"I normally wouldn't talk with strangers": Introducing a Socio-Spatial Interface for Fostering Togetherness Between Strangers

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ABSTRACT

Interacting with strangers can be beneficial but also challenging. Fortunately, these challenges can lead to design opportunities. In this paper, we present the design and evaluation of a socio-spatial interface, *SocialStools*, that leverages the human propensity for embodied interaction to foster togetherness between strangers. *SocialStools* is an installation of three responsive stools on caster wheels that generate sound and imagery in the near environment as three strangers sit on them, move them, and rotate them relative to each other. In our study with 12 groups of three strangers, we found a sense of togetherness emerged through interaction, evidenced by different patterns of socio-spatial movements, verbal communication, non-verbal behavior, and interview responses. We present our findings, articulate reasons for the cultivation of togetherness, consider the unique social affordances of our spatial interface in shifting attention during interpersonal communication, and provide design implications. This research contributes insights toward designing cyber-physical interfaces that foster interaction and togetherness among strangers at a time when cultivating togetherness is especially critical.

CCS CONCEPTS

• **Human-centered computing** → **Ubiquitous and mobile computing systems and tools**; **Ubiquitous and mobile computing design and evaluation methods**; *Mixed / augmented reality*.

KEYWORDS

Socio-Spatial Interface, Embodied Interaction, Proxemics, Small Groups, Mixed Reality

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1 INTRODUCTION

Being surrounded by *familiar strangers* - people we recognize in public spaces but who remain apart from us [43] - cultivates a sense of familiarity and belonging in physical places [8, 50]. The COVID-19 pandemic has, however, disrupted this sense of familiarity [61], especially when people abide by social distancing and mask-wearing mandates.

Studies in HCI have investigated different methods on how interactive technologies could mediate social interactions between strangers, such as facilitating gaming experiences, promoting conversational topics, and displaying shared photos [20, 25, 35, 41, 51, 69]. Towards advancing this previous work, we argue that people's proxemic behavior - the negotiating of personal space during face-to-face interactions - should be especially considered when designing for interaction between strangers, particularly in a pandemic when people may be "social distancing" [61]. Following this argument, we introduce a socio-spatial interface called *SocialStools* (Figure 1) that leverages the human propensity for embodied social interaction in our everyday surroundings [13]. A socio-spatial interface is an interface that integrates people's social behaviors with digital feedback in a physical environment. The goal of this research is to explore how this interface-modality fosters experiences that cultivate a sense of "togetherness" among strangers.

As defined by Bauman [5, 28], "togetherness" is a state of "being together" in three different modes: "*being aside*," in which strangers keep others at a distance; "*being with*," in which people have the potential for communication with some expectations of understanding and trust; and "*being for*," in which people are willing to have a relationship that nurtures the unique needs of one another [5, 28]. Our research focuses on the second mode, "*being with*," to explore how to promote various kinds of "*being with*" in people we don't know. Our research question is: *In which ways can a socio-spatial interface foster togetherness among strangers?*

In response to this question, we developed *SocialStools*, an integrated, physical-digital experience of "social affordances" defined as *"the relationship between the properties of an object and the social characteristics of a group that enables particular kinds of interaction among members of that group"* [9]. In practical terms, *SocialStools* is three stools on caster wheels that generate sound and digital imagery around them in response to three people sitting on them,

Figure 1: People sitting and chatting on *SocialStools*.

moving them, and rotating them relative to each other (Figure 1). To examine how *SocialStools* helps cultivate togetherness, we conducted a study with 36 participants in 12 groups. We observed patterns of socio-spatial movements and verbal and non-verbal communication patterns that suggest the emergence of togetherness within a small group of strangers. We also provided our understanding of what factors influence the experience of togetherness.

In addition to reporting these findings, we contribute to design research an exemplar of a novel, socio-spatial interface that provides a collaborative, playful, and immersive experience cultivating connections between strangers. Additionally, we contribute insights about which social behaviors indicate togetherness, how strangers could experience togetherness, and on designing for the shifting focus of attention considering different group dynamics. Finally, we offer design implications for other design researchers who may be designing for interpersonal communication between strangers.

2 RELATED WORK

2.1 Interaction Between Strangers

It is well-known in psychological science that the quality of close relationships serves people's well-being [27]. However, scientists advancing the importance of *weak ties* have shown that even subtle interactions with strangers yield short-term happiness: a greeting, a smile, or a brief exchange boosts people's happiness for both those who initiate them and those who receive them [14, 21, 63]. The benefit of interacting with strangers may include obtaining good advice and useful information, but more importantly, fulfilling people's need of affiliation, desire to belong, and relatedness, which all lead to people's long-term well-being [6, 57, 64]. The result is a sense of belonging in a community, where people are surrounded by *familiar strangers* [44, 50].

If connecting with strangers has so many benefits, why do most people still avoid connecting [58]? According to recent research, the challenge of interacting with strangers is what social psychologists call a form of "pluralistic ignorance": people fear that they themselves are not good conversationalists and that others are not interested in talking with them [14, 52, 65]. The true barrier of interacting with strangers is therefore a person's overblown fear of exchanging with others when in fact, conversations always tend to go better than people expected [56, 58].

One way to help individuals overcome the fear of interacting with strangers is through interactive installations using different modalities, with the most common interface being the public display. *VideoMob* is an art installation that displays portraits of people who have visited the same art exhibit to promote connection among strangers across different locations [20]. Similarly, *Demo Hour* is an installation that displays shared topics among people on a public screen to promote communication between strangers [7]. Another kind of interface commonly studied in interactive installations is the media façade at the urban scale [15]. For example, *CityWall* is a large public multi-touch display installed on a street façade with a gesture-based feature that allows people passing by to rearrange images of the city on the screen [51]. Similarly, *Solstice LAMP* augments a building façade with interactive light projections and music to promote shared encounters [25]. Common to these prior efforts is an interface of primarily large screens or projections intended to promote encounters among large numbers of strangers.

Research that supports interactions between relatively fewer strangers typically features smaller scale interfaces. Such an interface is exemplified by *TouchBranch*, a set of interactive branches that light up when individuals touch each other using different body regions, encouraging people, including strangers, to experience interpersonal touch [35].

Our research explores a different installation modality: a socio-spatial interface supporting interaction between strangers, integrating audio-visual feedback in an augmented, spatial experience.

2.2 Socio-Spatial Interfaces

Building on Krogh et al., we define a socio-spatial interface as one that considers the dynamically changing relations between groups of people, technology, and physical spatial elements [37]. In the following, we consider prior work on the concept of socio-spatial interfaces.

2.2.1 *Embodied interaction.*

People's bodies play an essential role in experiencing rich interactions in the physical world. Embodied interaction emphasizes the importance of considering the dynamic relationship between our body and the digital system, leveraging the human body's complex and rich experience in the real world [13]. This extends to collective experiences between bodies [42, 45]. in *e-Topia*, William Mitchell urges researchers of interactive systems to account for people's inherently social nature and to move beyond a "one human, one computer" interaction paradigm. Mitchell envisions "smart space" as a socio-spatial extension that engages our bodies; its physical manifestation is what Mitchell calls a "robot for living in" [45]. Building on Mitchell, Fogtmann et al. has coined the notion of "spatial sharing," moving from designing GUIs or TUIs to designing spaces for contextual, multi-person, bodily sharing - not only involving certain body parts but the whole body's movements among multiple people [16]. For example, *iFloor* is an interactive floor surface that affords multi-users to use their body positions to change the graphics on the floor, facilitating communication and collaboration among participants [16].

Promoting embodied interaction between strangers is especially important during a time when people are encouraged to "socially" and "physically" distance.

2.2.2 *Proxemics.*

When interacting with other people, proxemics – a "human's use of space within the context of culture" is the foundation for us to understand the socio-spatial aspect of computing [23]. In *The Hidden Dimension*, Edward T. Hall defines different ranges of interpersonal distances, from small to large: *intimate* that allows touch and embrace, *personal* that accesses the odor of another, *social* that allows longer-distance gazes, to *public* which often happens in public speaking settings [23, 37]. He also emphasizes the impact of proxemics on interpersonal communication, especially nonverbal communication [23]. Previous studies have explored how interactive technologies apply proxemics to mediate interpersonal interactions. Some studies explore tangible applications as a bodily extension, a prosthetic, as does an interactive hairstyle [39] or changing clothes patterns [33]; others utilize digital methods such as public displays or personal projections [7, 41, 47, 66]. Krogh et al. further made the distinction between "proxemic interactions" and "interaction proxemics" [37]. He argues that "proxemic interaction" takes proxemics as an input of an interactive system. Designers, however, might consider a mindset of "interaction proxemics": behavior of proxemics as an output when people respond to an interactive system [37]. In our work, we explored the possibility of integrating "proxemic interaction" with "interaction proxemics," in which human behavior triggers environmental cues while being altered by environmental cues.

By thinking about proxemics and design in this way, we aim for tangible, embodied interaction with environmental, digital feedback as a holistic experience facilitating novel and natural interpersonal communication between strangers.

2.2.3 *Visual metaphor.*

To enable an intuitive interaction between people, technology, and the physical environment afforded by the socio-spatial interface, we borrow insights from research on visual metaphor. In *Metaphors We Live By*, Lakoff and Johnson define metaphor as "understanding and experiencing one kind of thing in terms of another" [38]. They claim that metaphor does not only exist in language, but also in people's thinking and experiences, and it could be represented visually, haptically, kinesthetically, and acoustically [19, 38]. In HCI, metaphor plays an important role in designing interfaces, such as the desktop metaphor in GUIs, or the metaphor of shape and texture in TUIs [30]. Visual metaphors are often used as a method to create intuitive interactions as they reflect primitives of thoughts [19].

Visual metaphors have also been applied in disciplines outside of HCI. One example related to togetherness is the work of psychologist Arthur Aron and colleagues who have developed a visual/pictorial measure to replace the traditional text-based way for investigating people's emotional closeness - the inclusion of an "Other in the Self (IOS)" scale [2]. The scale uses circles with different overlapping areas to describe interpersonal relationships by tapping directly into people's senses of interconnectedness. As people have vast experience interacting in space, we believe the potential of applying visual metaphors to space has not been fully exploited yet.

Our work attempts to apply this method to a three-dimensional environment that strives, through moving images, to tap into people's immediate senses to cultivate a feeling of togetherness among strangers.

