they checked on more with their friends and families while stuck at home. Both older and younger participants mentioned watching YouTube

videos more during the lockdowns for entertainment, indoor exercises, and to learn new skills (e.g., playing guitar, making cards, etc.).

In addition, we found participants' food purchase activities partially transitioned from in-person to online (e.g., online grocery and meal ordering). Although online food ordering services were present before the pandemic, the use of these services were heightened during the pandemic to mitigate risk exposure to the virus.

Food Purchase: Half of the participants ordered meal pickup and delivery from local restaurants to support local business in the face of economic challenges brought about by the pandemic. For instance, P8 ordered food from the local restaurants to help the community:

> "I did some online food ordering from restaurants, just to help them out, not so much that I was afraid to cook. It's just I wanted to support the local economy in that way." (P8)

Although participants used online food ordering services for meals, most participants did not use online services for groceries. For instance, P22 shared that she lost control over grocery planning and food preparation while ordering groceries online because she did not get the items she wanted when others (e.g., Instacart shoppers) bought groceries on her behalf:

> "There have been times where I'm trying to plan a recipe [...] and half my cart is replaced and then I'm like, I actually can't make what I was planning on making anymore." (P22)

A few participants (N=6, 20.0%), especially those who were immune-compromised and had prior chronic conditions, shifted towards online grocery purchasing activities to mitigate risk exposure in public spaces, such as grocery stores. For instance, P23 shared that she transitioned from in-person to online grocery ordering because she was concerned about virus exposure due to her health issues:

> "I had some health issues recently, and I felt like I had to take more precautions. I get my groceries delivered. I am too afraid to go to the grocery stores [...] I don't see anyone wearing masks and so I'm just very apprehensive." (P23)

Although by transitioning the activity to the virtual space, participants were able to continue with the activity while changing the space, they missed the spatial experience. For instance, P23 shared that she valued the experience of her encounter with physical public spaces, such as restaurants, which was limited when shifting the activity to online:

> "It's been twice since COVID that I've delivered food for myself. [..] Before, I went to a restaurant always in person. I would never order in. I always valued the experience of going someplace. I have none of the spatial stimulation in my life now." (P23)

4.2 Co-located Activities in Private and Public Spaces

We define *co-located* activities as social interactions and activities that participants did with others while being in the same space (Table 2). Participants

continued with some prior co-located activities in private and public spaces taking more precautions to avoid pandemic risk factors, whereas adopting safer alternatives to a few co-located activities (e.g., volunteer activities). They also shifted towards technological adaptation as the only option for some activities in public spaces (e.g., having Zoom happy hours with family and friends, working from home).

4.2.1 Non-Technological Adaptation: Adapting Existing Activities and Adopting Alternative Activities

During the early stages of the pandemic, public health authorities and government regulations encouraged individuals to limit their interactions and activities with others to mitigate contagion (Fig. 1). Further, the closure of public spaces, such as restaurants, theaters, parks, workplaces, churches, volunteer organizations, etc., led participants to explore non-technological adaptations of their regular co-located activities.

Social Visits: Although the restrictions were relaxed for social gatherings in public spaces (Fig. 1), a few participants, particularly older adult participants, chose to continue social visits in private spaces such as on porches, at doorsteps, and in apartments instead of public places like restaurants. They formed a small *social bubble* consisting of a few close and trusted family members and friends who had a mutual agreement to limit their contact to the individuals within the group. For instance, P9 shared her experience of having social visits on the porch with her friends who were also carefully following safety protocols:

> "I would say, sometime in March, we (friends) started sitting on someone's porch for visits, but those are fairly limited. I would say I just sit with about five different friends. [..] I try to stay with people who are following protocols. I pretty much have known from the beginning what most of them are doing, we talked about it. One of my friends recently around someone who was tested positive and she called me (to let me know)." (P9)

A few participants described adopting alternatives of in-person social visits while they felt the calculated risk of continuing the activities in public spaces was higher. Thus, participants ended up changing both the activities and the corresponding physical space. For instance, P14 discussed her experience of sharing food among friends during the pandemic to maintain social relationships:

> "One thing, a group of friends and I did was that because we like to bake, so anytime we bake, we cut things up and we deliver them to each other's houses. So we share whatever we bake." (P14)

Exercise & Physical Activities: Most participants used to engage in various group exercise and physical activities before the pandemic. Participants reported that their usual group physical activities were disrupted due to the closure of activity centers and fear of infection. We found that participants continued some of their in-person group activities (e.g., walking with friends, playing basketball, etc.) in public spaces by making small adjustments.

The adjustments included finding ways to maintain social distancing, wearing masks, etc. For instance, P9 continued walking with her friends by changing to trails that were wide enough for social distancing:

> "I would say sometime in March friends and I started walking together, but not together. You know, it's that weird, [...] let's find a trail that is wide enough for us to walk on" (P9)

Volunteer Activities: Most participants stopped their usual volunteer activities (e.g., helping at soup kitchens, shelters) for personal protection and in response to the closure of different volunteer organizations. Additionally, participants reported that a few organizations stopped using volunteers, especially older adults. A few participants continued their usual volunteer activities as the volunteer organizations adapted their programs to offer support safely. For instance, P2 continued driving for Meals on Wheels service (Thomas et al, 2020) because the volunteer organization shifted their service model to *no contact* delivery to mitigate virus exposure:

> "I drive for Meals on Wheels. I still have that among my volunteer activities because they (organization) have arranged it so there is no contact delivery. [...] The person who is receiving the services is supposed to have a container for us to put it (meal) in outside their door. We just put it there and then we knock on the door and say, 'Meals on Wheels,' so they know it's there." (P2)

Further, we found that a few participants replaced their regular volunteer activities with different ones. Such alternatives allowed the participants to change the activity and associated space where they used to do this activity. For instance, P18 donated money as an alternative while he could not continue his usual volunteer activities in the community club:

> "I'm secretary and we do it (volunteer activities) through the club. Obviously, no one's here anymore (during the pandemic). So that's not happening. I try to do my bit of activism by donating money, which doesn't really feel the same as actually going to the soup kitchen and domestic abuse shelter and actually volunteer." (P18)

In summary, participants adapted their existing social visits and volunteer activities to reduce risks. Participants had the agency to adjust their social visits and exercise activities (e.g., interacting with people within a social bubble, walking with friends on wide trails), whereas the volunteer organizations authorized adaptation of their programs for volunteer activities instead of participants (e.g., no-contact delivery model). Participants also tried to find alternative activities to social visits and volunteer activities while their usual opportunities were disrupted due to mitigation measures.

