The Show Must Go On:

A conceptual model of conducting synchronous participatory design with children online

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Co-designing with children in an online environment is increasingly important due to external factors, such as the COVID-19 pandemic, and the diversification and inclusion of youth participants. Many prior studies about co-design with youth focus on co-located or asynchronous online sessions. However, conducting synchronous online co-design sessions adds layers of complexity and uncertainty to collaboration. This paper introduces a model explicating factors to consider when co-designing with children synchronously in an online space. We examined ten consecutive intergenerational participatory design sessions online where children (ages 7-11) and adults designed new technologies. Along with highlighting unexpected moments and interactions, we use theories of improvisation to guide our understanding of dynamic situations that are out of the control of researchers. This work contributes to improving theoretical understanding of improvisation as a method of inquiry for co-designing with youth, and offers practical suggestions for suitable online co-design techniques and implementation.

CCS CONCEPTS • Human-centered computing • Human computer interaction (HCI) • HCI theory, concepts and models

Additional Keywords and Phrases: Participatory design, Improvisation, Children, Design methods

1 INTRODUCTION

In HCI, children are important participants in co-designing future technologies for other children. Only today's children can reflect on the current time of what it is like to be a child, and propose which technologies they want to use. Most studies for co-design with children have been developed for co-located in-person sessions [34, 37, 48, 51, 67]. Yet there are many situations when one must co-design online synchronously, not just as an alternative. In extreme cases, online could be the only mode of interaction that is possible for some groups of children. For instance, children participants could have health issues, transportation limitations, and time constraints of adult caregivers, which could limit their participation in co-located sessions [45]. Participating in co-located participatory design (PD) sessions can be seen as a privilege for families who have flexible schedules and easier transportation options. Some scholars have recognized this limitation and attempted to create PD workshops in neighborhood community centers, which are often more accessible places for some local participants [44, 65]. However, for some families, having to be in a fixed place at a specific time for a workshop can present other challenges, as it can overlap with work hours or it can be hard to access if they live in remote and rural areas [11, 59]. Therefore, in this work, we aim to explore co-designing synchronously online which affords us to accommodate more families and situations when online interaction is the only option.

For many people in the world, the COVID-19 pandemic in Spring 2020 was one of these constraining situations. Our team typically co-designs with children (ages 7 - 11) in-person, and we were forced to conduct synchronous participatory design sessions online. Going online synchronously introduced many complexities and ambiguity, particularly when co-designing with children. Many of the methods and techniques we used to interact with children were initially designed for co-located sessions. Therefore, we had to quickly modify existing techniques, and learn how to design, communicate, and collaborate on different online platforms and tools. While prior literature investigates distributed co-design [11, 35, 55, 56, 59], many studies discuss asynchronous (occurring at different time) [11, 35, 55] and hybrid models (mix of synchronous and asynchronous session) [56, 59] to accommodate time differences. There are limitations of co-designing in an asynchronous model as young children have to be assisted in the absence of the facilitator and the child has to understand how to use and co-design with the platform (e.g. Facebook, Minecraft) [35, 55, 56].

Synchronous video chat, on the other hand, supports in-the-moment interactions with the help of facilitators. Studies have shown the value of presence and relationship building that arise from synchronous video chats within group of teenagers and family members [2, 6]. However, synchronous online sessions can also be disrupted by numerous external and internal factors because sessions occur in real-time. Because fewer co-design sessions on synchronous platforms have been studied, we have found little knowledge in HCI research to help understand how to navigate this complex space to co-design with children design partners. Given that the COVID-19 pandemic may isolate children longer, there is an imperative need to support the child-computer interaction community through new knowledge of how to effectively co-design through synchronous online means.

In this paper, we identify and discuss the new considerations we need to take when moving to a synchronous online space. We examined ten consecutive intergenerational participatory online design sessions of an intergenerational co—design team (called *KidsTeam UW*), where children (ages 7 - 11) and adults co-designed new

technologies together through video chat. Our design team participated in online co-design sessions using *Cooperative Inquiry*, a PD method focused on children and adults as equal and equitable design partners [14, 15, 21, 64]. We conducted and video recorded a total of ten PD sessions with ten children during the months of April to July 2020. We interviewed all ten children to learn about their experiences in the session. We triangulated across our data to analyze co-design session videos, interviews, and artifacts to address three research questions:

RQ1: What are project logistics considerations when co-designing in a synchronous online space?
RQ2: What are online factors considerations when co-designing in a synchronous online space?
RQ3: What kinds of participant interactions do we need to consider when co-designing in a synchronous online space?

Through our investigation, we learned we could not create a 'how to' model of doing PD synchronously online with children, because there are many unexpected moments and interruptions that are out of the control of the facilitators. Therefore, we turned to literature on ***improvisation*** [27, 30, 40] for inspiration to make sense of our data as disruptions occurred, and people frequently needed to modify session plans. Improvisational theories also focus on the collaborative and emerging nature of the environment and assist in understanding what roles a facilitator can play in emerging situations, as well as how they can incorporate ideas from participants [3, 19]. Talented artists, comedians, and skilled architects often embrace disorder to make the most of any situation [40]. In our work, we had to be agile and swift when running our co-design sessions online, where unexpected situations arose frequently. With more uncertainties, we had to be willing to diverge from planned techniques in the session and leverage ad-hoc approaches to continue to engage with children to co-design.

Drawing on improvisation theories, we developed a conceptual model and explicating factors to consider when co-designing with children synchronously in an online space. Our model consists of three themes of consideration for improvisation during online co-design sessions: ***Project Logistics***, ***People and Setting***, and ***People's Co-design Interactions***. We contribute a model that offers researchers a lens to scaffold and reflect on synchronous PD sessions and supports them in identifying factors to improve for their future design sessions. Overall, we make three contributions to the HCI community:

1. Empirically, we uncover the implicit and nuanced complexities of engaging in synchronous online co-design sessions with children and adults.
2. Theoretically, we extend Kang et al.'s [30] HCI improvisation features to consider improvisation as a way to balance the tensions in the known and unknown factors for synchronous online co-design.
3. We provide design recommendations and ethical implications for engaging in online co-design through improvisation.

2 RELATED WORK

2.1 Children as Design Partners

Participatory design (PD) focuses on the democratic means to engage end-users in the collaborative work processes to increase the utility of designs [28]. PD projects have roots in the spirit of democratizing the workforce, which trace back to the 1970's when researchers included trade union members in designing new technologies [42].

Inclusion of users in the design process does not only develop viable designs [53] but also support the empowerment of users in shaping the direction of innovating technologies [38]. While there are multiple methods of involving the end-user to varying degrees in the design process [31], we specifically focus on working with children as co-design partners using the method of Cooperative Inquiry [14, 15].

Druin [14, 15] developed Cooperative Inquiry to allow idea elaboration between both adults and children by equally valuing the voices of children and adults alike. In this PD method, children are considered designer partners who hold expertise in being a child. In order to be design partners, it takes time and effort to build and sustain relationships. Therefore, researchers work with a small number of children, as opposed to a large group, primarily work with children ages 7 -11 as they can articulate their ideas. Yip et al. [64] adds how the partnership between children and adults is not static, but rather a combination of dynamic interactions over time. Many scholars have worked on creating new techniques to generate a more balanced relationship between adults and children [13, 20, 22, 41, 58, 61].

To engage in PD, designers can use *design techniques* to communicate and co-design with children. Walsh et al. [60] created a framework to help researchers select, create, and modify design techniques based on the understanding that each context differs. When selecting a technique, facilitators must consider their project goals, the context of their participants, and the limitations and advantages of the technique. When considering the project goals, techniques can be chosen based on the design stage that the project is in: from early stages of the design process (asking children how they perceive a topic), to later stages (asking to evaluate a higher-fidelity prototype). Techniques can differ by how much expertise a child has in designing with adults, and the kinds of accommodations a child may need to use the technique. Other aspects to consider when selecting a design technique include the cost of using the technique (i.e., materials), the portability of the technique to other contexts (i.e., field vs. controlled lab setting), and the amount of required physical interactions of the participants.