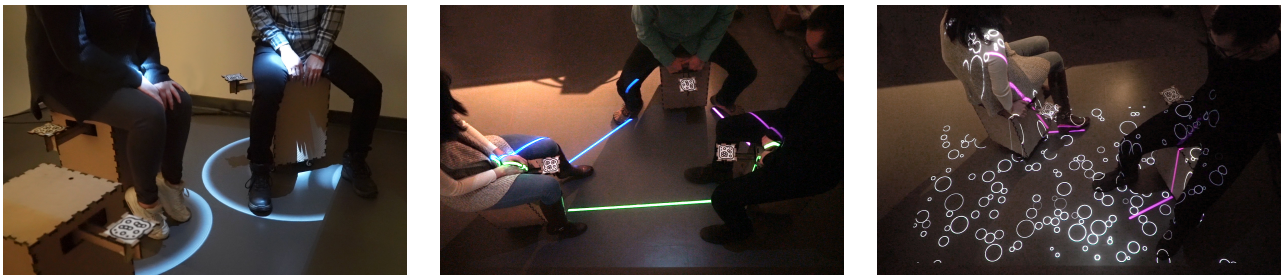
3 SOCIALSTOOLS

Research has shown that a sense of "playfulness" could make social interactions casual and rewarding [35, 49]. Inspired by the research that a sense of serendipitous discoveries enabled by the playful elements in design might positively influence user's social proactivity [48], we focused our *ludic design* efforts [18] on playful, embodied interactions between strangers afforded by a system of interactive furniture.

To understand how a socio-spatial interface foster togetherness, we followed the Research through Design approach [70]. In the following, we describe the design concept of *SocialStools* and its technical realization.

3.1 Design Concept and Interactions

SocialStools [22] are three identical units of interactive furniture – three stools set on caster wheels. The input of our socio-spatial interface is the physical movement and rotation of each of three individuals seated on the stools, detected by a camera above. Mapped



a . ***Ripples*** b . ***Sound*** c . ***Bubbles***

Figure 2: Three interaction setups of *SocialStools*: (a) *Ripples*: a visualization of personal space; (b) *Sound*: changing volume, pitch, and timbre of music output by distance between the stools; (c) *Bubbles*: changing of shapes and colors of bubbles on the floor by angular orientation of the stools.

to the inputs are visual and audio effects that create an immersive experience that has the potential to facilitate togetherness of strangers in the physical space.

We designed three different interaction states for *SocialStools*: the sitting state, the state of changing the distance between stools, and the state of rotating the angular orientation of the stools. Three interactive states of the cyber-physical *SocialStools* map to digital outputs, changing the atmosphere of the shared space through dynamic, user-controlled sounds and projected, moving images (Figure 2). We leveraged these affordances (Figure 3) and designed various kinds of visual and audio effects to encourage interpersonal communication. The interaction design for *SocialStools* was previously presented as a CHI Interactivity demo [22].

3.1.1 *Interaction A: Visualization of Personal Space: Ripples.*

According to the theory of proxemics, human beings are surrounded by a set of invisible zones of interpersonal distance, from smaller to larger: Intimate, Personal, Social, and Public [23]. Studies of proxemics show that proximity has psychological and neurological effects on social behaviors [23]. *SocialStools* interactively visualizes and embodies these interpersonal zones, offering social cues that encourage interactions between strangers.

As a metaphor for the interpersonal zones, we designed a projected ripple that follows the sequence of rings, like a doppler effect, caused by, for instance, a droplet's impact on the surface of still water. This ripple envelopes people to symbolize the proxemics during stranger's interaction (Figure 4a and Figure 4d). When a person enters a room and sits on a stool, a ripple starts to spread out from the position of the occupied stool and slowly begins to embrace a second stool as a social cue for welcoming the next arrival. When another person sits on a stool, the ripples emanating from that stool add to the other ripples, providing a psychological cue for merging the boundaries of interpersonal spaces and a social cue to start an exchange (verbal or non-verbal) with the other seated strangers. A dynamic between strangers unfolds, each time unfolding differently depending on the personalities and how they respond to the visual cues offered by *SocialStools*.

3.1.2 *Interaction B: The distance between people: Sound.*

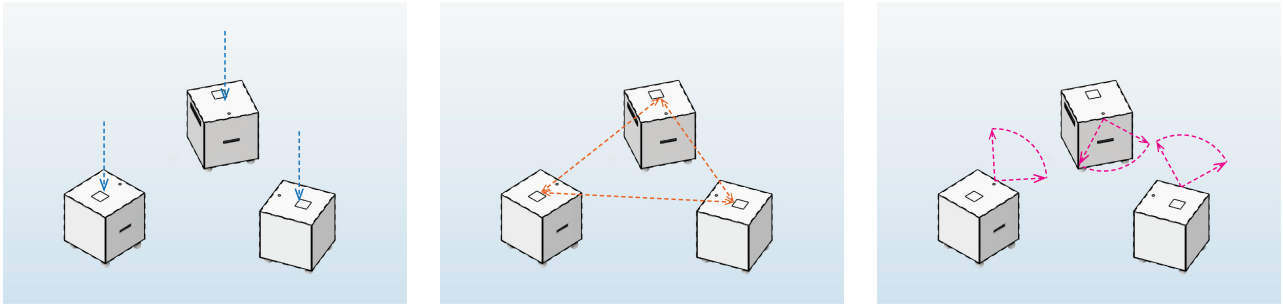
The physical distance between people suggests psychological distance. People naturally form different spatial patterns in physical space, and the dynamics of these spatial arrangements encourage or discourage certain types of interpersonal communication [40]. Music offers people a wide range of emotional expressions and social significance, creating rich associations with the atmosphere of a space [12]. Therefore, in the second interaction, we explore the possibility of combining human senses of kinesthesia with the auditory sense in interpersonal interaction. *SocialStools* provides different electronic musical outputs based on the different measures of distances between people to cultivate communication.

Inspired by the *Kaossilator* [34], a touchpad musical synthesizer, we transform the floor underneath *SocialStools* into a large "touchpad," leveraging the movement of the three stools to change different parameters of music (Figure 4b and Figure 4e). We translate the distances of three pairs of stools respectively into volume, pitch, and timbre of the generated electronic musical output. The closer or farther pairs of stools are from one other, the higher or lower the volume, the pitch, or the timbre of the background music. The manipulation of the adjacency not only allows people to make music together but also permits individuals to have equal power as a member of the trio to control the audio effect of the environment.

3.1.3 *Interaction C: The orientation of people: Bubbles.*

Eye contact and body orientation are hidden components of interpersonal communication. People's body orientation suggests attention, and eye contact may suggest a gestural greeting or a start of a conversation. These nuanced social behaviors are part of our everyday lives, but physical spaces are typically unresponsive to them. *SocialStools* registers these instances by projecting interactive imagery on the floor when users rotate themselves to orient towards each other. As flower petals growing and their colorfulness often symbolize vitality, for *SocialStools*, we offer imagery of petal-like "bubbles" as a metaphor for growing togetherness. We hope to create emotional bonding between people by providing positive visual feedback to encourage people to orient more often towards one another.

In the third interaction, we calculate the orientation of the stools so that when the two individuals begin rotating to face each other, projected bubbles slowly "grow" on the floor (Figure 4c). When they rotate away from each other, the bubbles slowly shrink and fade (Figure 4f). When a third individual rotates towards the first



a . Sitting b . Distance c . Orientation

Figure 3: The three socio-physical affordances of *SocialStools*: (a) Sitting on the stools; (b) Distance between stools; (c) Angular orientation between stools.

two, the bubbles change from white to colorful, and when rotating away, the bubbles change back to mono-color. Like in the previous scenarios, each individual has equal power to control the effects. To smoothen the visual transformations, we set up a certain threshold of the angle differences of the stools so that the bubble would gradually grow up and slowly fade away following the individuals' body movements.

3.2 Technical Design

Our system is comprised of three stools, a 4k webcam hung above the stools to locate the stools, and a projector (1080p, 3000 Lumens) to project images on the floor (Figure 5). The stools were fabricated of laser-cut MDF. Each of the stools has four casters screwed to the underside of it, permitting mobility by the person seated, much as someone moves an office chair.

We used projection mapping to project imagery on the floor around the stools so that the visuals themselves could change the atmosphere of the shared, local environment. We calibrated three different coordinates (the coordinates of the camera, the projector, and the physical world) using the homography mapping method [11]. The positions of the stools in the physical world are transformed and mapped onto the PC screen, and the chosen visuals are precisely projected back to the corresponding location in the physical world.

To get the location and the orientation of the stools, we put fiducial markers on the stools and utilized reacTIVision, an open-source computer vision framework to track the markers [54]. To detect if people are seated on the stools, we put a light sensor below the top surface of the stool. The visual and audio effects were coded using Processing. To sync the real-time data between different platforms, we used the TUIO protocol to link the input (sitting, position, and orientation of the stools) and the output (visuals and audio) [32].

4 METHOD

The purpose of developing *SocialStools* was to investigate how an interactive spatial interface with visual and audio feedback can be designed to facilitate interpersonal communication and cultivate togetherness between strangers. In order to assess how *SocialStools* supports togetherness between strangers, we conducted a qualitative and exploratory lab study in which strangers were invited to try out our installation. Unlike testing our installation in the field, in the lab we could better control the setting – lighting, background noise, room layout, environment, etc.

As mentioned before, we followed a Research through Design approach [70] given that we were especially interested in the nuanced ways in which togetherness emerged, socially and contextually, as participants' behaviors unfolds during the interaction. We also hoped to understand participants' personal experiences through interviews with open-ended questions. (In the future, we are planning to conduct a controlled experiment to learn whether *SocialStools* affects the emergence of togetherness compared to no intervention.)

4.1 Participants

We recruited 36 (21 females, 15 males, age M=20.9) undergraduate and graduate students for 12 study sessions, each with 3 participants. The 3 participants in each session did not know each other before the study. Participants were compensated with $10 Amazon gift card for a 45-minute study.