4.2.2 Technological Adaptation: Transitioning to Virtual Sphere

Before the pandemic, 13 (43%) participants used video conferencing tools to communicate with their family and friends, and 11 (36.7%) participants used them for work and professional activities. Nine (30%) participants used to play

online games with others. Since the pandemic, more participants have adopted technological solutions for online group activities to compensate for the lack of face-to-face interactions and in-person social activities. They shifted their common in-person co-located activities (e.g., social visits, work/education, religion, etc.) dramatically towards the virtual sphere. The accelerated reliance on technological adaptation brought on by the pandemic revealed different power dynamics among participants and organizations/institutions. Participants had control over the digital transitions of social visits, exercise, and entertainment activities from in-person to virtual, whereas the organizations/institutions led the transition of work and other community activities (e.g., religious, volunteer, and civic) to the virtual sphere.

Social Visits: Most participants (N=27, 90%) described interacting with their family, friends, neighbors, and community through various web-based platforms, such as Zoom, FaceTime, etc. A few participants also shared experiences of celebrating occasions such as birthdays, graduations, etc., online. In essence, they were able to continue with the activity by changing its space. For instance, P9 celebrated birthdays with her family members over Zoom while she was at her home:

> "We've done some Zoom extended family birthdays. Whoever's birthday it is, somebody in their family organizes the Zoom and sends out the link, then we all meet, and sing happy birthday, listen to stories, and talk to each other. We just did one last week." (P9)

Entertainment Activities: We also found that around 63% (N=19) participants transitioned their co-located entertainment activities in public spaces (e.g., watching shows at theaters, attending concerts, festivals, etc.) to the virtual sphere. For instance, P19 described a remote movie-watching experience with her friends over FaceTime and Teleparty (formerly Netflix Party) :

> "I've had a couple of movie nights where like we (friends) would FaceTime and watch the same movie. I also tried Netflix party but it wasn't what I thought it was going to be. I thought there was some video aspect to it and I plug my computer and my TV so I couldn't really chat." (P19)

In a few cases, participants adapted co-located entertainment activities in private spaces (e.g., board games, card games, etc.) to the virtual sphere. For instance, P11 shared that her son set up remote games so that she could have the in-person game-playing experience with her grandson:

> "My son sent me the same games that my grandson likes to play. [...] We pretty much just started playing the games after this (COVID) happened. We spend an hour, an hour and a half or so. [..] We joke because my other son and I were like the X team and they're the San Francisco team." (P11)

Exercise & Physical Activities: Most participants shifted their in-person group exercise and physical activities to the virtual sphere and the transition occurred in both public and private spaces. For instance, P11 shared that she

and her walking buddy talked over the phone while walking separately in their own neighborhoods to have the experience of walking together:

> "I have one friend, she lives here. On Tuesday mornings, we each take walks separately in our own neighborhoods, but we talk on the phone while we're walking so it feels like we're walking together." (P11)

On the other hand, participants shifted towards online exercise classes and wellness programs over digital platforms. For instance, P9 described attending online exercise classes at home while the activity centers were closed down:

> "There's an agency on aging. [..] They have a three-days a week exercise class over Zoom and I do that. I really liked the instructor and she mostly knew all the people. Most of the people had been going to her classes forever. Then, there's another website that has some exercise classes (over Zoom) and I started doing Qigong too." (P9)

Work/Education: Most of the non-essential in-person work activities were adapted for work-from-home to combat the spread of the virus. Educational activities also transitioned to online to mitigate disease spread. Participants adapted to the changed nature of work and educational activities. They were comfortable working from home because it saved commute time as well as protect them from the virus at workplaces. However, participants often shared concerns about restarting their in-person work activities for safety purposes. For instance, P12 shared that she was contemplating delaying her in-person work because of the lack of personal protection against the virus at her workplace:

> " I used to work at the office [...]. I was asked to work recently, but I've decided that's a little too dangerous [..] there's too much uncertainty on because you don't know the people around you, you have to have some trust if you do it (go to work). So I will start it up when I feel safer about it." (P12)

Although participants highlighted the perks of technological adaptation of work-from-home, they pointed out changes to their usual work schedules, working hours, and ways of working. For instance, P22 shared how the lack of impromptu discussion opportunities with colleagues in remote work impacted her work experience:

> "We often walk over to each other's desk and say, hey, this is just something I've been struggling over. (Now) I can't just go to someone else's desk. So honestly, I think our work has been negatively impacted from the dearth of these opportunities." (P22)

Religious, Volunteer, and Civic Activities: These community-based co-located activities were disrupted as the local organizations (e.g., churches, support centers, town halls, etc.) stopped or limited in-person interactions (Fig. 1). To adhere to pandemic restrictions the community organizations adapted their functioning model to shift the activities to the virtual sphere.