Although extensive work in children and PD exists, most of these studies only focus on designing together in co-located physical spaces. Some of these spaces are university labs [67], schools [13, 46], libraries [66], community centers [44, 65] and refugee camps [1, 16, 62]. Only a handful of studies have examined children's co-design in non-physical locations through distributed co-design [57, 59].

2.2 The Space of Distributed Co-design and Play

For distributed PD, researchers highlight three key distinctions: *synchronous* (occurring at the same time), *asynchronous* (occurring at different times), or *hybrid* (a mix of synchronous and asynchronous) [47, 51]. For asynchronous sessions, scholars have explored PD with adults on social media sites (e.g., Facebook) [35] or on researchers' own online platforms [57]. For instance, Walsh et al. created DisCo [57] a co-design tool for asynchronous distributed co-design. DisCo is a desktop-based tool that allows children from multiple locations to draw, make audio clips, and layer ideas on top of other children's ideas. In a hybrid model, researchers have investigated how children co-design in a three-dimensional gaming space (Kidscraft, a modification of Minecraft) [55, 56]. Despite the importance of the sense of presence and relationship building in co-designing with children, many current studies focus on the asynchronous mode. The asynchronous design sessions, however, lack the ability to support in-the-moment idea sharing. Additionally, asynchronous design sessions require multiple reminders for participation, as young children often struggle to participate [55]. In particular, distributed co-design (whether synchronous or asynchronous) requires an extra level of facilitation that is taken for granted in co-located contexts [57].

Multiple scholars have stated how synchronized platforms, in the form of video chats, can provide a sense of presence and connectedness [6]. For instance, Yarosh et al. [63] created ShareTable, a system that provides video chat and shared tabletop space for children to engage with their parents from faraway. Inkpen's numerous work in play and video conferencing functions have demonstrated that there are opportunities and challenges for using multiple cameras and hands-free devices for telepresence, such as playing with multiple mice setups [25, 26]. However, both Yarosh, Inkpen, and others have only created conceptual ideas and prototypes, which are not yet mainstream consumer devices. Few, if any, studies have looked at the role of video chat and online synchronous co-design for an entire intergenerational team. This calls forward the need for an investigation into the construction and facilitation of meaningful synchronous remote co-design sessions with children as design partners.

Our study focused on synchronous sessions, which required more in-the-moment decisions. For researchers who have studied distributed co-design, the motivation was to overcome different time zones. In our case, the children were all co-located in the same time zone and we focused more on emphasizing relationship building in synchronous sessions, which supported participants' sense of presence. However, because numerous unknown and unpredictable factors exist in synchronous online co-design (e.g., technology infrastructure disruptions, people's lack of engagement), we needed a theoretical model that allowed us to be flexible, but still provided guidance and structure. Therefore, we turned to improvisation in HCI as a theoretical concept to help guide our investigation.

2.3 THEORETICAL FRAMING

We explore how improvisation in the arts could help us in understanding the unexpectedness of working with children in an online space. There are multiple ways to interpret improvisation based on its context. In music, improvisation is 'playing extemporaneously' or without written music [43]. In health education, improvisation are judgement calls, which are made in-the-moment in crisis situations [24]. To improvise is also to draw upon one's own knowledge and focus on the very moment to make the best of the given situation [40]. As improvisation emerges when we are forced to deviate from pre-determined plans, the underlying implication is that there was a 'right' plan to be followed. Therefore, improvisation is often associated with being inferior as it is seen as a substitute of a pre-established rule. In other words, improvisation is a back-up plan when the original plan is impossible [32]. However, it is important to note that while it is true that improvisation emerges as a response to unanticipated situations, it also can emerge voluntarily [27]. Artists, musicians and designers have valued improvisation for creative practices. While improvisation emerges from a response to a breakdown or glitches, it also emerges to accommodate creative practices. For example, artists and musicians sometimes purposely deviate from their original plans for creative purposes, such as jazz musicians adding a 'blue note' to discover new musical phrases [23].

Scholars also defined different levels of improvisation [29]. In the first level, modest adjustments are made to the pre-existing structure. For example, a jazz musician starts to diverge after playing their standard familiar notes to people. At the second level, the music starts with hardly any similarities to the pre-planned structure. However, there are moments it imitates the pre-planned structure. In the most extreme level, the improviser discards the whole activity and starts to compose new patterns. When the activity is discarded, the time used is not considered wasted but a time to discover new ideas based on previous knowledge by interacting with the old activity. Some artists deliberately make detours and accidental interactions to reveal creative ideas from the changed circumstances [49]. We see an opportunity to introduce a model of improvisation for working with users in PD

methods, given that co-designing with children is full of noise and disorder. Moving to the online space adds even more complexity, as there are technical glitches and breakdowns that can occur.

For our analysis, we rely on Kang et al.'s [30] five key features in HCI improvisation. The five features illustrate different manifestations of how improvisation emerges in practices.

- *Reflexivity* states that improvisation is not purely random, but that there is constant trial and error for constructing creativity.
- *Transgression* states that improvisation is not always a passive learning mode as practitioners actively encourage unforeseen factors in order to promote discovery.
- *Tension* states that when a practitioner strives for both freedom and structure, improvisation emerges.
- *Listening* is essential in order to be aware of the changing factors of a situation. Listening in design closely parallels listening in improvisation.
- *Interdependence* discusses how improvisation is co-constructed with other relationships and environments.

3 METHOD

3.1 Context and Changes

Our investigation is part of a larger project of an intergenerational co-design group where adults and children design new technology for children, with children. Before COVID-19, KidsTeam UW team members met twice-a-week afterschool for 90 minutes. During the in-person 90-minute sessions, children and adults gathered to first share snacks provided by the researcher (snack time), afterward the researcher prompted the children to begin thinking within a design oriented mindset by asking the question of the day (circle time), the team had a design session for around 45 minutes (design time) and the session ended with group discussion and reflection. The team has worked on multiple design projects with other faculty members, students, industry partners, and librarians.

In March 2020, due to the COVID-19, our university was closed to the public and families had to stay quarantined. From March to April 2020, we spent one month reconfiguring KidsTeam UW to transition the group to only synchronous online. The lead principal investigator opened up the possibility of still being connected through a video chat platform. Families of the children allowed this option, which gave us the opportunity to explore how to co-design with children during this difficult time.

A number of changes needed to be made to make synchronous online co-design more viable. First, based on the attention span of young children, the session time was reduced from 90 minutes to 75 minutes. We also changed from meeting twice-a-week to once-a-week to ease children into the new process. Although the new session format had no initial snack time, we followed the rest of the previous session format with reduced time. For example, we included questions of the day to prep and prime the participants to engage (10 minutes), design sessions to engage together (25 – 35 minutes), and discussion time to summarize and reflect on the session (15 minutes).

3.2 Participants

The team consisted of adults from the university (researchers and undergraduate students) and child participants ages 7 – 11 (n = 10). With the exception of one new child, who had not participated in any of the previous in-person co-design sessions, the nine children were all existing members of the co-design team. Their previous participation

in KidsTeam UW ranged from six months to four years (Table 1). The one new child (Suga) was recruited because she showed interest in the past but her caregiver could not drive her to in-person sessions. While adult participants were situated across four different time zones (Korean Standard, Pacific Standard, Central Standard and Eastern Standard), all the children were in the same time zone (Pacific Standard).

Table 1: Participants demographics (pseudonyms)

Child Pseudonym	*Age*	*Gender*	*Ethnicity*	*Years in KidsTeam UW*
Alan	11	Boy	Hispanic	4
Ethan	8	Boy	Hispanic	2
Hope	10	Girl	Asian/White	2
Jack	8	Boy	Asian/White	2
Marcus	10	Boy	White	2
Mia	8	Girl	Asian/White	2
Ryan	11	Boy	Asian/White	4
Sarah	7	Girl	Asian/White	3
Suga	10	Girl	Asian/White	0
Tae	10	Boy	Asian/White	3

3.3 Design Sessions

We held a total of ten design sessions from April to June 2020 on Zoom (a video/audio chat streaming platform). We recorded audio and video of the design sessions using Zoom's in-cloud recording feature. We collected all data following the procedure approved by the University of Washington's Institutional Review Board. In Table 2, we present the different activities that occurred during each session and the technologies used. For each session, we also saved the generated artifacts and the first author wrote field notes both before and after the session for planning, reflection, and analysis.