4.2 Setup

The room included sensing and projection devices hanging at the ceiling height, three stools on the floor, and a table with a PC and a speaker (Figure 6a). The light in the room was dimmed for a better effect of the projected imagery. The area boundary was marked with orange tape on the floor. In the initial state, all three stools were placed side-by-side, facing the same direction. Two video cameras were placed to record the interaction: one from the top of the study area and one from the side of the study area (Figure 6b). The study was carried out by one facilitator and two research assistants who helped operate the equipment, observed, and took notes.

4.3 Procedure

Upon a participant's arrival, a member of the research team introduced the study and obtained informed consent. To minimize fully disclosing the purpose of the study, the informed consent form offered that the study's purpose was to evaluate the design of the installation. No pre-questionnaire was collected. During the

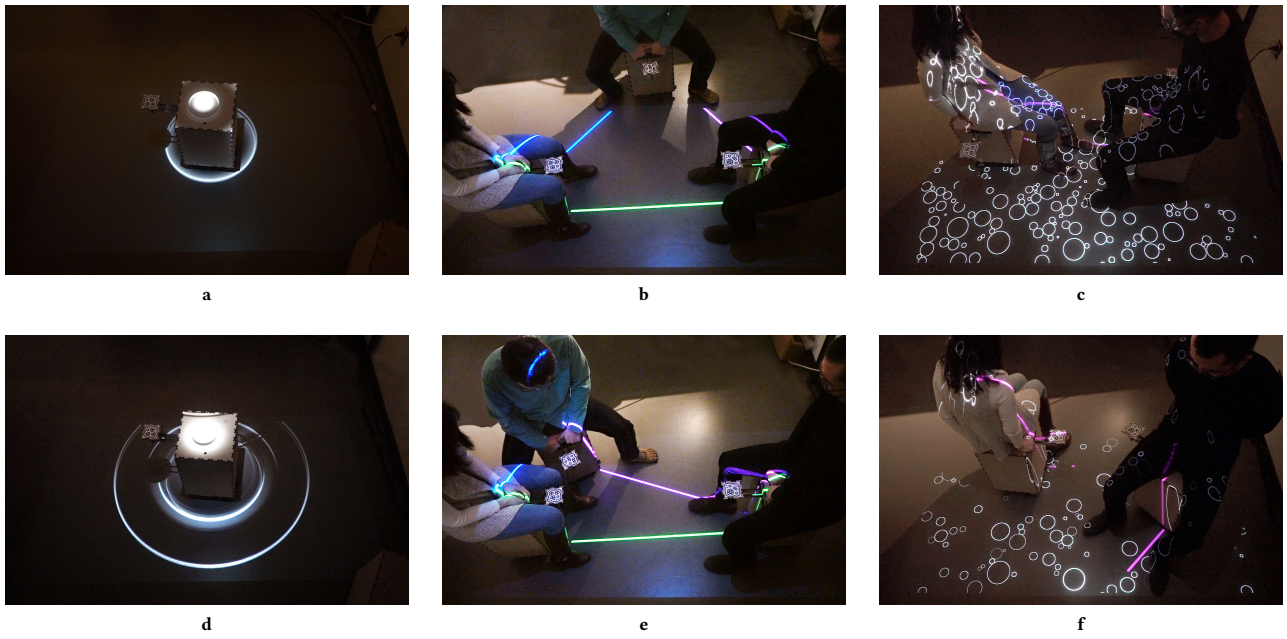


Figure 4: The three core interactions of *SocialStools*: (a, d) The expanding of ripples; (b, e) Distance between stools controlling volume, pitch, and timbre music; (c, f) Angular orientation between stools controlling bubble effect.

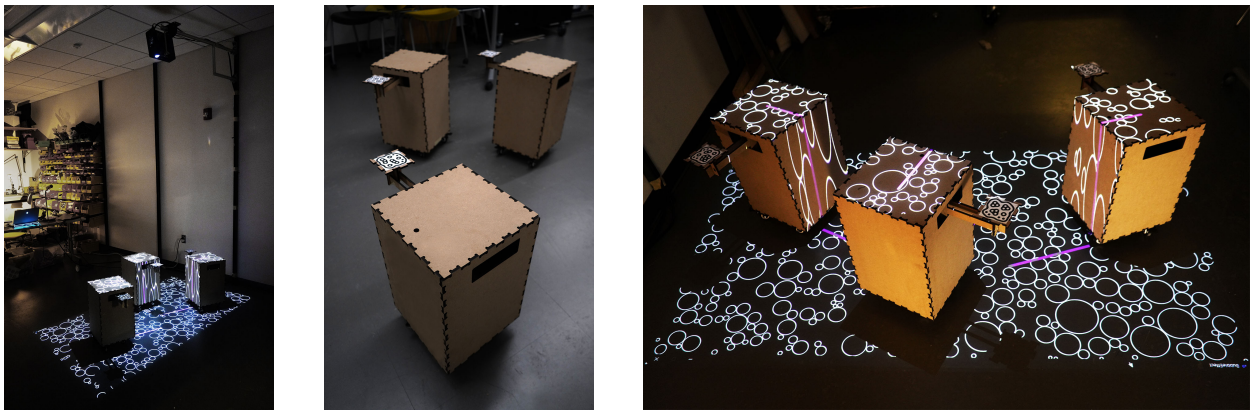
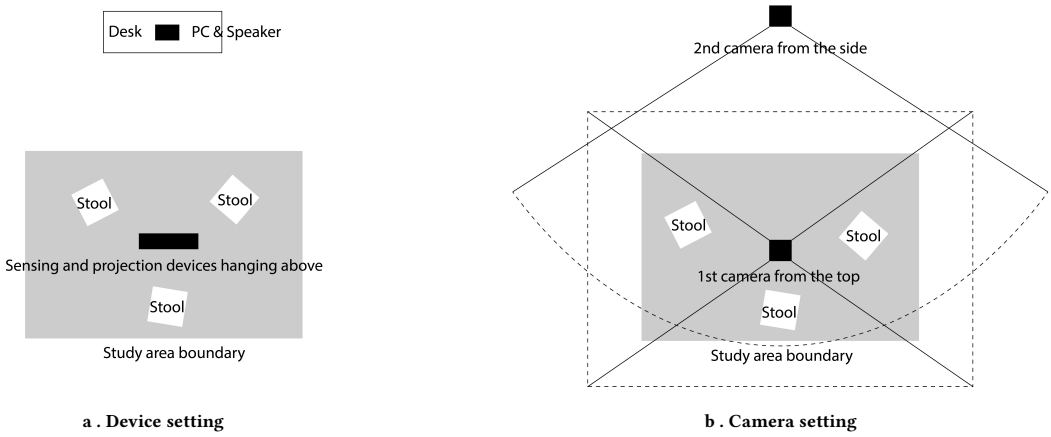


Figure 5: Physical setting of *SocialStools*: (a) The overall physical settings including a projector, webcam, PC, and the stools; (b) Details of individual stools including markers and light sensor; (c) Imagery projected on the floor and on the stools.

introduction to the study, participants were asked to imagine themselves in a transitional space like an airport terminal[1], and they were offered time to freely explore the stools and talk with each other, just like what they normally would do in an airport terminal. To encourage natural behavior as much as possible, we told participants that there were no right and wrong ways of interacting with the installation; they were allowed to move around, use their phones, and even get up and leave.

Participants were then invited to sit on the stools. Next, we started the system, with each of the three interaction setups as a separate, 6-minute session, one after the other: *Ripples*, *Sound*, and *Bubbles*. We randomized the order of the three setups across the groups. We did not give participants further instructions, apart from informing them of the start and end of each session. At the beginning of each session, some visual hints were projected on the ground: an expanding ripple (Figure 7a); three lines connecting the

[1]During our pilot studies, we tested various prompts, asking participants to imagine themselves in a library public lobby, a museum, or an airport terminal. We found that participants had different expectations of the social interaction in different imagined contexts, so we settled on the context of an airport terminal to minimize confusion.



a . Device setting **b . Camera setting**

Figure 6: Overhead view of the study setting: (a) Device setting; (b) Camera setting.

three stools (Figure 7b); or an arrow in front of each stool (Figure 7c).

After the three sessions ended, the facilitator carried out a short group interview, asking the group of three participants how they felt about the experience and what they thought the design intention was for each session. We hoped that, following the shared experience amongst the participants, the group discussion would trigger a multiplicity of views and shared emotional responses. Additionally, we were hoping to learn if participants had figured out, as a group, how their movements mapped to the audio and visual projections. After the group interview, the facilitator debriefed the group, explaining the design rules for the mapping.

Following the group interview, we conducted three separate semi-structured interviews with individual participants, each participant interviewed by one member of our research team. Unlike the group interview where participants might feel pressure from the presence of other participants of their group, in the individual interviews, we asked questions to individual participants about their personal feelings and behaviors. For example, we asked participants about certain behaviors that we observed during the experiment (e.g., "I noticed that you…, could you tell me what you were thinking at that moment?") and memorable experiences during the study (e.g., "What moments do you remember from the last 20 minutes?"). We also asked what they each learned about the other participants in their group, their first and last impressions of these other participants, and if there were certain topics they would like to continue talking about with these other participants after the study. We also asked about their social behaviors in daily life (e.g., "Do you normally initiate conversation in a group?"). We also invited each of them to offer comments about the spatial interface, and let them compare it to a situation when they met strangers without our design. Finally, we asked each of them for their feedback about the installation design and their overall feelings about the experience.

After the interviews ended, we closed the session by sharing with participants the purpose of the study: to learn how strangers interact in the context of the design. The purpose of debriefing participants only at the end of the study was to avoid their bias during the study sessions and during the interview.

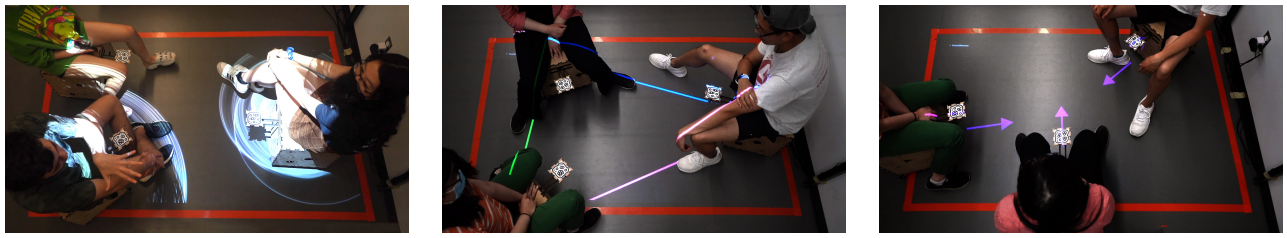
4.4 Data Analysis

Our data consisted of video recordings of the study sessions, audio recordings from the group interview, audio recordings from the individual interview, and observation notes.