Technological adaptations included the churches broadcasting (live or pre-recorded) activities (e.g., sermons, prayers, memorials, etc.) over online platforms, volunteer organizations creating new opportunities of virtual volunteering, town hall meetings shifting to online, etc. We found that participants adapted to these digital transitions, which allowed them to continue the same activities while changing the spaces where they used to take place. For instance, P2's in-person volunteer activity as a docent in a local museum transitioned to online while the museum adapted its working model for virtual interactions. She mentioned that her volunteer activities involved training on Zoom instead of face-to-face tours:

> "I am volunteering at the museum. We were having so many Zoom meetings for everything, for volunteer work at the museum. We have meetings and lectures on Zoom. Obviously, we can't give museum tours on Zoom yet. Maybe we will later, but for now, we have the training and that sort of thing on Zoom." (P2)

Participants highlighted that the accelerated technological adaptation of community activities provided potential avenues for new community-based activities. For instance, P22 shared that the switch from in-person to virtual town hall meetings was beneficial for her because she did not have to reschedule her regular activities just to attend the meetings:

> "Previously, going into things like town halls was much harder because I would have to basically disrupt my schedule in some way to go. I would have to physically go, I'd have to figure out parking. [...] With the move to virtual, those were much easier. [...] I was able to get what I wanted out of it, which was to have a higher awareness of just what's going on civically." (P22)

In summary, the technological adaptation to the virtual sphere provided participants with new opportunities to continue performing their social and community activities among the pandemic restrictions.

Takeaways of Evolved Relationships between Space and Activity: Table 3 summarizes how various individual and co-located activities in public and private spaces were adapted in response to the pandemic. Adaptation practices have resulted in three types of changes in the relationships between space and activity. Firstly, adapting an activity with slight modifications has allowed people to continue with the same activities in their usual spaces where they used to take place. Secondly, adopting alternatives has led to changes in both the activities and the associated spaces. Finally, transitioning to virtual spaces has kept the same activities while changing the physical space in which they occur.

4.3 Tensions Around Changes

Our findings demonstrated that although participants were able to adapt in non-technological and technological ways, there existed tensions around

Table 3: Changes in individual and co-located activities during the pandemic

Activities	Examples of activities	Non-technological strategies: Adapting existing activities	Non-technological strategies: Adopting alternative activities	Technological strategies: Transitioning to the virtual sphere
Individual	Food purchase	✓		✓
	Eating activities	✓	✓	
	Exercise & physical activities	✓	✓	
Co-located	Social visits	✓	✓	✓
	Exercise & physical activities	✓		✓
	Entertainment activities			✓
	Work/education activities			✓
	Religious activities			✓
	Volunteer activities	✓	✓	✓
	Civic activities			✓

those changes. We found tensions around social interactions, multimodal communication, and home space. In the following subsections, we detail these tensions.

4.3.1 Changed Nature of Social Interactions

Participants' adapted activities created tensions around the intimacy and genuineness of social relationships. Participants reported that simple casual social interactions required more planning and coordination. For instance, P9 shared how she had to coordinate the time and her friend's presence at home for casual social moments such as having visits on porches:

> "I think one of the hardest parts for me is making appointments with friends, like, are you going to be home on your porch? I have one friend who lives close to me. And then the others I have to go to their places." (P9)

We found that participants' usual co-located social and community activities became isolated individual activities through technological adaptation (e.g., video calls over Zoom). Although these technological alternatives provided opportunities to maintain social interactions while adhering to self-isolation measures, participants highlighted the absence of organic interactions for those alternatives. They reported the lack of impromptu social moments while interacting with others over digital platforms. For instance, P6 shared her experience of virtual social visits with her friends, and she pointed out the artificiality of those interactions:

> "I miss talking with people. And with this Zoom service, you are not chatting with people, you know, you are not gossiping with people. You can't ask how their dog is or their cat or their husband, and you are not really chatting, and you cannot hug anybody." (P6)

Although most participants appreciated the opportunities for virtual social interactions, they did not consider it as a complete replacement for in-person

social activities. For instance, P15 mentioned that seeing people on screen was not a substitute for in-person interaction:

> "I had several groups that have zoom meetings. I would rather just do something else than be looking at a small screen. Just seeing in a little square on the screen isn't the same as being with those people." (P15)

We also found that prior individual activities such as grocery shopping now became the *exciting* in-person social alternative while maintaining social distancing. For instance, P21 shared that going for groceries allowed her opportunities to be social and be around other people even though she did not interact with anybody in the grocery stores:

> "If I didn't go out for grocery shopping, it means that 100% stay at home. So sometimes I take going to grocery as a hangout, as a trip for myself [...] Even though I don't see anybody I know, I still see somebody." (P21)

In summary, we observed tensions around the changing nature of social interactions while participants adapted non-technological and technological solutions to maintain social relationships with other people. Although participants acknowledged the significance of having digital or online social interactions, they reported the missing essence of *organic* social interactions. Further, there was a transition when traditional co-located activities became isolated and previous individual activities turned to be the *new* in-person social alternatives.

4.3.2 Altered Meanings of Home

During the pandemic, *home* had promptly turned out to be the central base to reduce exposure risks and ward off the detrimental consequences of the pandemic. Social gatherings at home, which used to be more welcoming, changed to be more cautious. A few participants described being wary about allowing others beyond their social bubble (e.g., service people, neighbors, etc.) inside their homes. For instance, P13 said that she had chronic health issues, and she did not feel comfortable having her neighbors who did not follow proper safety protocol to come inside her home:

> "I have three issues or four (health) issues. So I'm very careful if I see my neighbors going around without a mask. If they don't wear a mask then I don't (let them come inside), I just peek out of my peephole, and if it's them, I just don't answer the door. I just pretend I'm having a nap or something. I don't want to be anywhere close to them." (P13)

Despite limited and cautious social interactions inside the home, participants continued considering home a domestic social zone to foster and materialize relationships during the pandemic. For instance, P14 shared her experience of providing emotional support to her friend by inviting her to her home when her friend was feeling lonely:

> "One day, a friend of mine called me up. This was in May (2020). She called me up and she was crying. And she said, 'I am so lonely and I'm so depressed and I needed a hug.' And I said, 'listen, first of all, come over here (her home). I'm going to make you something for dinner."' (P14)

Participants reported that the overwhelming technological adaptation of most in-person co-located activities in home space blurred the boundary of personal, social, and professional space. The space for relaxation now became a space where virtual social and professional gatherings happened. For instance, P22 shared that she used to maintain a clear boundary between her home and workplace. However, she had to adapt by switching her mind-set from relaxing to working for work-from-home activities:

> "Home space being different from other spaces. I actually don't like doing work at home because I like to have home be very comfortable. And so to have to switch into the work mindset (while working from home during the pandemic) has been hard for me. I don't have the break of driving from campus back home to serve to let me switch gears." (P22)

Participants had to reconfigure their home space for work-from-home; for example, having a dedicated space for work, infrastructure set-up, etc. For instance, P27 mentioned configuring a particular space at his home for work:

> "I basically, I've prepared a rather small space. What I did was I took on my kitchen counter. And I stacked up some books. So I had something to rest my hands on and something to elevate my laptop up. That just kind of became my workspace. So when I would need to work, I would just go over to that area of the apartment. It's still made things a bit weird because that's also where I cook." (P27)

In summary, we observed that the transition from in-person to the virtual sphere shifted activities into the home, which obscured the boundary of participants' personal, social, and professional space.