Table 2: Design Sessions

Sessions	*Design Questions / Project Goals*	*Design Stage*	*Design Technique and Digital Tools*
1	What is the future of KidsTeam UW online? Our goal was to understand how children wanted to communicate online.	Early ideas	Bags of Stuff technique: Children used their own arts and crafts materials found at home. The camera in Zoom was used to share their design.
2	What do children think about the SunSmart technology ideas (Session 1)? Our goal was to understand children's initial feedback on prototypes for sun protection. SunSmart is an application to teach children about sun protection.	Mid Prototype	Line Judging technique: We shared the mid-prototype through a storyboard, which had some initial sketches that would be included in the mobile application. Children shared their preference of the prototypes by voting by color. PowerPoint and the Screen capture tool was used to capture their vote. Zoom was used for discussion.

3	How can we design for refugee children? Our goal was to understand how refugee children can also co-design using SMS texting, radio, and loudspeakers.	Early ideas	Bags of Stuff technique: The researchers sent children the same arts and craft materials (colored paper, popsicle sticks, and pipe cleaners). The camera in Zoom was used to share their design.
4	What can librarians do to help kids online? Our goal was to understand what online library sessions would look like.	Early ideas	Comicboarding technique: Children filled in blank slides in PowerPoint of what a fun library session would look like. For children who drew on a physical piece of paper, the adults took a screen shot. Zoom was used for discussion.
5	What do children think about the SunSmart technology ideas? (Session 2)	Mid Prototype	Big Paper technique: Children designed on their piece of paper using pencil to improve prototypes. The adults shared the prototype ideas in PowerPoint. Zoom was used for discussion.
6	What do children think about online safety? Our goal was to understand what children regarded as online safety issues and solutions.	Early ideas	Comicboarding technique: Children filled in a blank slide about what made them upset when they were online and possible solutions. We used PowerPoint to design. Zoom was used for discussion.
7	How would positive 'Would You Rather' (WYR) questions influence children's' responses? Our goal was to understand children's priorities and values in decision making. Would You Rather is a game for understanding people's preferences [47].	Early	Line Judging technique: Children voted on WYR questions. PowerPoint and the Screen capture tool were used to share the questions and to capture their choices. Zoom was used for discussion.
8	What would children want to do if they can control computers with physical objects? Our goal was to understand children's use of an AR device that detects physical objects and movement.	Late evaluation	Wizard of Oz technique: Adults gave a simulation of a new technology based on children's interaction. PowerPoint was used to write and sketch ideas. Zoom was used for discussion.
9	How would children create Would You Rather questions regarding Slither.io? Slitheri.io is an online game the children liked playing.	Early ideas	Line Judging: Children played each other's WYR game by voting with their hands up and low. PowerPoint was used to share questions and Zoom was used for discussion.
10	How would children still have fun with their friends during	Early ideas	Comicboarding: Children filled in a blank slide of how they can have fun with their

quarantine? Our goal was to understand what 'distant play' would look like for children.	friends while they are apart. PowerPoint was used to add in ideas and Zoom was used for discussion.

3.4 Interviews

To understand how children experienced the online synchronous co-design sessions, we conducted semi-structured interviews with all ten children in July 2020. We began by asking questions about what their environment looked like when they came online and what other activities (e.g., school) they had online during COVID-19. Second, we asked questions regarding their experiences engaging with the different co-design techniques we used in the online space. Third, we asked about the different tools in Zoom, such as chat and breakout rooms. Finally, we asked how they compared the online sessions with the in-person sessions (with the exception of the child who only participated in online sessions). The interviews lasted for approximately 25 minutes and were transcribed for analysis.

3.5 Data Analysis

We first used an inductive and grounded method to understand the emerging themes of moving to an online space [6, 7]. Five co-authors observed and annotated the 10 session videos. Primary and secondary observers/reviewers open-coded the data after annotating the videos. We used Miro Board, an online collaborative whiteboard platform, to share parts/quotes from videos. Based on the quotes that were found in the videos, the researchers analyzed overall patterns and started to develop themes. Afterwards, we deductively compared our themes to the FACIT PD model [60], which takes into consideration the co-design participants' needs and experiences, the design goals of a session, and the characteristics of design techniques. We then followed a deductive approach by mapping the FACIT PD model and applying Bronfenbrenner's ecological theory of human development and socialization [5] for a holistic view of the data. While coding the data and attempting to create a framework inclusive of different considerations, we prioritized extracting the theme that would be 1) unique themes specific to the synchronous online space. We chose these themes because there is already an extensive body of work that supports in-person interactions; and 2) that other PD researchers could find these broad themes helpful for conducting their own sessions. During the analysis, the researchers noticed that there were many factors out of the researchers' control in the online space. This prompted the group to turn to theories of improvisation in order to make sense of these uncertain situations. Finally, to analyze the clustered themes of our data we used Kang et al.'s [30] five features of improvisation. Kang et al. outline the practices that emerge when engaging in improvisation, which include: reflexivity, tension, listening, transgression, and interdependence. We triangulated our findings with themes that also emerged from the children's interviews.

4 FINDINGS

We first introduce the conceptual model of improvisation in synchronous online co-design (Figure 1). In Sections 4.2 – 4.4, we describe each theme from the conceptual model, their subthemes, and provide example vignettes with analysis. As we describe our data, we indicate facilitators with superscript F (Name^{F}), children with superscript C (Name^{C}) and adults, who are not facilitators, with superscript A (Name^{A}).

4.1 Introducing the Conceptual Model

Based on an in-depth analysis of the ten recorded synchronous online co-design sessions, children's interviews, and artifacts, we developed a conceptual model (Figure 1) for consideration when conducting PD with children online. After conducting multiple rounds of inductive and deductive processes, we created our conceptual model. Our model is informed by Walsh et al.'s framework on how to design PD techniques [60] and Bronfenbrenner's ecological systems theory [5] for a holistic view of the data. Our conceptual model consists of three themes: 1) Project Logistics; 2) People and Settings; and 3) People's Co-design Interactions. Project Logistics are the properties of the co-design session that influence which design techniques and digital tools are used for synchronous online sessions. The theme of Project Logistics is based on portions of the FACIT model [60], which concern the important features of a co-design technique (deductive). People and Settings refers to the external factors that exist in the multiple locations of the participants (e.g., technology infrastructure, location changes, spectators). This theme stemmed from the unique characteristics of a synchronous online space where outside factors, such as technology and infrastructure, influenced the online design sessions (inductive). People's Co-design Interactions emphasize the specific engagements that occur when adults and children meet synchronously online. This theme stemmed from our observations from co-design sessions. Interestingly, this theme also connects to Makhaeva et al.'s work on the important balance between freedom and structure for creativity in design [36].