Previous studies have examined people's sense of social presence through language, paralanguage, and non-verbal behavior in small social group settings [4]. In light of this, we decided to examine togetherness by looking at three different kinds of behaviors in the video recordings: verbal, non-verbal, and movements. We used a video annotation tool to mark each individual or group behavior. We then visualized these behaviors on a timeline for each group, as explained below.

Verbal behavior, i.e., what participants were saying, was grouped into three categories: talking directly about the design (e.g., figuring out the "rules", talking about the background music), talking indirectly about the design (e.g., talking about "swimming" in response to seeing the light ripples on the floor, etc.), and casual talk unrelated to the design (e.g., people's favorite restaurant, study major, etc.). We were interested in analyzing participants' conversational focus because research has shown that the balance between paying attention to the task versus to each other is a factor in the social dynamic of groups [3]. We recognized that in conversation, people don't follow the same linear structure as in writing, and they jump around and between topics across sentences even within the sentences. We identified those moments of topic changes, visualizing blocks of times when participants were talking about a certain topic with different colors. When there was silence for more than 3 seconds, we marked the conversation as an end. Figure 8 shows an example of a group's verbal behavior timeline.

To analyze *non-verbal behavior*, we marked on the timeline events of eye contact between participants, laughter, touch, and when individuals looked down and looked up. We coded these non-verbal



a . Visual hint: expanding ripples b . Visual hint: three lines c . Visual hint: arrows

Figure 7: Visual hints projected on the floor at the beginning of each session: (a) An expanding ripple around each stool; (b) Three lines connecting the three stools; (c) An arrow in front of each stool.

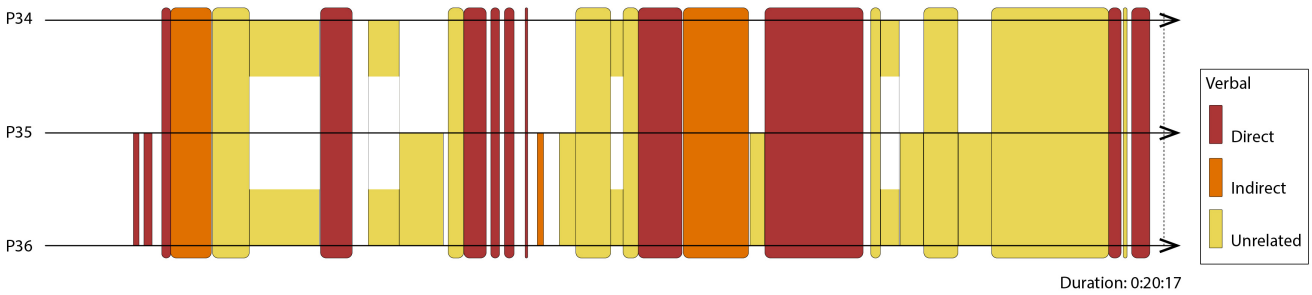


Figure 8: Verbal analysis of Group 12.

behaviors following the literature that has shown that these behaviors were signals of attuning, liking, and connection in social interactions, thus they may signal togetherness. According to Kleinke, one of the functions of eye contact is to express intimacy [36]. The eye contact in the study was defined as situations in which one individual gazes at the other in the general face area and vice versa, simultaneously [31]. Laughter, according to Chadwick, indicates empathic harmony and pro-attuning, suggesting close psychological connection [10]. Finally, touch, according to Hertenstein, plays in emotional communication, attachment, bonding, compliance, intimacy, and liking [24]. We added looking down and looking up, based on our observations that individuals might apply these behaviors when exploring the design, trying to understand how the system works, or to "get away" from the group conversation (i.e., reducing the level of intimacy [1]). Figure 9 is an example of a group's non-verbal behavior timeline.

To analyze *movement*, we marked time blocks of interpersonal synchronized movements among two or three participants. We identified interpersonal synchronized movement when participants were moving together at the same time, with a temporal alignment at the bodily scale, e.g. rotating in the same direction, moving back and forth at the same speed, circling together, etc. [59]. Research has shown that rapport and pro-social attitude can lead to interpersonal motor synchrony between strangers [53, 55], thus indicating a sense of togetherness. Figure 10 shows an example of the interpersonal synchronized movement timeline of a group.

Finally, we overlaid the three timelines of verbal, non-verbal, and movement for each group to examine cumulative behavior patterns. Figure 11 shows the overlay of one group's video analysis timeline.

The video analysis was carried out by two research assistants. Initially, they watched the same video and independently annotated the behaviors using the same coding protocol. An inter-rater agreement was established by examining whether both researchers assigned the same codes at 30-second intervals. Agreement levels were 0.875% for verbal behavior, 0.95% and higher for the various non-verbal behaviors, and 0.92% for movements. Given the high agreement levels, we split the data between the two research assistants who coded the remainder of the videos.

To understand how different interactions (*Ripples*, *Sound*, and *Bubbles*) affected group behaviors, we calculated for each interaction session the time duration of verbal behaviors and movements, and the total counts of non-verbal behaviors, averaged by the group. Table 1 shows the means and standard deviations of verbal behaviors, non-verbal behaviors, and movements per group for each interaction type.

To analyze participants' interview responses, we transcribed the audio recordings of the interviews using *otter.ai*, then manually cleaned and corrected the transcripts. We used inductive and thematic-free coding method by grouping the interview responses by questions, reading all of them, and highlighting important sentences. We then iterated the grouping as our insights emerged during the analysis. Our data analysis of the interview complements

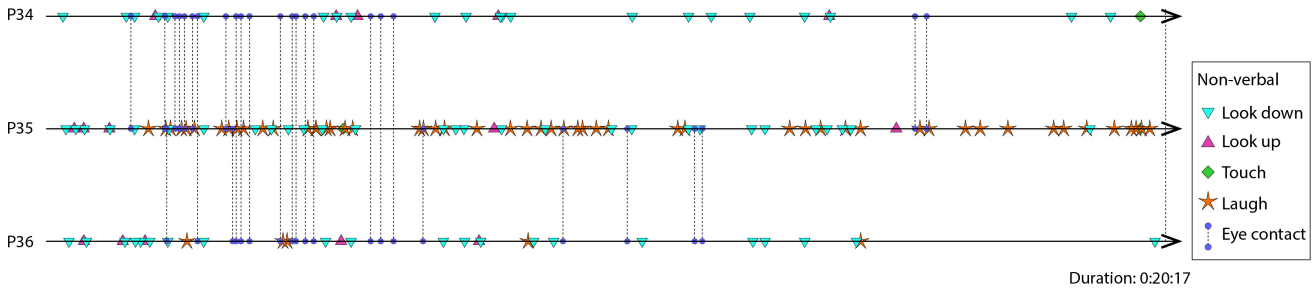


Figure 9: Non-verbal analysis of Group 12.

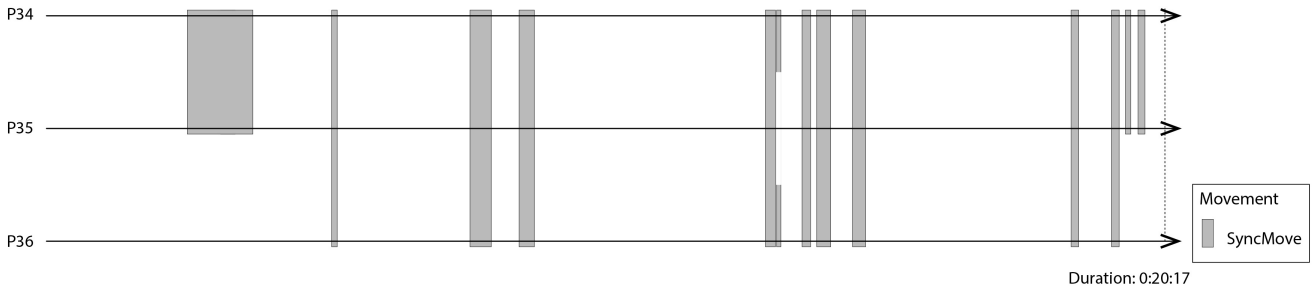


Figure 10: Movement analysis of Group 12.

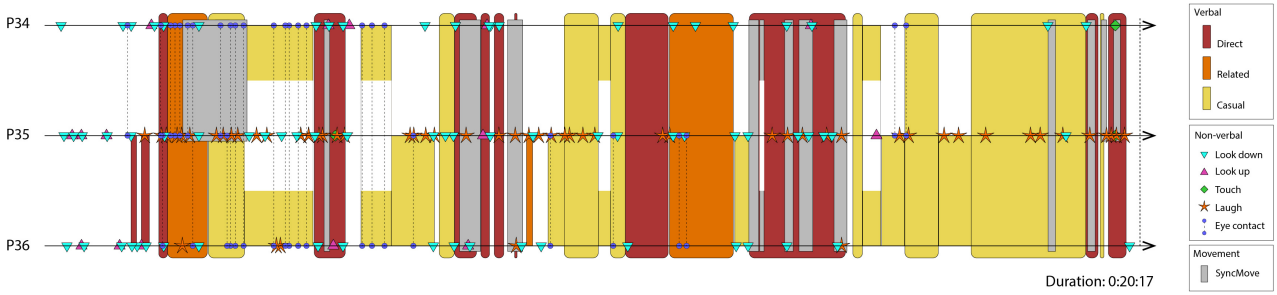


Figure 11: Overall video analysis of Group 12.

our behavioral data analysis towards understanding participants' experiences and providing their perspectives.

5 FINDINGS

Although participants were not informed of the purpose of the *SocialStools*, most participants perceived the project in ways that aligned with our design intention. When asked *How you would describe the project to others?*, some responses included: "get people to engage," "work together," "interact with each other," "responsive environment," "augmented social experience," etc. A few mentioned the project's mechanics, with responses like "tracking individual movements." Participants also engaged and recognized the playfulness of the project. More than two-thirds of the participants commented at the end of the interview with "very fun" "interesting", "really cool," etc. One participant noted *"Thank you for the opportunity, I forgot everything in my life and had a lot of fun. It made my day." (P9)*

In the following, we present our results in two parts. We first report on verbal and non-verbal communication and movements, to explore which patterns of social behaviors emerged that may signal togetherness. We then report, from the point of view of the participants, on their perceptions and experiences of togetherness during the study.