4.3.3 Adaptations to Complexities of Multimodal Communication

We found that technological adaptation of co-located activities in home space created tensions around re-imagining the space for different activities while arranging and assembling multimodal communications, such as video, audio, and text-based communication. Participants reported that they had to figure out workarounds and navigation of virtual platforms to ensure effective virtual social communication. For instance, P20 shared that she had to learn how to conduct Teletherapy for her work as a speech therapist:

> "I do speech therapy kind of things. And normally this would be done in person. [...] So I've never done a Teletherapy by myself. But I've observed some, it has something to do with knowing how to navigate Zoom because sometimes you have to share screens. [...] I have no clue how to do that. And that might be something I need

> to learn how to do it. So I can communicate better and make the therapy more effective." (P20)

Participants were also motivated to reach out to others (e.g., family, friends, support centers, workplace, etc.) to help them setting up the new digital platforms and thus made the technological adaptations of multimodal communication quite convenient. For instance, P8 shared her experience of adapting to social communication over Zoom and how comfortable the virtual transition was while receiving tech-support from others:

> "Finally learning how to use Zoom. I belong to a book club. We used to meet in person. And this was my first Zoom experience and we decided we wanted to continue meeting. One of our members is a technological wizard. So he got us all set up. And it was kind of fun learning to use some of this technology and now I'm using it for lots of different kinds of meetings and social get-togethers." (P8)

Furthermore, existing technologies are not fully catered to support virtual activities, such as remote socializing in public and private spaces, which require more interactions beyond verbal communication. In a few cases, participants reported adapting their traditional technology to experience enriched interactions for adaptive activities in public and private spaces. For instance, P19 shared her experience of playing remote games with her family adapting to a three-way phone call to mimic in-person game playing experience:

> "I played online ugur, like a card game with my family. We used to play that a lot like in person. We talked on the phone while we did it (play the game). At first we just really couldn't figure out a good way to do that. And then my mom discovered three-way phone calls and then it was all better." (P19)

In summary, participants reported that changes in activities from in-person to virtual triggered them to figure out workarounds and adaptations to ensure effective communication.

5 Discussion

Based on our findings, it is evident that the relationships between space and activity have undergone significant evolution as a result of both technological and non-technological adaptations in various individual and co-located activities, occurring in both public and private spaces. These adaptations have caused the reconfiguration and reshuffling of activities and their associated spaces, creating tensions around the changes.

Although a couple of adaptive activities in public and private spaces (e.g., online grocery and food delivery, technological and non-technological means of social communication, and working from home) were present before the pandemic, participants' perceptions and experiences of the spaces where the activities took place differed from their pre-pandemic experience. Before the pandemic, remote work was often a choice for individuals who needed or wanted it, whereas participants (e.g., students, part-time, and full-time

workers) were mandated to work from home for safety purposes during the pandemic and had to adapt and accommodate changes within a short span of time. Furthermore, participants reported attending the funeral and religious activities from home, which became a space for virtual social gatherings beyond relaxation. Thus, participants' co-located activities in public places (e.g., workplaces, churches, etc.) became isolated in private spaces. As a result, previous individual activities became new in-person social alternatives in public spaces (e.g., in-person grocery shopping and remote walking buddies), particularly for individuals who lived alone.

Most of our findings on adaptations in response to the pandemic restrictions agree with and confirm the conclusions of existing studies exploring pandemic-invoked transitions, challenges, and opportunities for a specific activity (e.g., social interaction, work, eating behaviors, etc.) (Newbold et al, 2022; Cho et al, 2022; Koch et al, 2020; Poelman et al, 2021). This paper's novel contributions lie in exploring how the relationship between space and activity decoupled and evolved through various adaptation strategies in the context of the pandemic. For instance, while making slight adjustments, the same activities are kept in the same spaces where activities used to take place before the pandemic. On the other hand, adaptation strategies, such as finding alternatives, change both activity and its associated space. Lastly, transitioning activities to virtual spheres has allowed continuing the same activity while changing their space. In addition, we uncover tensions around adaptations, such as the changing nature of social interactions, home spaces, and the complexity of multimodal communication, created by the changes in the relationships between space and activity. The work explores multiple activities at once, ranging from personal to professional activities in public and private spaces to unpack high-level understandings of the evolved relationships and their prevalence across different spaces and activities in the context of the pandemic.

In this section, we propose a framework to examine evolution of adapted activities decoupled from their physical spaces. Although we devised the proposed framework in the context of COVID-19, we hope this framework will be a starting point to understand people's relationship with space and activity to promote adaptation in response to change. We believe the framework can guide research and design of socio-technical systems supporting adaptations. To enhance individuals' and communities' resilience and abilities, we encourage researchers and designers to revisit and update the proposed framework by examining changes in activities and spaces in other contexts.

5.1 Space-Activity (SA) Framework

Our proposed Space-Activity (SA) framework contains three key dimensions: space, activity, and elements of space (Fig. 2). The space dimension is divided into private and public. We define private space as both indoor and outdoor spaces of a person's home, whereas public space is any place that is open and accessible to the public, e.g., restaurants, workplaces, parks, grocery stores, etc. The activity dimension comprises individual and co-located activities.