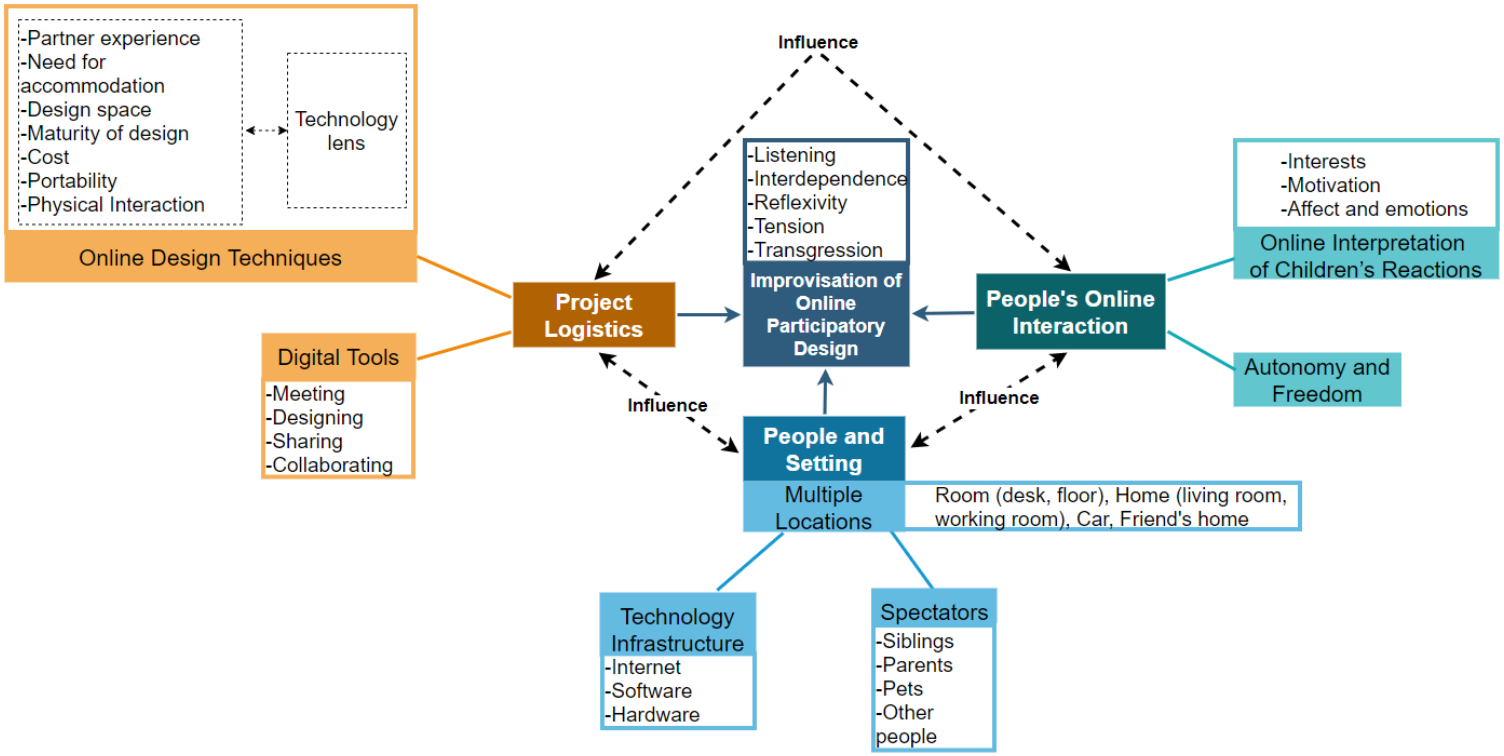

Figure 1: A conceptual model of conducting synchronous online participatory design with children.

All three themes in our conceptual model influence each other with different limitations and unexpected surprises throughout the sessions. For example, an unexpected Internet outage in a facilitator's location (People and Settings) can influence how a design technique may need to change (Project Logistics), and how the adults and children react to disruptions of the online co-design (People's Co-Design Interaction). The core concept is the *Online Improvisation* engagement of participants that needs to occur in order to mitigate tensions, either as micro moment-to-moment or macroscale shifts. These improvisations tie back to Kang et al.'s [30] five improvisations in HCI: listening, transgression, tension, interdependence, and reflexivity. We use video vignettes to illustrate moments from the PD sessions, as well as quotes from children's interview transcripts, to highlight their reflections on the sessions. We employed the comparative case study method [10], which allowed us to closely examine the expected and unexpected moments that occurred in online co-design sessions with adults and children over time. We organize our findings section by first describing the emergent sub-themes. Afterwards, we provide examples from videos, artifacts, and interview data to illustrate the range of participants' synchronous online co-design experiences, and then outline connections to improvisation theory.

Our model does not present a 'how to' approach for doing PD with children online because every PD session, including its environment, participants, and context, is unique. Rather, our model provides researchers information about different factors and corresponding scenarios to use for reference before entering the session. Prior work states how people are able to improvise better when they have a known structure in mind [50]. Applying frameworks from theories of improvisation, we were able to reflect on the various uncontrollable situations during our sessions in depth and embrace these moments as opposed to avoiding them.

4.2 PROJECT LOGISTICS

Every co-located design session with children has its own logistics to be managed, such as booking a location, finding time to meet with participants, and handling transportation. Additionally, planning co-design sessions with children requires determining what techniques can be used for communication between children and adults [60]. When considering the logistics of an online synchronous session, we compared issues from physical locations to those from online spaces. *Project Logistics* focuses on the characteristics of a session that pertain to how the session might be planned and implemented. For our conceptual model, we outline two subthemes of Project Logistics: 1) the Techniques needed to run a synchronous online co-design session; and 2) the Digital Tools that make online synchronous co-design possible.

4.2.1 Creating or Modifying Techniques for Online Synchronous Co-design.

Techniques for co-design have mainly been studied in physical co-located sessions. When we consider Walsh et al.'s [60] dimensions for choosing, creating, and modifying techniques for co-design, there is no direct distinction between demarcating techniques for physical spaces or online spaces. Our conceptual model notes that when implementing synchronous online for co-design with children, previous co-located techniques can be modified for online interactions using Walsh et al.'s [60] dimensions as a guide (Table 3). As techniques for online synchronous

co-design are intractably tied to meeting and collaborating online, we note that the rest of the seven dimensions of Walsh et al.'s [60] framework all must be considered through a technology lens.

Table 3: Walsh et al.'s [60] Dimensions for Online Co-design

Dimensions	Description	Technology lens
Partner experience	How much co-design experience is needed to participate?	How much experience do children have with the digital tools for online?
Need for accommodation	What is the age and cognitive ability of the participant? Does the participant need accommodation to design?	Does the participant need help with the online technology?
Design space	How specifically is the problem defined?	Can the problem definition be translated to an online space?
Maturity of design	How far along is the current design in the design process?	Is the idea and/or prototype ready to be explored online?
Cost	What is the financial price of materials for required techniques?	What is the cost of the technology for co-designing online (e.g., time, money)
Portability	What is the physical mobility of the artifact generated from the technique?	Can the technology properly record, view, document the technique online?
Physical interaction	What is the degree of participant movement? (low: children sit and draw, high: children move between rooms)	How much does the participant need to interact with the digital tools?

4.2.2 Digital Tools for Meeting and Designing.

The shift from physical to synchronous online co-design requires consideration of the technological tools for remote access: including software, hardware, and physical materials. Tools enable participants to communicate with each other. In physical co-located sessions, tools such as whiteboards, arts and crafts materials, and tables can be shared among participants while situated in a common space. Our data suggests that for synchronous online sessions, different digital tools are needed to support the following online interactions:

- Meeting: How do the participants gather together to communicate in online space?
- Design: How do the participants create new artifacts together in online space?
- Sharing: How do the participants present their ideas and artifacts together in online space?
- Collaboration: How do the participants work together in online space?

A single digital tool does not always address all four factors; therefore, a combination of tools might be needed to support a session. We consider the software and hardware used to execute a technique as a tool, including: access to shared documents, virtual backgrounds, breakout rooms, and the mute button which were new tools to our PD sessions.

4.2.3 Two Examples of Technique Modifications.

In this section, we detail how we modified two existing co-design techniques for an online space: **Comicboarding**, which is used during ideation and scenario design; and **Line Judging**, which is used to evaluate multiple ideas. During in-person PD sessions, children could interact physically with design partners and had access to shared materials. In this new synchronous online context, accommodations to the techniques were necessary, given the limitations of being completely reliant on the technology to engage in the session.

Description of Comicboarding. Comicboarding [41] is a technique used to scaffold children's brainstorming process. When used in co-located settings, facilitators give children a piece of paper with three scenario panels: the first panel contains the context of the design problem and the last panel has the ending to the design problem. In the middle panel, children describe their ideas for how to arrive at a solution while a volunteer artist (i.e., an adult) sketches their ideas and designs out.