Table 1: Verbal behavior, non-verbal behavior, and movements per group by interaction.

		Ripples	*Sound*	*Bubbles*
		M (SD)	M (SD)	M (SD)
	Total Session Time (min per group)	6.23 (0.46)	6.12 (1.09)	6.95 (1.94)
a. Verbal Behavior (min per group)				
	Direct	0.94 (0.97)	1.95 (1.45)	2.11 (1.95)
	Direct/Total time	15.05%	31.93%	30.38%
	Indirect	0.48 (0.52)	0.02 (0.06)	0.45 (0.71)
	Indirect/Total time	7.75%	0.37%	6.44%
	Unrelated	0.90 (1.63)	1.27 (2.32)	1.16 (1.76)
	Unrelated/Total time	14.41%	20.75%	16.76%
	Total Talk Time	2.32 (1.89)	3.25 (2.26)	3.72 (2.98)
	Talk Time/Total Time	37.21%	53.05%	53.60%
b. Non-verbal Behavior (count per group)				
	Eye contact	7.55 (7.90)	8.5 (10.75)	6.33 (7.62)
	Touch	0.09 (0.29)	0.42 (0.79)	1.08 (2.75)
	Look down	15.09 (8.74)	16.08 (9.40)	15.00 (6.40)
	Look up	4.00 (3.34)	1.92 (1.62)	1.67 (1.15)
	Laugh	7.45 (7.03)	7.17 (6.60)	9.33 (7.50)
c. Movements (min per group)				
	Sync Movement	1.24 (1.13)	1.82 (1.48)	1.25 (1.46)
	Sync Movement/Total time	19.85%	29.70%	18.03%

*The order of interactions *Ripples*, *Sound*, and *Bubbles* was randomized across the groups.

5.1 Behaviors that emerged with *SocialStools*

5.1.1 Verbal communication.

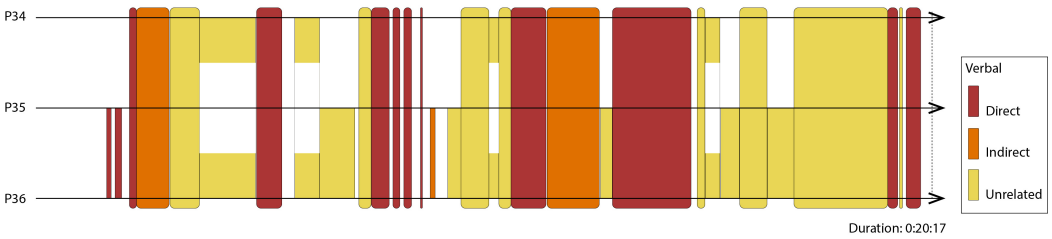
To understand participant's verbal communication in using the *SocialStools*, we categorized groups based on the verbal analysis into four categories, illustrated in Figure 12. In order to understand the reason for the different verbal behavioral patterns, during the post-experiment interview, we asked participants why they decided to talk about certain topics or to keep silent. While personality plays an important role in how individuals behave in this kind of social settings, some answers pointed to the role that the system played in these interactions.

a. Four of the 12 groups talked more or less equally "directly about the design" and "unrelated to the design," with the talk "indirectly about the design" as a transition between the first two types of talk. See an example of one group's verbal analysis in Figure 12a. Participants in these groups mentioned they felt having a natural flow of conversation throughout the experiment. One of the reasons was because the visual and audio feedback gave them some cues to start topics and expand on them. One participant noted: *"I think because of the signs on the floor, we have a lot of topics to expand, such as we talk about water, we talked about swimming classes. And when we see the bubbles, we talk about orchestra[s], we talk about music. It has a lot of great start[ing] points for conversation" (p34).* Participants also commented that the stools helped them to move away from approaching others with routine topics: *"Without this [SocialStools], you don't have a topic to talk about. You just approach others [in a] very routine [way], maybe [about] lives or [academic] majors."* In groups of this type, *SocialStools* promoted various kinds of topics by providing cues in the environment, and moreover, those cues served as departure points for other topics.

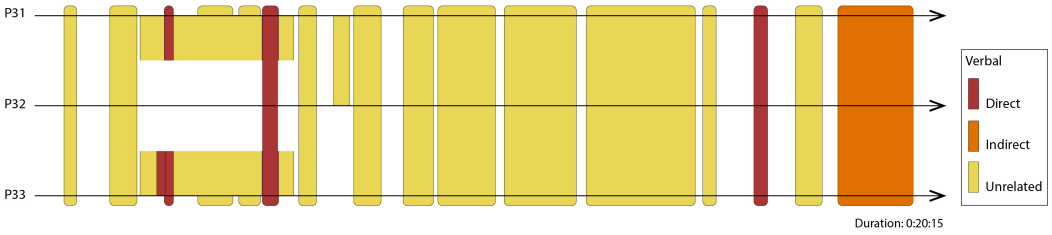
b. One group talked about topics "unrelated to the design" for most of the experiment's duration (Figure 12b). The interview of participants in this group suggested that participants mainly talked about topics unrelated to the design because they did not pay attention to the environment and were curious to know more about each other. One participant noted: *"They [the other participants] are basically my attention. People just got my attention more [...] So I prefer not to focus on the environment" (P32).* Another participant in the same group mentioned: *"One of the reasons was to fill the silence, because it will be a little awkward. But another reason was I was genuinely curious about them" (P31).* In this group, it seems that participants already had the motivation to talk among themselves even without a design intervention.

c. Four groups talked "directly about the design" for most of the experiment's duration (example of one group in Figure 12c). Participants in these groups found the visual change and audio change in the environment a natural attraction so it became the focus of their conversation. One participant said: *"At first, we [were] just chill and kept talking. Then we see the changes of the patterns [on the floor]. And then probably we just intuitively wonder why there were changes and how it got changed" (P22).* In these groups, *SocialStools* was the main source of conversation, being a new experience for participants. Interestingly, a few participants mentioned that if they had more time, they would be curious to know more about the other participants.

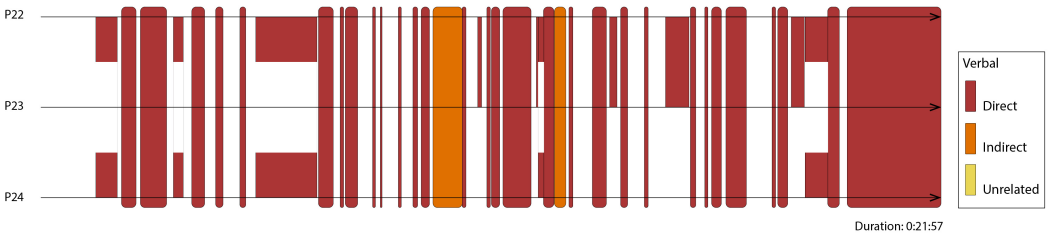
d. Three groups talked little or not at all for most of the experiment (example in Figure 12d). A few explanations contribute to the observed silence in these groups. First, some thought that talking was not allowed during the experiment. One participant said: *"I was afraid to ruin the experiment. If I can start the experiment again, I would probably talk to them more and get to know them. I feel like if people knew that they could talk freely, I feel like [the design] would be a good conversation starter and it'd be fun" (P12).* Second, participants had different perceptions about the study setting which led them to believe they should not talk. One mentioned that he felt the installation was in a visual art museum, and the atmosphere should be serious so that he should not talk. Another participant said she



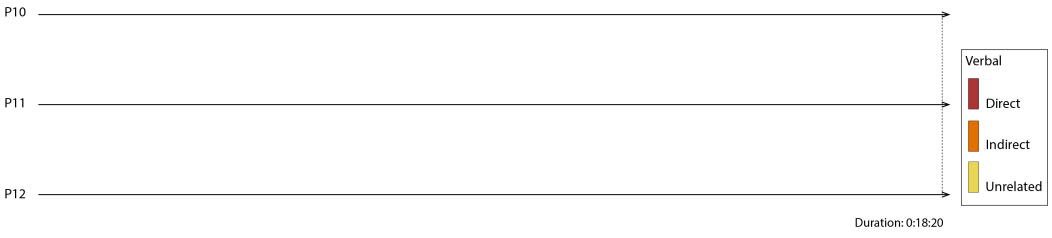
a . Group 12



b . Group 11



c . Group 6



d . Group 4

Figure 12: Verbal analysis of four typical groups: (a) Group 12, mixing all three kinds of talk; (b) Group 11, mostly talking about topics unrelated to the design; (c) Group 6, mostly talking directly about the design; (d) Group 4, staying silent throughout the experiment.

intentionally did not talk much because she normally would not talk with strangers in an airport waiting room. Finally, given the experiment was conducted at the university, an invisible "power dynamic" might have contributed to the silence, as one participant said: *"It seems difficult to talk with her because I think she might be a professor, as we are not at the same age" (P33).* In groups of this type, it seems that *SocialStools* did not help "break the ice" of verbal communication as we intended; and, as we discuss later, other forms of social behaviors emerged.

Table 1a shows the distribution of groups' verbal behaviors across the three interactions. Groups on average talked directly about the design about 1 minute longer in the *Sound* session (31.9% of the time) and in the *Bubbles* session (30.4%), compared with the *Ripples* session (14.6%) session. We think this resulted from the more complex mapping of movement to the system's responses in the *Sound* and *Bubbles* interactions compared to the *Ripples* interaction, instigating participants to be more engaged in the interface itself and trying to solve its rules. The *Ripples* expanded regardless of participants' movements, whereas the *Sound* responded to distances between participants and the *Bubbles* changed their colors, sizes, and amount in response to participants' orientation relative to one another. Figure 13 is one group's verbal behaviors visualization that shows the group's different amounts of talk in three interactions.

5.1.2 Non-verbal behavior.

To understand groups' non-verbal behaviors in using the *SocialStools*, we first looked at the non-verbal analysis for each group, and then compared it with the group's verbal analysis. Examples of three groups' non-verbal behaviors are presented in Figure 14.