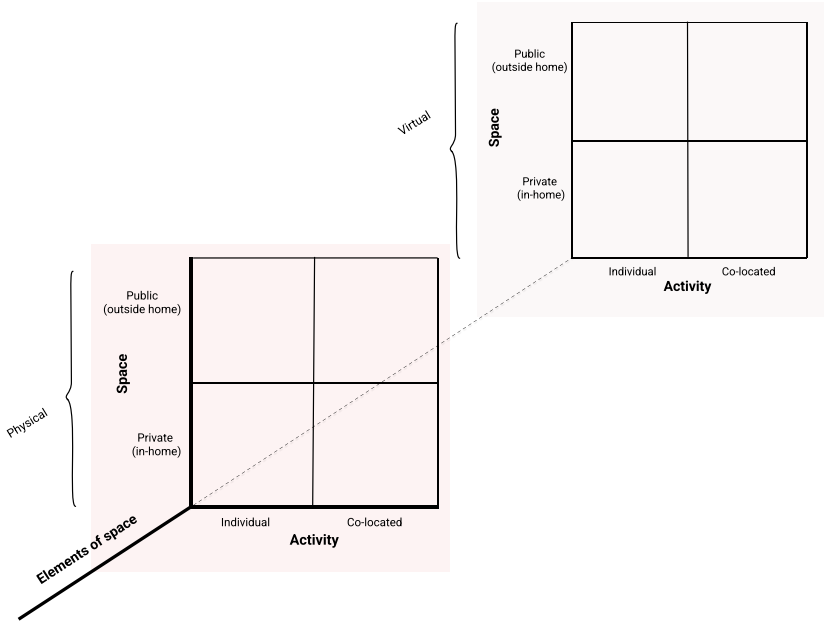

Fig. 2: Space-Activity (SA) framework, demonstrating three dimensions: space (X-axis), activity (Y-axis), and elements of space (Z-axis). Each dimension is comprised of two constructs: public vs private (space), individual vs co-located (activity), and physical vs virtual (elements of space). The three dimensions divide space and activity into eight octants.

Individual activities are performed alone in private and public spaces (e.g., home exercise, grocery shopping, etc.). Co-located activities are performed with others in public and private spaces while all the individuals are present in the same physical space; for example, work, social visits, group exercise, etc. Lastly, the third dimension represents elements of space, which is divided into physical and virtual. Public (private) individual virtual activities are the activities that are performed alone by an individual in public (private) spaces while they interact with smart devices (e.g., smartphones, game consoles, laptops, tablets, etc.). Examples of such context in private spaces include ordering food/grocery delivery, playing online/video games, etc. Individuals creating a personalized workspace in offices leveraging technology (e.g., connecting two or more devices) is an example of public individual virtual activity. On the other hand, co-located virtual activities are activities performed by a group of people (two or more) while they interact online. A person could be alone in a physical space while interacting with others online, such as when they have remote walking buddies or collaborating and coordinating with their colleagues while working from home. Alternatively, a person could be with others in the same physical space while interacting with others online. For instance, a remote family game night is an example of when some family members reside in one physical space and interact with other family members remotely. Although

co-located virtual activities existed before, these activities became more pervasive in the era of social distancing. The three dimensions divide space and activity into eight octants, i.e., private individual physical, public co-located physical, public individual virtual, private co-located virtual, etc. To demonstrate octants using 2-D quadrants, we split the graphical representation of the framework in two parts: physical and virtual (Fig. 2).

While developing the framework, we drew inspiration from earlier work on social interactions in computer-supported collaborative learning (CSCL) environments by Kreijns et al. that captured the relationship between constructs, such as sociability, social space, and social presence (Kreijns et al, 2013). We were also inspired by Jones et al.'s P3 framework that characterized relationship between virtual spaces (i.e., online communities) and physical places (Jones et al, 2004). In addition, our analysis revealed changes in individuals' regular activities, their social and home spaces, and corresponding adaptive strategies as they passed through a time of sweeping change during the COVID-19 pandemic. Furthermore, COVID-19 profoundly reshuffled participants' activities and their perceptions, use, meanings, and relationships with spaces where the activities took place. For instance, participants attended funerals from home instead of churches, and thus home became a space for virtual social gatherings beyond relaxation. The reconfigured space and activity emphasize the need to rethink the relationship between activity and space that might create opportunities and invoke challenges for researchers, designers, and industries engaged in building space-oriented interventions to support different activities. Towards that goal, the proposed framework can be viewed as a starting point to understand and reflect on relationships between space and activity and associated adaptations.

Applications of the Framework: The proposed framework will facilitate rethinking the meaning of space by exploring design opportunities of technological systems for reshuffled activities and spaces. Our findings revealed that various adaptations in response to the pandemic reshuffled activities and the spaces where these activities took place. We utilize our proposed framework to capture the relationship among space, activity, and corresponding adaptations in the context of COVID-19. Fig. 3 depicts adaptations of personal and professional activities experienced by our participants. Reflecting on our findings, we show three adaptation strategies in the framework. The strategies are 1) adapting existing activities (bold text in Fig. 3), 2) adopting alternative activities (dotted arrow), and 3) transitioning to the virtual sphere (solid arrow).