Modifications of Comicboarding Online. Our new meeting space, hosted on the video chat software Zoom, meant we had to modify Comicboarding by transferring the comic strip to a digital platform that still allowed for collaboration. For our design and sharing space, we aimed for a simpler solution and used a familiar digital tool, Microsoft PowerPoint. We created slide decks so that designers could easily import pictures and share them with others on their design team. We utilized Zoom's Breakout Rooms feature for collaborative small group discussions. We created copies of a PowerPoint slide for each group of adults and children, as well as illustrated the design problem at the beginning of the slide deck and the story's conclusion at the end of the slide deck. We left blank slides in the middle of the PowerPoint, and asked the children how they would fill the design story inside. Like Comicboarding in-person, the children directed the adults to draw the images around the slide, asking them to find visuals online (e.g., Google Images), and writing in the textboxes themselves. The level of accommodation online was higher than in-person sessions because we had to consider how children voiced their ideas together and support volunteers in illustrating the children's concepts. The physical interaction was low, as the children were still in front of their computer while directing the adults. The cost of executing the technique was high, in that each small group needed an adult facilitator to take time to draw out their ideas.

Example Comicboarding Online Vignette. During Session 4, we used our modified Comicboarding technique to get children's ideas on how librarians can help other children remotely. Ethan^{C} asked Kim^{F} to find images of Yoda (a character from Star Wars). After the adults found the images online, Alan^{C} and Tae^{C} discussed which one was the best. They all agreed upon a "Baby Yoda" that was drinking soup. Tae^{C} then stated that *"In the library you can't eat, maybe we can eat with the librarian online"*. In another group, Suga^{C} decided to draw directly on a white paper, and then held her picture up to the camera. Tiffany^{A} took a picture (Figure 2) and imported the photo into the slide deck. At the end of this session, a researcher noted that one limitation to the technique was that "only the vocal kids [were] able to participate."

Connections to Improvisation for Comicboarding. In improvisation**, 'listening'** highlights the importance of being aware of how people interact with the environment and with each other [30]. In this example, we were interacting differently than how we would interact in-person: the adult facilitator only heard children's voices, rather than seeing social cues in-person (like what Ethan^{C} was drawing or what Alan^{C}'s movement was). The adults and children could only see one comic board frame at a time. For example, in the online space, children could only see one slide at a time while adults may have multiple screens to view many slides at once. When trying to design what should be on the next slide, sometimes both children and adults forgot what was in the previous slide. We noticed it was especially difficult for children to focus on sharing their ideas when they could only see one part of the comic board. We needed to provide frequent reminders to the children about what was on the previous slide. One affordance in modifying this technique for an online space was that the children did not spend too much time drawing images, and utilized the Internet to search for a range of images instead.

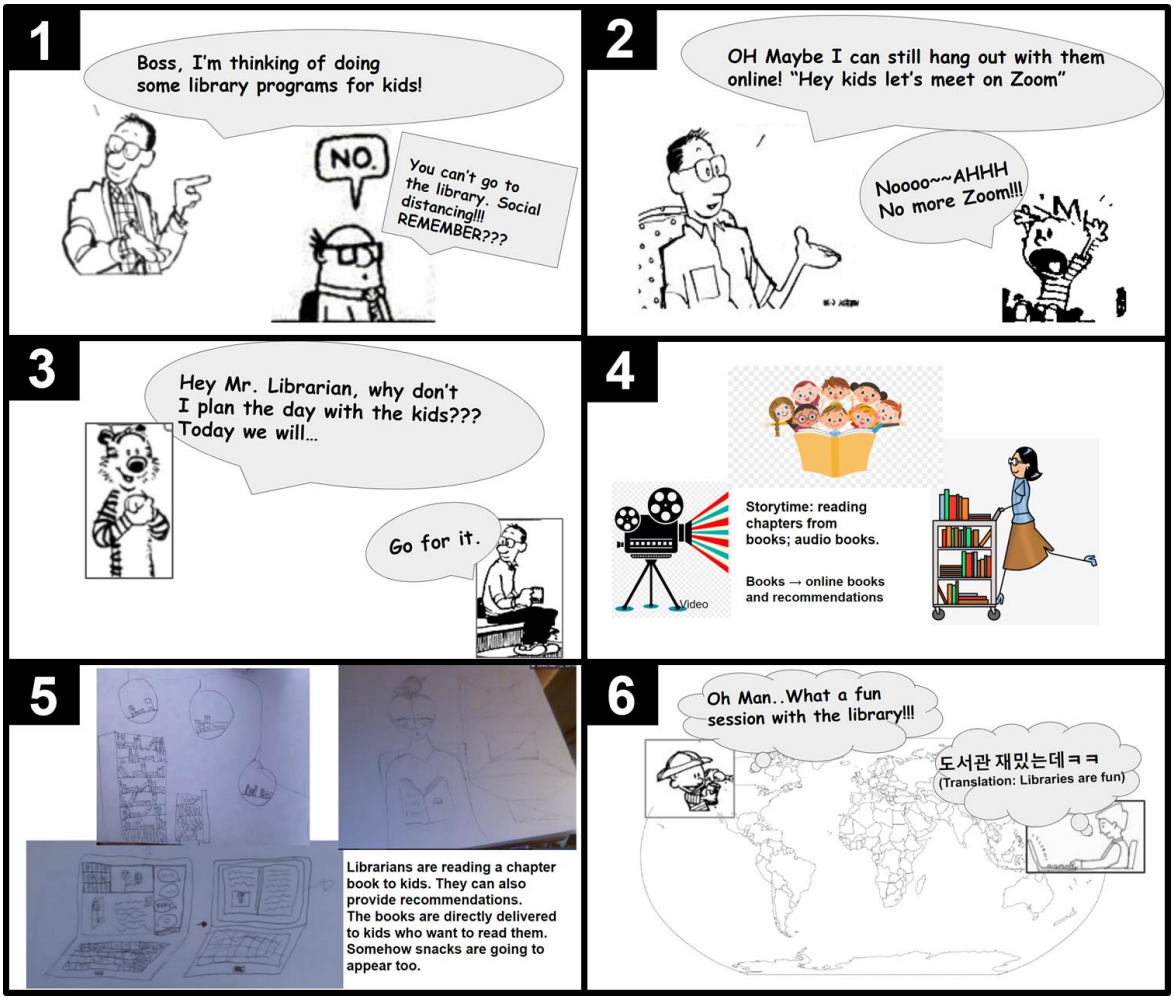

Figure 2: An example of Comicboarding technique in a shared PowerPoint. Slides 4 and 5 were the empty slides for the children to fill in.

Description of Line Judging. Line Judging [60] is a technique used to support children in evaluating multiple designs in an engaging way. In-person, facilitators draw a line on the floor or wall and the children start by standing in the middle of the line. Facilitators share each design idea, and the children indicate their preference of the idea by positioning themselves along the line (positive on one side, negative on the other, unsure in the middle). Once everyone is in their position a facilitator takes a photograph. Afterwards, facilitators ask the children why they are standing in that particular place. This technique allows children to vote on a spectrum using their bodies.

Modification of Line Judging Online. In the online space, the children could no longer move around the room to indicate their preferences. We needed to find an engaging way for them to express their vote preferences on a spectrum. We first considered which digital tools children would most likely to have access to, and how we could capture everyone's vote for a larger discussion. While we were aware of the built-in Zoom features for voting, such as the thumbs up reaction, we had to make necessary adjustments because: 1) some children were using phones,

which made it difficult for them to navigate desktop features; and 2) some families did not have the latest Zoom software updates. We chose to vote with bright colors because video chat afforded visualization of voting preferences, and we knew color was something children could differentiate between. We asked children to find three objects in their home: one red, one yellow, and one green. To capture everyone's vote for a larger discussion, we decided to use the screen capture tool so that the adults could see everyone's vote on a single screen in a slide deck, which, in turn, supported sharing. The facilitator then shared the screenshot with everyone to view the results and discuss.

Example Line Judging Online Vignette: During Session 2, we used our modified Line Judging technique to get children's evaluations of different sun protection technologies. To vote, adults used objects from their desk (*e.g.* markers). However, we observed that the children took a more creative approach. Ryan[C], for instance, voted with a new stuffed animal every time. Children said they liked seeing what their friends had at home (Figure 3).