Laughter occurred in most groups, ranging between 59 times in group 12 (Figure 14a) to 0 times in group 4 (Figure 14c). Eye contact also occurred in most groups, ranging between 81 times in group 11 (Figure 14b) to 2 times in group 4 (Figure 14c). Touch was least observed, only occurring in three groups, with one case of one participant touching another participant's arm, and two cases of three participants' using their legs to touch each other.

Overlaying the non-verbal analysis with the verbal analysis, we found that when participants talked "directly about the design," they more often looked down at the ground, looked around, or looked up to see the changes in the environment, instead of making eye contact with others. On the other hand, we found that participants had more eye contacts when their talk was "unrelated to the design" compared with the other topics. In the post-experiment interview, a few participants recalled that they made eye contact when they shared memories or wanted to confirm their thoughts with others. The verbal and non-verbal analysis overlays indicated that these moments happened when they talked "indirectly about the design" or "unrelated to the design." These findings suggest that when participants moved away from simply talking "directly about the design," they made more eye contact, further fostering a sense of togetherness in the group. The occurrence of laughter did not seem to vary across the different types of talk.

Looking at Table 1b, given the high standard deviations, we did not find meaningful differences between groups' non-verbal behaviors across the three interactions.

5.1.3 Movements.

To understand how *SocialStools* affect people's movements, we first examined the movement analysis of the group, then overlaid it with the verbal analysis. Synchronized movements occurred commonly across all groups, as expected, since our design encouraged bodily movement, and the socio-spatial interface required collaborative movements to achieve certain audio-visual effects. Figure 15 shows examples of the movement analysis of two groups.

Overlaying the movement analysis with the verbal analysis, we found that participants had longer, slower synchronized movements (Figure 15a) when they talked "unrelated to the design," compared to shorter, quicker synchronized movements (Figure 15b) when they talked "directly about the design" or "indirectly about the design." The interview responses suggest a possible explanation for this observation: when participants were more focused on one another, they could not spare more cognitive load to move their bodies, thus making slower and longer-lasting movements. One participant said: *"So he [one participant] started moving around in a circle, I think. And we just continued moving for a long time, with the conversation" (P33).* Another potential explanation is that participants wanted to show respect to others by sitting still and listening carefully to others: *"...I try to be respectful of everyone" (P7).* These findings suggest that *SocialStools* supported different rhythms of synchronized movements that corresponded with different talking topics.

To examine synchronized movement at a finer-grained level, we used the videos to identify patterns of movement (Figure 16). For example, we observed that participants were typically rotating around themselves (Figure 16-a) when the study just started, and circling around as a group (Figure 16-b) later in the study. This change of behavior might suggest that participants were moving from an "individual" to a "group" mode of movement as a sense of togetherness emerged. We identified additional patterns of movements: crossing in the middle of two other participants (c), getting in line (d), spreading out (e), and oscillating back and forth (f). These synchronized movements require coordination and collaboration among all three participants, and as such, may serve as another indicator of the emergence of togetherness. One participant noted: *"We kind of moved together when [we] realized [we] are collaboratively changing the environment" (P22).*

Table 1c shows the distribution of group movements across the three interactions. Groups moved synchronously more in the *Sound* session (29.7% of the time) compared with the *Ripples* (19.9%) and the *Bubbles* (18.0%). The design of the *Sound* was such that in order to achieve a certain sound, participants had to find how to position themselves relative to each other, and the feedback loop between their motion and the generated sound resulted in further synchronized movements. Figure 17 is one group's movement visualization that shows the group's different lengths of synchronized movements in three interactions.

5.2 Feeling and Experiencing Togetherness

The previous section presented social behaviors – verbal, non-verbal, and movement – that indicate togetherness between participants. In this section, we take the analysis a step further, examining the emergence of togetherness through participants' perceptions of the study and of each other, and through shared experiences of togetherness fostered by *SocialStools*.

5.2.1 Perceptions of Togetherness.

When participants were asked, *What was the most memorable moment during the experiment?*, nearly 80 percent of participants identified a moment during which they related to other participants as "we" instead of "I." A representative example of a participant recognizing membership in a group of three offered, *"I remember we were all cringing when the song was off. And I remember the joy we all felt when the song was right. Oh, we finally got it right. That was good!" (p23)* The use of "we" in describing the most memorable

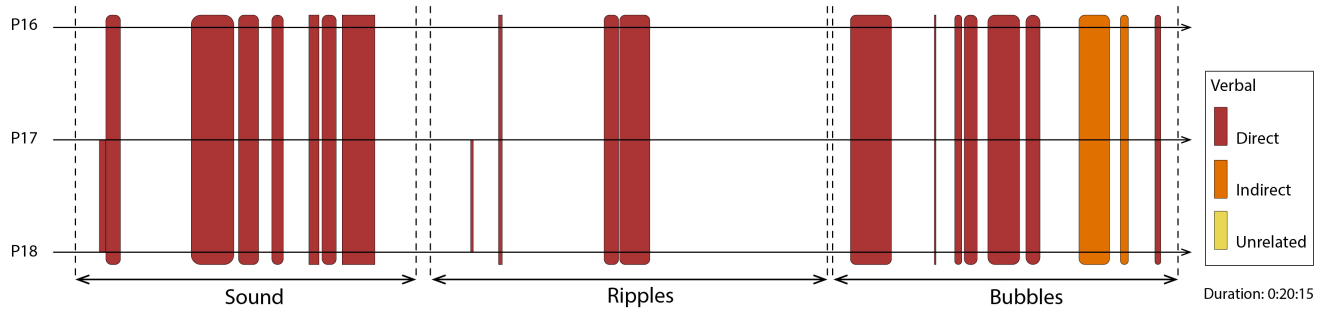
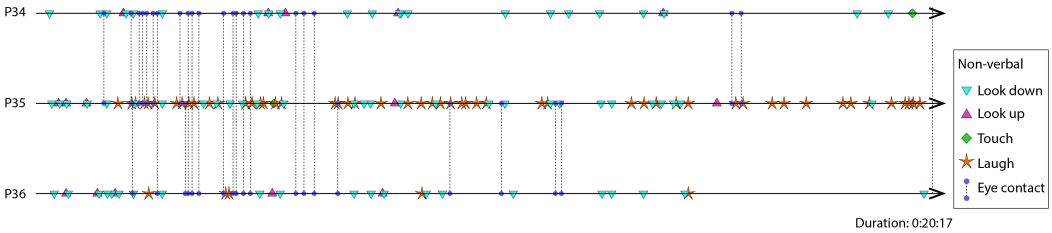
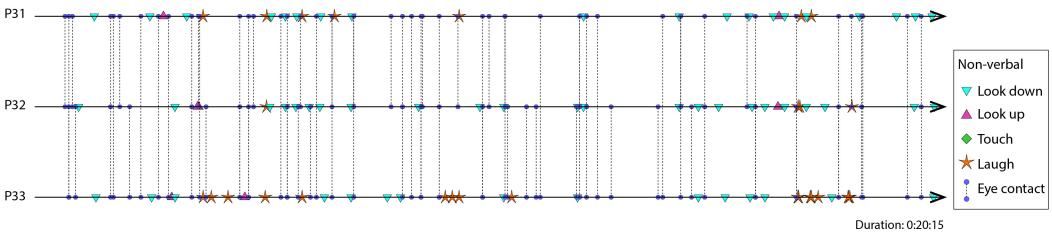


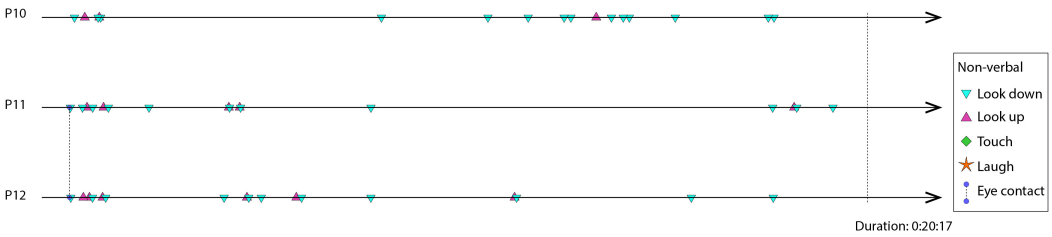
Figure 13: Group 6's verbal analysis in three interactions.



a . Group 12



b . Group 11



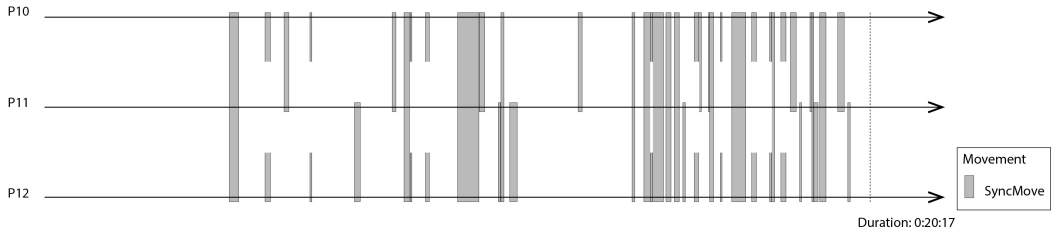
c . Group 4

Figure 14: Non-verbal analysis of three groups: (a) Group 12; (b) Group 11; (c) Group 4.

moment of the *SocialStools* experience suggests an identification of the individual with a group, or a sense of "togetherness."

Moreover, after the experiment, half of the participants were able to characterize the other two participants with traits of personality instead of purely demographic information (e.g., a student's department affiliation). Some examples include: *"Yeah, she (another*

a . Group11



b . Group4

Figure 15: Synchronized movement analysis of two groups: (a) Group 11; (b) Group 4.