These adaptations reshuffled activities and their traditional physical spaces and thus changed the meanings of spaces threatening the emotional connections with space. Traditionally, a home space was considered a personal space for relaxation. The workplace was considered for work and formal social interactions. Other public spaces, such as parks, restaurants, churches, etc., were used for informal social interactions. However, with the pandemic restrictions, people attended work, education, and social gatherings from home, which

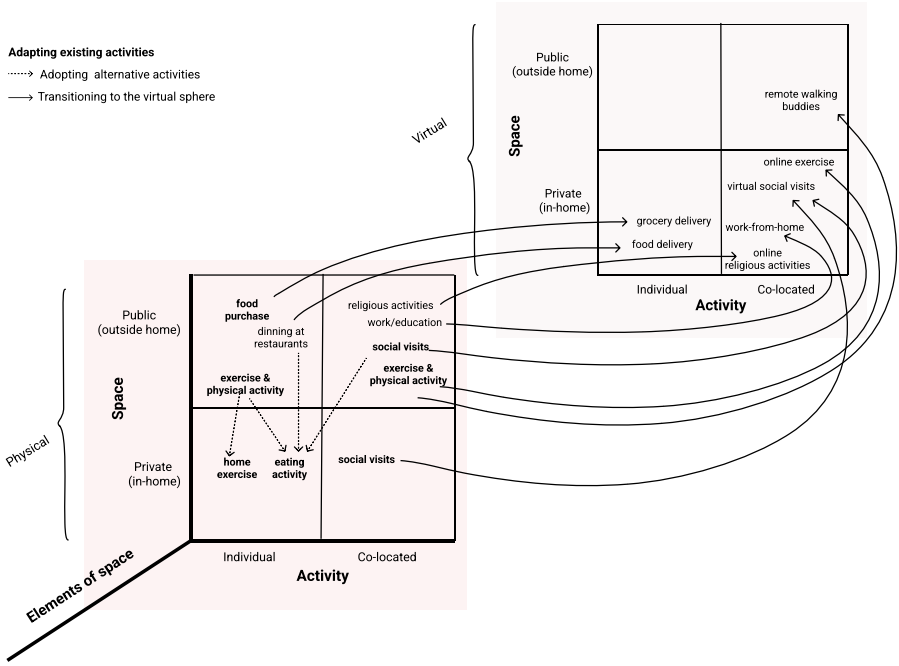

Fig. 3: Illustration of adaptations experienced by our participants in the context of COVID-19 using proposed Space-Activity (SA) framework. The adaptation strategies illustrates the shift of activities across different dimensions. Activities in bold are adapted, but stay in the same octant. Activities with dotted lines stay in the same physical or virtual realm, but change space and activity. Activities with solid lines transition from physical to virtual realm.

altered the meaning of home as a personal space. Further, shared spaces posed threats in new ways, especially when other people were present (e.g., virus transmission (SAFE, 2021)). As a community, we need to rethink the meaning of space that was strongly coupled with activities before the pandemic. We believe the proposed framework will facilitate researchers to answer questions about 1) how do adaptations to crisis (e.g., pandemic) impact the use and perception of space? 2) how do relationships with space change while adapting? 3) how do the meanings of space change in response to adapted activities? and 4) how will the social behaviors illustrated through the framework evolve over time?

Although our proposed framework is inspired by the lived experiences of individuals during the COVID-19 pandemic, the framework can also be used for other HCI and CSCW research studies exploring changes and adaptations of activities and spaces. We can use the framework to understand how individuals change their needs and activities based on spaces to adapt to health conditions. For example, Min et al. have explored the varied care needs and activities of people living with epilepsy across different spaces, i.e., home, school/work, and public areas (Min et al, 2021). The proposed framework

could facilitate the investigation of activities in different spaces to support care providers and care receivers (i.e., people with epilepsy) when activities change based on space-specific care needs.

In addition, the proposed framework will create opportunities for designers and industry by 1) identifying potential design spaces to facilitate changes, 2) supporting designs for different changing strategies, and 3) devising contextual design guidelines for adaptive activities based on their spatial location. Our findings uncovered that individuals leaned towards available generic tools to adapt to pandemic-invoked changes within a short period of time. Reflecting on our findings, the framework highlights a relatively empty square (i.e., virtual co-located activities in public spaces Fig. 3), which indicates that the generic tools might fall short of supporting people's tailored needs and in-person experiences in that space. Thus, our proposed framework prompts designers for new design opportunities to better support the adaptation of activities in public spaces.

In summary, our proposed Space-Activity (SA) framework provides ways to capture the changing nature of space and activity. Future research is still needed to consider the applicability of the proposed framework in various contexts that might cause changes in activity and space.

5.2 Designing Socio-technical Systems to Support the Change in the Context of COVID-19

Our framework uncovers design spaces for different dimensions of space and activity (i.e., public individual virtual, private individual virtual, public co-located virtual, private co-located virtual, etc.), which could be explored by researchers and designers while designing systems to support adaptations and changes during the pandemic. For instance, our findings revealed design opportunities for individual virtual activities, such as online grocery ordering. Most participants expressed reluctance towards using online ordering services for groceries, citing concerns about losing control over their decision-making process when others (e.g., Instacart shoppers) bought groceries for them. One possible design consideration could be to re-design online grocery delivery systems to improve users' experience by providing more control over substitutions of grocery items. Currently, to substitute an item, the personal shopper either initiates a communication with the customer or makes the substitution decisions. It is difficult for a personal shopper to decide the next best option for a customer they have never met. We envision an AI-based system that provides real-time recommendations of the best next-available item based on diverse aggregate factors personalized to individual customers. The system can also improve its effectiveness by incorporating customer feedback into the adaptive learning algorithm for future recommendations.

The framework can facilitate technology design to accommodate the changes in the relationships between activity (i.e., individual and co-located activities) and space (i.e., private, public, physical, and virtual spaces). In this

section, we focus on exploring the design considerations aimed at supporting pandemic-invoked changes in social activities in private and public spaces because evolved relationships between activity and space created tensions around those changes (mentioned in Section 4.3).

5.2.1 Supporting 'Organic' Social Interactions

Existing research has emphasized the significance of social ties and interactions to mental and physical well-being during a crisis (Ye and Aldrich, 2019; Iwasaki et al, 2017). Our findings revealed that people adapted various ways of social interaction activities in different spaces. Although people could not eliminate in-person social interactions, individuals reduced their regular social interactions to avoid contagion. For instance, participants reported interacting in-person with only trusted people on their porches sitting 6-feet apart or at doorsteps rather than in public spaces. They also shifted most of their community interactions online. Participants shared concerns around back and forth, additional communication to coordinate such mundane social interactions. We believe there is an opportunity for designing socio-technical systems to ease the planning and coordination of social visits. Towards that goal, we take inspiration from the existing research on peer care-based support systems (Arreola et al, 2014; Li et al, 2018). Li et al. proposed a tablet application, Community Window, a virtual front porch, that allowed older adults to serendipitously interact and make video calls with other members in their peer group (Li et al, 2018). The application utilized the camera to take pictures every minute and display it on the community window indicating that the person welcomed social company with peers. If someone did not want to have company, they could put a "virtual curtain" over their window by pressing a close button. A similar feature is also built in the digital platform Discord [2] where people can create virtual rooms where they can have social interactions with other members. We envision a similar socio-technical system that allows peers to know when one is available to have social time and thus facilitate the coordination of social interactions.