For Session 7, we modified the Line Judging technique once more to have children vote with their hands in vertical positions (Figure 3). After showing a design idea a facilitator said, *"If you like the first idea, put your hands above your nose, If you like the second idea better, put your hand below your nose."* During the session Marcus[C] said, *"My hands are getting tired. Can I put my hands down?".* Unfortunately, the two facilitators did not respond to his comment because they were busy (one was giving instructions and the other was taking the screenshot). We did not realize this until we analyzed the video data. In his interview, Jack[C] made a similar comment to Marcus[C], *"It would be too close to the screen and it really hurts your arm. Or, if you just hold up a color, when you just want to do that for everything, it can kind of make your arm sore."* Despite some of the physical discomfort, our technique allowed for the inclusion of all the children's voices because they were able to express their opinions without relying on verbal processes.

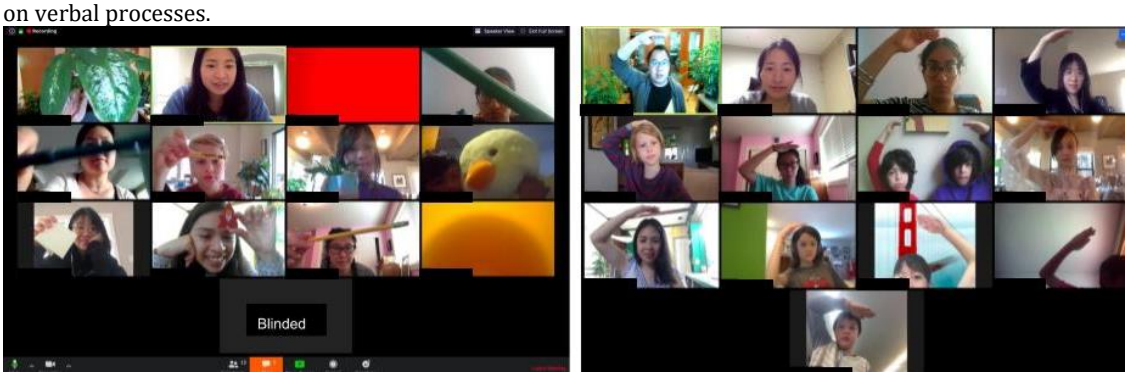

Figure 3: Screenshot of the result of voting by color and hand

Connections to Improvisation for Line Judging. In improvisation, '**reflexivity'** describes how artists, through multiple and iterative attempts, need to try different directions, make sense of multiple interactions, and continuously reconstruct their meaning in new contexts to arrive at a satisfactory point in their process [30]. A common misconception is that creativity comes from randomness. In reality, artists must go through trial and error before arriving at their final composition. In our process, after we tried to modify the Line Judging technique by using colors, then by using hands, we were iteratively trying different approaches. Through an improvisation lens, we did not engage in the session in a linear model of learning, such as how to use one specific technology at a time. Rather, we took a trial and error approach that enabled reflexivity throughout the process.

4.3 PEOPLE AND THEIR SETTINGS

In this theme, we highlight factors within participants' settings that directly affected their interactions during the synchronous online co-design sessions including: 1) Location and Technology Infrastructure; and 2) Location and Spectators.

4.3.1 Location and Technology Infrastructure.

Location refers to the specific places from which children were joining our sessions. While adult volunteers tended to be fixed in their locations (e.g., single room with webcam), many of the children's locations shifted between sessions or even during sessions. At a micro-level, locations changed when a child moved around in their room, thus changing the view of the video. At a larger scale, children also moved to different rooms in their home, to different homes (e.g., their home and another family's home) and, a couple of times, child participants even called in from a moving car. Overall, there was constant variance in how much a child moved depending on their location. Based on their location, the technology infrastructure changed.

Technology infrastructure refers to the basic structures and facilities needed for participating in synchronous online co-design sessions. This includes children's access to high-speed broadband, bandwidth, software, and hardware at the moment of co-design. Children's access to technology infrastructure is not static, rather shifting at any given moment depending on their location.

Examples of changing location and technology infrastructures. For Session 7, we had a combination of technology infrastructure breakdowns when Raymon^{F} was facilitating. For context, Ethan^{C} and Alan^{C} are brothers who joined our sessions through one shared computer. Jack^{C} was moving from a room to a car in the vignette below.

Raymon^{F} :	"Umm, Ethan^{C} and Alan^{C}, why did you pick no cavities over gaming? I thought you'd pick gaming instead of no cavities. Let's see, Ethan^{C} and Alan^{C}! Are you guys frozen?? Oh no, they're frozen!"
Ethan^{C} and Alan^{C} :	(Their online video chat got disconnected) / *Alan^{C} and Ethan^{C} did not shift in their location but their technology infrastructure was not stable.*
Raymon^{F} :	(Quickly moves on to ask Jack^{C}) *"Umm, Jack^{C} what did you pick?"* (Facilitator notices that Jack^{C} was no longer in his room)
Jack^{C}:	(moving in a car)
Raymon^{F}:	(Surprised) "What did you pick? I can't tell when you're inside the car. Oh sorry, you're muted. Let me unmute you. Let's see… you're muted. Jack^{C} can you unmute?"
Jack^{C} :	"What were the options? I couldn't hear you. You sounded like robots."

This instance shows how Ethan^{C} and Alan^{C}'s challenges with their broadband in their location and Jack^{C}'s movement across physical locations came together to bring the design discussion to a halt. There was only so much Raymon^{F} could do to continue the conversation given that going online meant every child could be in any setting, which might interfere with their engagement and interactions during the session.

Connection to Improvisation. This vignette highlights how the design researcher was not able to execute the session because there were unforeseen disturbances as a result of the technology infrastructure and the location of each child. While one would typically want to avoid such situations, this moment can be explained by the concept of **'tensions'**, where an external structure disrupts the original plan [30]. This disruption is a motivation for artists who improvise to engage in the 'curiosity' of the unknown [30], wherein their interest in new contexts leads to a

larger realization. In this particular case, after the session, all the researchers could have engaged in dialogues about whether this disturbance was a larger structural problem, thus questioning our method and not the participants' actions and engagement. We might ask ourselves, how is our engagement dependent on bandwidth? How do we shift the responsibility onto us as researchers to explore alternative ways and methods for participants to be included regardless of their bandwidth capacity or shifting of locations? While we have not yet found answers for this session, we have identified the need to alter existing techniques for when there is a sudden disconnect.

4.3.2 Location and Spectators.

Not only does location influence technology, but spectators, who are a part of the location, influence technology as well. Spectators refers to the people other than the participant designers in a session. Children, at a young age, are rarely alone. As researchers we were often exposed to the children's shared spaces, which included other family members, siblings, parents, friends, and even their pets. Below, we give two examples of parents as spectators.

Example Vignettes. In Session 6, the facilitator of the session gave instructions for the children to draw their ideas for two minutes. While the children were all engaged in drawing, Jack^{C} stated it would be better for them to just go in the breakout room. In the background, we heard Jack^{C}'s mother correcting him saying that he should be drawing right now. In his interview, Jack^{C} reflected on how it was difficult to be himself with the disturbance of his parents and siblings in the room commenting on his engagement in co-design. He tried to find a closed space to have privacy. Jack^{C}'s mom sometimes answered the question for him, and was part of the session. In contrast, during Session 4 when we did a design on the topic of the future of libraries for children during COVID-19, Suga^{C}'s mother Jimin^{A} was next to Suga^{C} in the video chat.

Raymon^{F}: "Oh wait, Jimin^{A}, and let's hear what she says, what she knows about libraries."
Jimin^{A} : "Alright, I'm actually multitasking. It looks like I'm here but I'm actually working."
Raymon^{F} : "Oh I'm sorry. I thought you were here."
Jimin^{A}: "My computer is here. I apologize. Give me the question I will answer."

Connections to Improvisation. In improvisation, **'interdependence'** refers to how one's behavior is co-constructed and in relation to other actors and the environment. In our session, our improvisation was not only dependent on the children designers, but also on the co-constructed relationship with their family members in the room [30]. In the two examples given above, the spectators' involvement changes. While we invited pets, parents, and siblings to the session, we learned that someone being in the video chat frame did not mean that they were truly part of the session. By asking a question to the parent (Suga^{C}'s mother), we also engaged in the process of improvising. More specifically, we utilized the improvisational feature of '**transgression**', where we purposely deviate to learn something we did not know. Transgression is the process by which an artist purposefully invites unforeseen and unexpected factors into their process for discovery [30].