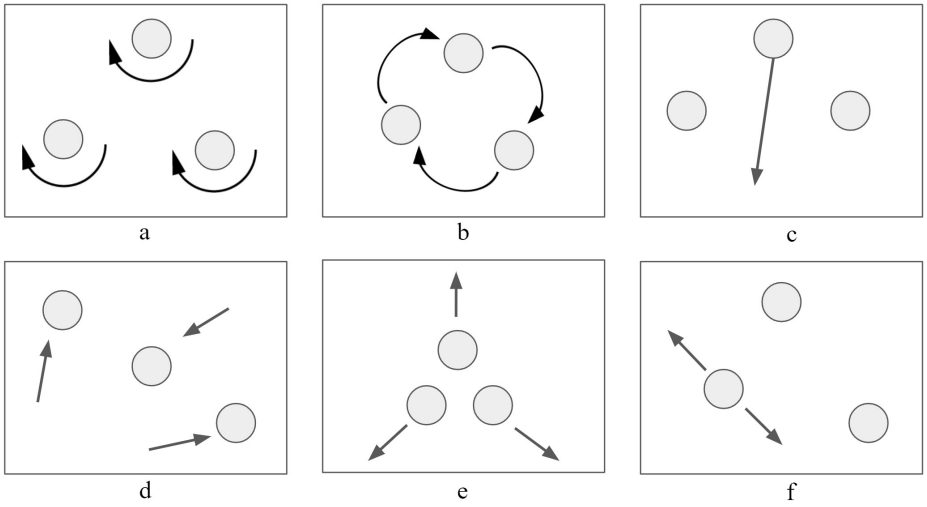


Figure 16: Examples of different movement patterns: (a) All rotating around themselves in the same direction; (b) Circling around; (c) Crossing in the middle; (d) Getting in line; (e) Spreading out; (f) Oscillating back and forth.

participant) is 'a doer'" (p7).; "I felt like she's a great communicator, like clearly, she took the risk…"(p8); and "I recognized him as more introverted, because he wanted, he … enjoyed … being silent" (p11). This happened even in groups that didn't talk with one another. When asked what they learned about the other participants, one participant said *"Even though we didn't talk. I could feel her (another participant's) personality. Maybe she's very affecting. She's enjoying this with me" (P11).* When asked about their most memorable moments, one participant offered that it was *"To figure out [a] person's personality from the really small details. We did not talk, but I know they actually were observing and thinking as well" (P11).*

When participants expressed empathy towards others, we interpreted this as another sign of "togetherness." One participant expressed empathy towards another participant when she realized that silence made them uncomfortable: *"I want to give emotional*

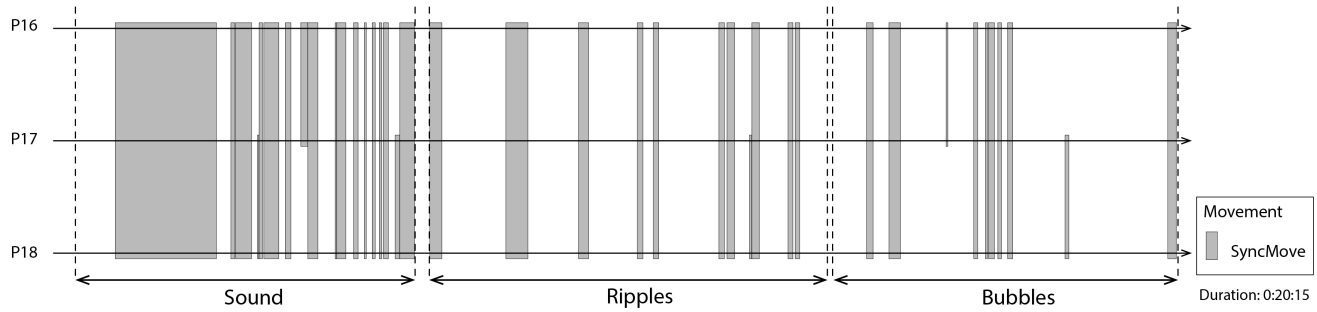


Figure 17: Group 6's movement analysis in three interactions.

support, but I don't know why I just don't do that. I feel she's uncomfortable" (p11). One participant expressed regret for crossing the personal boundary of touching another participant's arm: *"I don't know why I acted like we're already friends. I shouldn't have done that. Like, I feel kind of bad" (p7).*

Without our prompting, some participants volunteered that they felt a sense of connection with others. Some examples of this are: *"...previously, I also participated in a group experiment. But compared to those, I feel like this physical interaction is creating a more firm connection" (p8).*, *"I felt like we were working together. Through.. Wow, I definitely felt a connection" (p10).* One participant expressed that the design changed her behavior to be more willing to interact with others: *"I normally wouldn't do that [talk with strangers] in the real world, but I talked to her. And then I even touched her arm to help her move [the stool]" (p7).*

5.2.2 *Experiences of Togetherness.*

The following presents a number of experiences that we observed and that were reported by participants. Each of the experiences serve as an example of the cause of the emergence of togetherness with *SocialStools*.

Collaborating to solve the rules. We think one of the key reasons for the bond that emerged between participants was the collaboration required of the participants to find the mapping between their movements and the audio-visual responses in *SocialStools*. In the interview, one participant said: *"We were more of a group and less separate individuals. And we worked together, and we shared curiosity and interest in what was happening and how we could impact what was happening" (P7).* Another participant commented that sharing thoughts when working together let her feel connected with the other participants of the trio: *"And they were very cooperative. They could [have] just investigated [SocialStools] themselves..., separately, but they came to me and share[d their] thoughts, so I thought that's encouraging" (P8).* This experience helped break the ice, as one participant reported: *"SocialStools makes the awkward icebreaker a little less awkward, since all of us can focus on the music that's been created, or figuring out why each movement corresponds to some change in the sound" (P15).*

Connecting over the visual imagery. The socio-spatial interface served as a source of conversation topics for many groups through the visual cues, beyond a rule-solving experience. As one participant offered, *"I think because of the [projected] signs on the floor, we ha[d] a lot of topics to expand, such as we talk[ed] about water, we talked about travel experiences. And when we s[aw] the bubbles, we talk[ed] about orchestra[s], we talk[ed] about music. [SocialStools] has a lot of great start[ing] points for conversation" (p34).* For example, the *Sound* included the projection of a line between the stools to hint that the system responds to the distance between them. One participant commented that the projected lines suggested to him that they were a connected trio with a shared goal. This participant inferred the meaning of these lines: *"The triangle is a kind of a shape...linking each [of us to the] other. And when one of us moved, the shape will change. And when three of us move the shape, we're willing to see ourselves as unseparated" (P30).*

Sharing memories. Often people build connections with others by discovering that they share past experiences. The sound and imagery of *SocialStools* sometimes prompted participants to discover and talk about their shared memory. For example, one group talked about their swimming experiences when they saw the ripples projected on the ground. During their individual interviews, when asked what moments they remembered, all three mentioned the same conversation about their shared memory of their past swimming experiences.

Moving together in silence. Even when participants did not talk with one another, we observed that they communicated through non-verbal cues, such as when circling around together (Figure 16-b). A participant in a group that stayed silent throughout the study reported how the non-verbal coordination happened: *"During [the period] when we were moving around, even though we didn't talk, I think there were physical cues. Like I'm moving this way. And I would just avoid you that way..." (P11)* Another participant in the same group said, *"Our [nonverbal] contacts remind me, okay, they want to collaborate" (P10). SocialStools* offered groups a comfortable, unawkward, safe space to stay silent, as one participant shared: *"Yeah, still cool. With [SocialStools], if nobody wants to talk, I feel cool. [...] The environment made me feel comfortable to stay silent. I just enjoyed the music and the emotional impact" (p11).* The constantly changing visuals and music replaced the need to engage in verbal communication: *"I don't think it was awkward, because that was when I was sort of spaced out looking at the bubbles. So, ...it felt appropriate to be quiet" (p17).*

Being immersed in the same environment. Finally, simply being immersed together in the physical environment served as a shared,

co-located experience. During the interview, many participants mentioned that the experience involved multi-senses which created an immersive feeling. Sharing the immersive moment with others, like watching a movie together with a friend, may create a sense of togetherness. As one participant said, *"We had the same thought, same guess; we have shared thoughts, shared visuals, shared music, we engaged in the same activity" (P29).* Another participant commented, *"Just to see the [other participants] just relax and be in the moment is kind of special" (P11).*

6 DISCUSSION

In the book *Alone Together*, Sherry Turkle argues that technological development, originally intended to promote interconnectivity between people, has instead created a sense of alienation [62]. The distraction of phones, social media, and the internet has moved people away from experiencing genuine in-person relationships. In our work, we hope to motivate people to move back to person-to-person communication, to experience the genuine connections that happen between strangers in physical spaces.

Despite research showing that interacting with strangers improves well-being and a sense of belonging [6, 57, 64], people avoid direct contact with strangers because of the fear that they are not good conversationalists [56]. Our findings suggest that a socio-spatial interface that integrates people's proxemic behaviors [23, 37] with audio and visual feedback can help people overcome this fear, which could help alleviate the "alienation" between people mentioned by Turkle. Next, we discuss these findings with respect to group dynamics and offer design implications.

6.1 Group Dynamics and the Shifting Focus of Attention

Our findings present different patterns of verbal and non-verbal behaviors and movements we observed emerging in the groups. We turn now to an examination of these behaviors as a whole, illustrating the kinds of group dynamics that were supported by *SocialStools*. We focus on how participants within groups shifted between paying attention to the interface versus to each other, a dynamic that has been shown to be an important dimension to indicate how a small number of individuals become a group that functions together [3].

Figure 19 demonstrates our conceptual mapping of the focus and periphery of attention based on the video analysis: when participants talked about the design, looked up or down, or moved quickly to examine the interface's responses, we interpreted this as paying attention to the system (defined by Bales as *task focus* [3]). *SocialStools* became the focus of attention when the visual and audio provided topics of conversation and when groups collaboratively played to "solve the rules" of the interface. On the other hand, when participants talked not about the design or when they made more eye contact, we interpreted this as moving the interface to the periphery and paying attention to each other (also called *socioemotional expressiveness* [3]).

As a catalyst for social interaction, we had hoped that *SocialStools* could be a kind of gateway, opening up new conversations for participants to get to know each other. The design intention was that the interface would attract the group's attention at the beginning of the experience, serving as a focal point of interaction through the novelty of the imagery and music; thereafter, gradually, the three participants would shift their attention from the *SocialStools* artifact to each other as a group as the interface fades into the periphery. The interface, in this way, serves as a point of departure for more engaged social contact between the participants: people gradually forget the interface, turning their focus on each other – a disappearing computational interface [67].