Our participants pointed out that seeing people in a '*little square*' disrupted organic conversations, which aligned with past research that highlighted the significance of emotional sharing and interactions in virtual spaces during prolonged crises like the pandemic (Jo et al, 2021). The intimate, emotional, and organic conversations are directly associated with the number of social cues exchanged (Daft and Lengel, 1986) during the conversations. Thus, face-to-face interactions are considered a much richer form of communication where people perceive various non-verbal cues from body language and surrounding contexts. Although videoconferencing tools are able to provide limited cues (e.g., facial expressions), incorporating more cues such as body movements, postures, and contexts of the physical space could further facilitate organic social conversations. One possible solution could be to make the camera view

[2] https://discord.com/

larger to reveal more bodily cues beyond facial expressions and the surrounding contexts. At the same time, we have to balance the privacy of the users by providing them the agency to adjust their viewed display (e.g., blurring facility, virtual background, customized obfuscation part of the display, etc.). There also exists a few studies that have explored various ways to provide enriched social cues (e.g., facial responses and head gestures) over videoconferencing platforms during workplace meetings (Murali et al, 2021; Bleakley et al, 2021). For instance, Murali et al. (Murali et al, 2021) proposed a Microsoft Teams bot, *AffectiveSpotlight*, that analyzes audiences' facial responses and gestures to dynamically spotlight the most expressive ones to mimic real-time audience feedback similar to face-to-face presentations. These technologies could be extended beyond workplace settings to facilitate social chat and remote collegiality during causal interactions over videoconferencing.

5.2.2 Supporting Missing 'Tangible Affection'

Although digital tools connect individuals with family, friends, and community, there is only the audio/video component and lack in-person social aspect; the essence of human touch. Among all the different social groups, people living alone were hit hard due to the missing tangible affection (Child and Lawton, 2019; Armitage and Nellums, 2020; File and Marlay, 2021; Clark and Clark, 2009; Bound Alberti, 2018). For instance, participants reported that they missed hugging people while attending birthdays, festivals, funerals, etc., over Zoom. In general, the social life and sociability of people living alone are centered more on everyday interactions and activities in public spaces and events (e.g., workplace, restaurants, activity centers, theatres, etc.) (Roseneil and Budgeon, 2004). Therefore, the online transition of social activities amid mandatory confinement became isolating for solo-living individuals.

People living with others (e.g., family members, friends, partners, roommates, etc.) still have some social interactions with others while living with them. Whereas people living alone might not be able to see anyone except on a screen. They seek to find even a glimpse of opportunities to meet that tangible social need. Hence, we found that our participants considered individual activities in public spaces like grocery shopping as an alternative to being around others and seeing people in person. The transformation of such mundane, individual activities as the *exciting* in-person social alternative might not be prevalent among someone who is living with others.

We envision designing interactive technologies to support physical intimacy. Prior studies have investigated opportunities of technologies within intimate relationships across different age groups (e.g., couples separated by distance, older adults) (Lindley et al, 2009; Gaver, 2002; Tollmar and Persson, 2002; Vetere et al, 2005). Mueller et al. (Mueller et al, 2005) introduced a functional portable prototype, Hug Over a Distance, a vest that allowed unobtrusive tactile interactions (similar to holding hands or giving a hug). We suggest leveraging the existing familiarity with videoconferencing tools and augmenting these tools with wearable and sensing components to support the need

for touch during virtual social interactions. For example, a tangible object (e.g., blanket, vest, cushion, etc.) embedded with sensing technology and connected with the videoconferencing tools to sense tactile interactions (i.e., touch, warmth, hug, etc.) and display it to the other person.

5.2.3 Designing for Public Spaces

Prior research on urban spaces highlighted the importance of people's presence in public spaces and associated social and health benefits (Woolley, 2003; Dunnett et al, 2002). For instance, public spaces create a sense of community when people attend public events, such as shows, fireworks, music events, fairs, etc. Public spaces can create opportunities for rest, relaxation, and well-being by allowing people to perform individual or group physical and recreational activities, such as jogging, walking, group sports, etc. However, with the social distancing and lockdowns, people's social interaction and activities in public spaces underwent significant changes for safety purposes (Abusaada and Elshater, 2022).

To adapt to the pandemic-invoked changes within a short period of time, most individuals have leaned towards available generic tools to support transitions of various in-person individual and co-located activities in public spaces to the virtual sphere. For instance, our participants reported using the Zoom videoconferencing tool to attend classes, work meetings, celebratory occasions, sermons, funerals, etc. Limited interaction capabilities of generic tools controlled the transition of adaptive activities from public to private space. If people want to engage in virtual social activities in public spaces maintaining social distancing, a generic videoconferencing tool may not be sufficient to support those in-person public space experiences.

Therefore, we encourage researchers and designers to think beyond the generic tools to support tailored needs in public spaces. Digital collaborative tools could be designed to provide support beyond video and audio for effective coordination. We could leverage augmented placemaking (Hespanhol, 2022) to explore opportunities to harness the existing digital tools to build on virtual spaces. For example, a virtual space of a museum to transform the museum going experience, where people can interact with the museum artifacts virtually, access information, and continue to be a part of the learning activities in a very accessible and interactive way.