4.4 People's Co-design Interactions

This third theme examines the in-the-moment people engagements that happen during synchronous online co-design. We present two sub-themes that emerged regarding the individual's experience during the online co-design session: 1) Online Interpretation of Children's Reactions; and 2) Autonomy and Freedom.

4.4.1 Online Interpretation of Children's Reactions.

This sub-theme encompasses the ways in which facilitators interpret a child's interest, motivations, and feelings that influence their interactions online. In the online space, we had fewer visual cues to interpret children's emotions and experiences, given we could only see what appeared on the screen. Audio can also be limiting. Furthermore, if a child's camera was off, we had even fewer cues to draw on as co-designers. Understanding children's reactions is crucial because children express themselves using different facial expressions (e.g. confusion or boredom). Being online makes it more difficult to detect and interpret these cues. In Zoom video chat, we had to juggle between 10 – 15 faces in a grid on a single screen. Below we share two examples where children were highly engaged and two example activities that children disliked.

Example Vignettes. Children expressed in interviews they were the most engaged during Session 3 when they were designing ideas for remote co-design for refugee children. They also noted Session 9 was their favorite because they worked on improving the game Slither.io. In Session 3, Alice^{F} asked the children: "What do you know about children and refugees?" Then, she gave details about the project and asked, "What are the similarities between refugee children and regular children?" Afterward, Raymon^{F} played a one-minute video from UNICEF about children at the Shamlapur Refugee camp in Bangladesh. Hope^{C} recalled this being her favorite session because it challenged her to think out of the box. Suga^{C} stated that she liked the session she "like[d] helping my community". In Session 9, we asked children to design 'Would You Rather' questions based on their favorite game 'Slither.io'. In the interview, Marcus^{C} and Ryan^{C} stated how they liked that they were able to create questions on a game they were used to playing.

Some children had strong negative opinions about Session 5 when they worked on the Sun Smart project designing new technologies to teach other children about skin cancer and sun exposure. Tae^{C} stated it was the worst session because they were being asked to work on a topic that seemed "so obvious." Some children also did not enjoy Session 1, where we asked them to design the future of online co-design sessions with adults. Alan^{C} stated that he saw no point in designing for the future of co-designing online as there was no future for it.

Connections to Improvisation. Improv actors, especially who engage in comedy, need to '**listen'** [30] to their audience. They often use techniques such as prompting the audience with a question and, based on how the audience is answering the question, they will make jokes or certain actions diverging from the original plan. In our sessions, we also were improvising by reacting to how the children were answering the questions and helping them find personal connections to the projects. As a result of moving to the online space, interpretating interest and motivation is more difficult as we have fewer cues of what is occurring on-screen or behind the camera. In person, we were more aware of how the child was interacting with the group, which ultimately influences the group dynamics.

A big difference between children's favorite and least favorite sessions was how facilitators prompted the children to connect their interest to the activity. In Session 3 and 9, the facilitator was able to scaffold their interests into the design context and find cues for connections between the design challenge and the children's lives. However, in Sessions 1 and 5, the facilitator went directly into the session with minimum context to the problem and limited connections to the children's experiences. In contrast to the offline space, children could not work side by side with the adults and adults could not give them additional information when it seemed like the child did not understand the concept or the point of design.

4.4.2 Autonomy and Freedom.

In the online space, children had more autonomy to do what they wanted. For instance, because we are a public university, children had to ask for permission to go the restroom because we are a public university. When they met us online, they could leave the session even without letting an adult know. Autonomy and freedom thus refers to how each child had more control of their actions while in the synchronous online space. Makhaeva et al. (2016) states how, in the design process, it is crucial to find the appropriate balance between freedom and structure for creativity [36]. In the online space, if a child is not interested, motivated or do not understand the session, it is easier for them to disengage by simply turning off their camera and microphone [33].

Example Vignettes. In multiple sessions, there were instances when a facilitator would ask a question to the children and there would be no response back. In Session 10, Raymon^{F} asked the whole group, "What sounds do you like to hear as an alarm?". Children shared their answers after Raymon^{F} called out their names. Raymon^{F} moved on to Ryan^{C} to ask what he liked to hear. There was no response. Kim^{F} said that he might be muted. In his interview, Ryan^{C} shared that during the online session he would leave the session to get snacks when he was hungry. While adults thought there were limitations in technical infrastructure, children in their interview shared how they intentionally chose which activities to engage in. Ethan^{C} said he went on mute because there was noise from the dishwasher. Hope^{C} said she often needed to step out to check on her lizard.

In Session 9, we used a modified Comicboarding [41] technique, where the children shared their preference on 'Would You Rather' questions and the adult took a screen shot for conversation. However, during the session many children had their camera off which made it difficult to capture their preferences.

Connections to Improvisation. In improvisation, '**tension**' refers to instances when a participant tries to diverge from the structure [30]. While our technique had structure for what activities the child had to engage, the online environment offered more autonomy to the child to simply log off or turn off their camera and engage in a different activity. It was also difficult to do behavior management in the chatting space. However, for the children, it was important for them to have freedom over structure. We learned that for the children, this freedom was a way for them to get breaks. By using the private chat feature, they were building friendships even when they were not responding to the facilitator.

5 DISCUSSION

5.1 Revealing the Structure and Freedom in Synchronous Online Co-design

Prior work on children's co-design focuses mostly on co-located physical contexts [37, 51, 67]. Other children's co-design research in online settings has looked into opportunities for asynchronous online settings or using avatars in online game worlds [55, 56]. However, the COVID-19 pandemic has forced both children and adult researchers into quarantine for a long duration of time. As such, for many user-experience researchers and designers, working with children in synchronous online settings may become more normalized than in pre-COVID-19 times. In this study, we found that online co-design sessions hold similar considerations for designing with children as in-person do, while nonetheless introducing unanticipated and unscripted considerations. By considering synchronous online co-design as an opportunity for HCI improvisation, we reveal the tensions between structure and freedom, planning and destruction, and the clarity and fogginess that surface when implementing synchronous online co-design.

Much of the research on design techniques mitigate unanticipated dynamics with physical co-located sessions [37, 51, 67]. Through our conceptual model (Figure 1), we introduce different factors that could contribute to the

engagement of children in an synchronous online session: *Project Logistics, People and Settings, and People's Co-design Interactions*. By adapting theories of improvisation, and leveraging features of the improvisation process, we provide a lens to support facilitators/designers to better anticipate and address disruptions that will be caused by a number of different factors. We take inspiration from musicians, artists, and actors who embrace improvisation as a form of creativity, as opposed to noise, in viewing the unanticipated factors that emerge. However, as researchers in HCI note, improvisation in HCI is only possible from a deep examination of prior experiences and accumulated knowledge [30, 32]. In our research, we have engaged in years of investigation into physical co-located co-design with children and adults. Like others in the world, COVID-19 shifted our balance to an unfamiliar space to learn what new rules and knowledge exist to make synchronous online co-design possible. In this sense, our model offers a way to systematically consider the factors, which could improve and reexamine prior traditional techniques and interactions, for co-design in a virtual space.

At the same time, our conceptual model for synchronous online co-design is not a recipe for success nor a rigid, pre-determined plan. Nor is the model meant to allow researchers and designers to just "make stuff up" at the time of co-designing with children online. Improvisation is about managing and embracing risk and structure to allow new ideas, techniques, and interactions to flow. Whether online or offline, when doing co-design with children there is always unclarity, noise, and disorder. As we have shown in our findings, synchronous online co-design has different pitfalls and challenges that are not present in co-located physical contexts. Our model informs designers of what deviations to consider, supports the use of moderate adjustments, and encourages discarding an activity in the name of creativity. By suggesting an improvisational model for co-designing online, we further Kang et al.'s [30] five key features of improvisation in HCI towards designing together with children and adults in online synchronous situations:

- *Reflexivity:* Engaging in synchronous online co-design is meant to invite further exploration of new ways to creatively work with children and adults together.
- *Transgression:* Not everything in synchronous online co-design is meant to be planned out. Instead, we invite researchers and designers to deliberately add unplanned elements of disruption into the situations.
- *Tension:* Synchronous online co-design is all about balancing opposing forces. It can embrace both the physical and online engagement, the fixed locations and changing settings, and the talkers and quieter personalities.
- *Listening:* Participants in synchronous online co-design listen together at all the things going on, including the changing situation, the context and technologies, and what happens between children-to-children, children-to-adults, and adults-to-adults.
- *Interdependence:* Interactions do not just happen between participants in synchronous online co-design, but between child-adults and technologies, the techniques, and the settings.