Figure 18a sketches our intended concept of this group dynamic. The group's shifting focus of attention is indicated by the wavy line. Interestingly, when examining the social behaviors that occurred during the experiment, we observed patterns of group behaviors that diverted from our design intention. We categorized them into the following types, conceptually mapping the experience: *Game player groups* and *Solitary groups* (Figure 18b) were two types of groups where *SocialStools* remained their focus for most of their time together, but in two different ways. In *Game player groups*, participants spent most of the time verbally discussing the design, e.g., trying to solve the rules of the design intervention. In *Solitary groups*, participants mostly explored *SocialStools* without verbally communicating with each other, although we observed many non-verbal cues of communication like eye contact and synchronized movements. In another type we called *Explorer groups* (Figure 18c), the group switched their attention between focusing on *SocialStools* and on each other throughout the experiment. Finally, in *Socializer groups* (Figure 18d), participants paid attention to one another most of the time, e.g., talking about their personal lives, while *SocialStools* remained in the periphery, almost as if it were not there, other than serving as three conventional stools.

Although we intended *SocialStools* to foster a certain kind of group dynamic, other forms of group dynamics emerged. In other words, there isn't one way of building a sense of togetherness between strangers: they can explore the design, talk with each other, move around in synchrony, or combine a range of these experiences. The dynamic environment, created with people's embodied interaction [13, 45], had become an incubator that allows natural interaction to flow between strangers through various types of verbal communication, non-verbal behavior, and synchronized movements. The socio-spatial interface provided opportunities for collaboration, playfulness, shared memories, synchronized movement, and immersion with multi-senses, all contributing to the experience of togetherness.

6.2 Design Implications for Togetherness between Strangers

To promote interaction between strangers in small groups, previous literature has proposed methods such as interpersonal touch [35], conversational topic suggestions [46], and shared images [41]. *SocialStools* has expanded the design space for interactions between strangers through an integrated experience: using audio and visual feedback in response to people's proxemics to motivate diverse types of conversational topics, let non-verbal communications emerge, and motivate different patterns of synchronized movements. We present here some of the lessons we learned for designing socio-spatial interfaces that support togetherness between strangers.

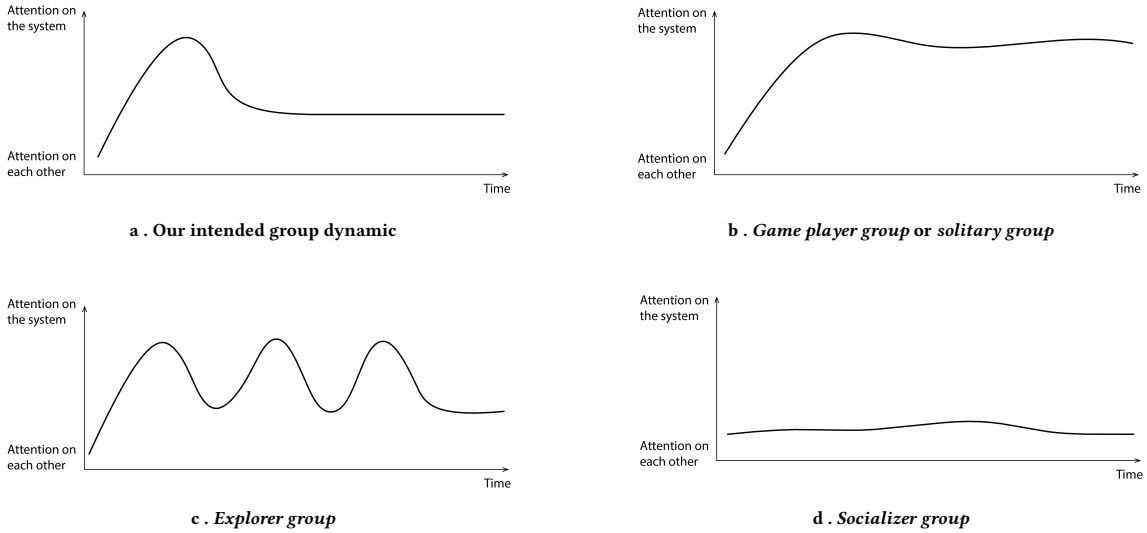


Figure 18: Conceptual diagram of Focus vs. periphery: (a) Our intended group dynamic whereby the interface starts as the focus of the group, then fades to the periphery; (b) *Game player* group or *solitary* group, in which the focus is on the interface for most of the duration; (c) *Explorer* group, whereby attention shifts to and away from the interface; (d) *Socializer* group, whereby the focus is on each other, not on the interface.

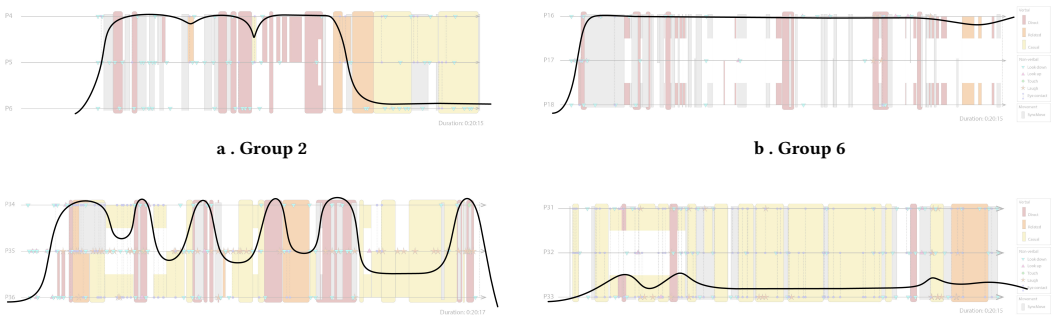


Figure 19: Conceptual mapping of focus vs. periphery of four groups: (a) Group 2; (b) Group 6; (c) Group 12; (d) Group 11.

6.2.1 The right level of difficulty.

One lesson we learned from the study is that designers should consider the complexity of the design's "rules," as users may view it as a puzzle to be solved. We found that the specific interactions we designed in *SocialStools* are better suited for "ice-breaking" than cultivating deep relationships. The visual and audio effects responding to participants' proxemics in the environment gave them cues to start a conversation, but also kept their attention away from more personal topics. An interface that has difficult-to-learn rules might interfere with getting to know one another and generating more intimate connections. On the other hand, if the rules are too simple, the interface might not engage participants to interact with each other verbally or non-verbally; indeed, some participants reported that they found the *Ripples* interaction boring, as the emanating ripples did not respond to their movement relative to each other.

6.2.2 Cultural and personal differences.

People may not all respond in the same way to the design of visual metaphors. Jörn Hurtienne and Johann Habakuk Israel argue that people's intuition to visual metaphors can be affected by factors such as genetics, upbringing, culture, and expertise [29]. In our study, we found that participants' understandings of the visual metaphor differed from one another and from our intentions. For example, we designed *Ripples* based on the metaphor of interpersonal zones [23] as a way to encourage participants to explore the invisible boundaries between them and to create overlapping interpersonal spaces, inviting them to get to know each

other. Participants, however, perceived this interaction as more individualistic, given that the *SocialStools* interaction did not directly respond to interacting with one another by orienting their bodies or changing the distance between them. As another example, *Bubbles* were designed to encourage people to orient more toward each other by growing and increasing in number. We observed that most participants were excited to see the bubbles appear and tried to orient their bodies toward others. However, one participant said in the post-study interview that he perceived the bubbles as raindrops on a windshield, and he tried to move his body in a way that will eliminate the bubbles just like using wipers to remove raindrops, in contrast with other participants.

6.2.3 *Extending the physical body.*

Embodied interaction doesn't always need to relate to just the physical body. The body can extend, especially in an augmented immersive experience like the one created by *SocialStools*, to elements in the environment perceived as belonging to one's body [60]. In the study reported here, perhaps because some projected images followed participants as they moved, they were perceived as "part of themselves." In the *Bubbles* interaction, for example, we observed that some participants used the tip of the projected arrow in front of them to touch another person's projected arrow tip. At the same time, physical touch was rarely observed in the study, perhaps because physical contact indicates an intimate relationship [17]. Our guess is that participants might implicitly consider the projected digital cues as "prosthetics" of their bodies. With digital projection, even strangers could have such contact with each other without breaking social norms related to physical touch (in contrast to [26]). This suggests that designers might consider leveraging personal digital cues as a form of "prosthetics" to extend the human body and, as such, the human ability [68] to promote connection between strangers.

7 LIMITATIONS

We are aware that a lab environment cannot replicate real-world interactions with strangers. Indeed, some participants weren't sure if they were supposed to talk with each other. In a follow-up study currently underway, we installed the system in a public location to learn how people interact with each other "in the wild."

Another limitation is that we did not include a control condition in the study to examine the differences between groups that experienced *SocialStools* with those who didn't, and the degree to which the design itself contributes to the emergence of togetherness compared to having no intervention. As an exploratory study, we think that our findings are valuable, showing overall trends of behavior and experiences with the design.

Furthermore, the fact that our participants were mainly university students may bias the findings, as college students might be more comfortable with the new technology and behave more sociably towards others. Certain social behaviors might be less observed if the participants were more diverse. In our study currently underway in the wild, we expect to learn more about the generalizability of what we learned from the study reported here.

8 CONCLUSION

This work is an investigation of how a socio-spatial interface can support interpersonal communication between strangers to foster togetherness. We presented *SocialStools*, a socio-spatial interface that leverages people's bodily, embodied interaction and proxemics, and transfers them into visual and audio feedback, in space, towards fostering togetherness among strangers. Although this research considers only a subset of the design space of leveraging bodily embodied interaction and proxemics with limited audio and visual feedback in the near environment, it offers a compelling artifact for fostering people's socio-spatial relationship during interpersonal communication, articulating important qualities and challenges of mediating interaction between strangers. Our results suggest that (a) a socio-spatial interface has the potential to promote different types of conversation, non-verbal communication, and movements, and (b) collaboration, playfulness, visual hints, bodily moving, and sense of immersion prompted by a socio-spatial interface help with cultivating togetherness. We have further investigated affordances of shifting between the focus and the periphery status of the socio-spatial interface which could provide unique benefits for different group dynamics during interpersonal communication. Additionally, we have highlighted the three more design implications: considerations of culture and personality, the concept of "imagery as prosthetics," and implications for affording, in the interface, a range of interaction "rules" towards balancing participants' engagement with the interface versus with each other. Altogether, our work lays out exciting opportunities for designing socio-spatial interface to support interpersonal communication between strangers, especially in a period where such communication is most needed.

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