Furthermore, to strive for a balance between social interactions and concerns (e.g., social distancing, virus transmission) in public spaces, we suggest designing technology leveraging social features in outdoors such as geocaching (Schlatter and Hurd, 2005) and augmented gaming (e.g., Pokémon Go) (Baranowski, 2016; LeBlanc and Chaput, 2017). For instance, a location-based mobile game based on augmented reality mechanics, Pokémon Go, produced opportunities for random-encounter social interactions with people inhabiting the same public geophysical space (Tateno et al, 2016; Baranowski and Lyons,

2020). Similar technologies might be augmented with spatial and tactile representation to facilitate flexible and casual social interactions in public spaces beyond entertainment and physical activity.

Designing technologies for virtual activities in public spaces introduces several challenges for researchers and designers. Jo et al. (Jo et al, 2021) discussed considerations for building virtual public places and their outcomes on the local community. They pointed out that not having digital equipment/Internet can limit participation in virtual activities in public spaces. Therefore, researchers and designers need to investigate how to rebuild public spaces to equip them with digital devices and seamless Internet connectivity. In addition, different public spaces impose different social norms of what is acceptable and what is not. Technologies are required to adapt to changing social norms in diverse public spaces and provide affordances that allow people to interact within these norms (Abdel-Aziz et al, 2016). Further, spontaneity, duration, and communication modality might impose additional challenges while transitioning from face-to-face social interaction to virtual interaction in public spaces. Therefore, researchers and designers should take into account the social norms, communication modality, and interaction spontaneity while designing virtual activities in public spaces for the post-pandemic world.

As people continue to inch toward a post-pandemic world, a lot of the transitions we identified in the study have likely reversed. While some individuals may find the return to in-situ and face-to-face interactions refreshing after the pandemic restrictions, others have grown accustomed to the convenience and flexibility provided by virtual opportunities (Ziffer, 2022). A shift has been seen in how individuals prefer to perform different activities in public and private spaces. According to a pew research, 35% of US citizen felt that in-person social gatherings have become less important since the outbreak of the pandemic (Sharpe and Spencer, 2022). There is a high demand for hybrid interactions, which allows the opportunity to blend the best of both physical and virtual realms (Davies, 2021; Carville and Mulzac, 2022; Hespanhol, 2022). Hybrid opportunities in the workplace, healthcare, and social events provide a choice to individuals whether they participate in in-person or online (or a combination of both). Researchers and designers should account for the new demand for hybrid interactions and explore ways to better support individuals' needs and experiences in the hybrid realm. Toward that goal, the design spaces revealed during the pandemic can serve as inspiration or can be adopted while designing hybrid interactions to promote greater accessibility and affordability for individuals.

6 Limitations

The work has a few limitations that are important to discuss. First, contextual circumstances of the pandemic "phases" might impact our findings. As the COVID-19 pandemic evolved rapidly, the restrictions on public spaces and social gatherings constantly changed at each phase to contain the spread of

the virus (Mosby, 2020). Further, the pandemic was in its early stage at the time of this study while individuals' adaptations of activity and space were still happening and had not yet been settled. Therefore, the findings provide a temporal snippet rather than a comprehensive overview of this prolonged crisis. Future research should investigate how rapid crisis-induced changes and practices adopted in the early stage of the pandemic persist or evolve in the post-vaccine world.

Second, our findings are focused exclusively on the individuals living alone in the USA, which may not be applicable in the context of other countries (e.g., Global South countries) because of multi-faceted aspects of tradition, culture, and social dynamics (Motahar and Ahmed, 2022; Sultana and Ahmed, 2019). There might be some parallels between the experiences of people living alone and people living with family members, partners, or roommates. However, a few adaptive activities are likely to be unique for individuals living alone. For instance, people living alone are unlikely to share their home workspace and additional household duties with others. Furthermore, people living with others may not consider grocery shopping as an in-person social alternative. Further research will be needed to examine the adaptation practices for the people living with others and compare them with solo-living people.

Third, our findings described space and activity adaptations that were salient across two age groups of our solo-living participants. We did not encounter significant age-specific differences among our participants' adaptation strategies and emerged tensions around adaptation. Potential explanations include that (1) our older participants were living independently in the community for ten years or more, (2) the majority of them were well-educated and tech-savvy (Table 1), and (3) they were healthy older adults without any physical impairments or cognitive declines. Future work should investigate adaptation strategies among older adults with a more diverse socio-demographic background and varying physical and cognitive abilities to unpack age-specific differences, challenges, and opportunities in the context of pandemic-invoked adaptive activities and spaces.

7 Conclusion

The global COVID-19 pandemic and resulting disease mitigation policies (e.g., lockdowns, social distancing, self-quarantining, etc.) have vastly disrupted people's individual and co-located regular activities at home and public spaces. People dramatically changed their usual activities and the spaces where they are performed to address pandemic disruptions. Based on interviews with individuals living alone in the community, we identified both non-technological and technological ways that an individual adapted their activities. The findings revealed that the adaptation strategies (i.e., making small adjustments, finding alternatives, and transitioning to the virtual sphere), which involved rearranging and decoupling activities and their associated spaces, altered the

relationships between space and activity. Furthermore, the changed relationships resulted in tensions around adaptations, such as the changing nature of social interactions, home spaces, and the complexity of multimodal communication. Based on the findings, we propose a framework reflecting on the changing nature of space and activity. The framework will facilitate the understanding of spatial practices and meanings of the spaces. It is critical to rethink the meanings of space and their entanglement with activities while space and activities are reconfigured in response to the pandemic. We encourage HCI and CSCW researchers and practitioners to expand their work on researching and designing technological systems to support adapted activities decoupled from its physical space to facilitate individuals overcoming the challenges of adaptations. Towards that goal, we propose design implications for future socio-technical systems exploring opportunities to support adaptions of activities and spaces.

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Declarations

Ethical Approval

The study protocol was approved by Indiana University's institutional review board.

Consent to Participate

All participants provided consent (verbally or via email) to participation and study session recording.

Competing interests

The authors declare that they have no competing interests.

Authors' contributions

NN collected and analyzed data, and drafted the manuscript; CFC, CC, KC revised the manuscript; CC, KC supervised. All authors read and approved the final manuscript.

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Availability of data and materials

Not applicable

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