5.2 On Timing and Scalability of Improvisation

As prior literature suggests in improvisation theories [3, 19, 30], improvisation does not simply occur during an online co-design session but could be understood **before**, **during**, and **after** the session. Going online was unexpected for all of us, including adults and children. Before each session we had to brainstorm what techniques we could use and how they should be modified to a new design space. When we entered each session, there were unexpected factors such as the children's location and the technological infrastructure. During the session, we

improvised how to react dynamically to these unexpected factors. Finally, improvisation in synchronous online co-design meant reflecting on and looking back closely at what we did, what shifted, and what decisions we made.

With respect to scalability, large efforts had to happen in our first meetings as we brainstormed how to go online. Small but more frequent moments of improvisation occurred when we managed micro moments, such as when we deviated from a session plan due to the interactions that occurred during a session (e.g. a child being tired of raising colors for voting). In these situations, we had to do the macro-planning, which refers to coming into the situation with a general idea of what to do. We also had to do the micro-planning, that is, the frequent and smaller scale moment-to-moment shifts and decisions in response to dynamic changes of people, technology, and information.

Disorder does not simply lead to creativity; in disorder there is constant effort that needs to be followed by organizing, dis-organizing and reorganizing. Similar to our principles when working with children in physical settings, we were not looking for consensus. Rather, we see co-design with children as an active and constant iterative process. In this sense, our approach to designing with children is similar to Picasso's or other artists, in that it does not follow a linear progression. Rather, our interactions with children continuously change based on unknown technologies and contexts in an online space.

5.3 Ethical Considerations and Challenges

While an artist can, at some level, be creative to experiment and engage with the properties that emerge in the process of design, researchers working with children have limits and ethical responsibilities regarding children's wellbeing. Researchers must adhere to highest ethical standards for children, which could limit the level of spontaneity allowed. We extend the improvisation literature to consider the implications of doing improv with children by taking into consideration important ethical standards, such as technology policies (e.g., USA – The Children's Online Privacy Protection Act; Europe – General Data Protection Regulation). In addition, future work may need to be intentional about children's screen time during online sessions, privacy issues of opening their homes to video cameras, and equity issues in technology and participation (e.g., how to include children with a certain level of Internet bandwidth for participation or different abilities in online spaces). We suggest three opportunities for future work:

- Screen time: Researchers might consider how their activities allow children to ensure their well-being (e.g., constant family check-ins, some physical movement for exercise).
- Privacy: Researchers might add a consideration of the necessary relationship building that needs to occur between researchers and families to understand and navigate privacy needs collaboratively.
- Technology and participation: Children with low-bandwidth were struggling with online technologies. We invite more researchers to brainstorm creative ways to co-design with lower-bandwidth and (a)synchronous hybrids.

When exploring new design techniques in an online space, or considering quick improvisation decisions that need to be made, we always adhered to online safety protocols such as limiting children's free exploration on the Internet. While we could have found new ways of interaction from purposely inviting unforeseen circumstances and uncertainty for discovery (through transgression), we also needed to be intentional and responsible for the outcome given our commitments to working with people from vulnerable populations.

5.4 Design Implications

In modifying the offline techniques for the online space, we learned that being dependent on mediating technology, such as the video chat and other tools, introduced more constraints. We also needed to understand how our participants would react to the changed mode of communication (i.e., using PowerPoint to draw and voting with colors and hands). There were multiple factors we considered when going online, including technical infrastructure and the mental model of understanding. Each technique we tried did not always accommodate each child's different needs, and possibly excluded some children during the session. While we acknowledge that there are difficulties in finding a perfect technique, we argue that there is a need of constant negotiation with the participants between the different tensions that arise during (and after) the session, as opposed to just going with the flow.

Among Kang et al's [30] five features of improvisation, interdependence highlights how improvisation is not a solo act; rather it is dependent on the 'others,' activities and surrounding material environment. We build the concept of interdependence to an online environment. Through the analogy of a show, we argue that children were not merely the audience of the show that we strived to continue, but they were also **active actors** that altered the scene and directed how the session would go. Through the lens of improvisation, the different factors that emerged were not factors that solely adult facilitators troubleshot and intervened in. Conversely, these factors provided possibilities for children to showcase their capabilities (such as a child pressing mute when his mom had the dish washer on or suggesting an adult prop their laptop to get a better camera angle) for the *show to go on.*

We believe our insights can help design practitioners prepare for improvisation. Practitioners need to know the larger systematic structures (e.g., infrastructures, contexts) and the potential interactions of people that govern how co-design sessions occur online before conducting sessions online. Our model provides 1) researchers/practitioners information about different factors, and 2) gives designers a lens to preemptively develop solutions (before), implement (during), and reflect (after) on the online co-design sessions. Moreover, our model creates generalizable knowledge for others to use in different contexts [39].

6 LIMITATIONS

We acknowledge that not all researchers have the infrastructure to do multiple co-design sessions as our team did. In many cases, researchers may only have one or two sessions with the families and children where it is difficult to deviate from the planned session. However, we argue that, in a synchronous session, regardless of how well and prepared the researcher is (such as sending prior surveys of understanding technological infrastructure), there are moments for improvisation. Yet, improvisation requires in-depth accumulated knowledge. Therefore, we encourage our framework and research to be used in adding more references to the unexpectedness (e.g., when a child joins a session from a moving car) to be ready for improvisation.

Importantly, we highlight that the children in this study already had an established rapport with the adults prior to us going online. In addition, multiple sessions afforded researchers extensive opportunities to understand each child's context. For instance, in the session where we asked children to find materials within their home, we knew each child's mobility needs and how they would impact their participation. Not all researchers are able to build a rapport in a short period of time or meet as consistently with their co-design partners. In some cases, researchers will meet the children online for the first time, and continue to meet them online, without any prior interactions with them in an offline setting. In those cases, we suggest that these researchers intentionally focus on children's cues and constantly monitor how the child is feeling. As children interaction researchers, there may be moments

where additional considerations should be made before experimenting with uncertainties in consideration of the ethics that are central to our approach.

7 CONCLUSION AND FUTURE WORK

The COVID-19 pandemic has given us an opportunity to investigate doing co-design with children synchronously online. Beyond designing activities (the techniques), facilitators need a conceptual model to comprehensively think through creating a synchronous co-design session where each child feels like they are a part of the design team, regardless of the different contexts that influences the session. Our work provides a model of the different factors a researcher can take into consideration when moving co-design to an online space. Our model is built upon prior theories in improvisation, which concern a holistic view of the child, technology, and the technique.

As we move forward, and more research papers propose different software, different tools, and different plug-ins, we argue that our conceptual model processes center our users' interactions and moves beyond the dependence of technology. For instance, new ideas and theories about hybrid models of physically co-located children working in-tandem with children in synchronous / asynchronous online situations can lead to more ways to become more inclusive of children in co-design. These new ways of co-designing will also require conceptual models of improvising and co-design. Similarly, synchronous online co-design may become more prevalent in the PD context. This addresses the population of participants who cannot meet locally with designers, but demonstrate a need for a sense of presence in the interaction. Such PD interactions could include chronically ill medical patients [9], teachers [7] senior citizens [4] people with accessibility issues [52], neurodiverse children [17, 18], and other vulnerable stakeholders.

Ultimately, in our work, we care about creating a synchronous environment in which children feel like they are on the same playing fields as adults to create and design. We made modifications that always centered the experiences of the different children while enabling us to reach our design goals. We have noticed the value and possibilities of improvisation in our work, as there are more unexpected situations in the synchronous sessions, which required us to deviate from the plan. As opposed to perceiving the unexpected as something to be avoided, we have attempted to re-examine the nature of change and free space as a learning process for new inquiry to emerge.

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