FluidMeet: Enabling Frictionless Transitions Between In-Group, Between-Group, and Private Conversations During Virtual Breakout Meetings

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ABSTRACT

People often form small conversation groups during physical gatherings to have ad-hoc and informal conversations. As these groups are loosely defined, others can often overhear and join the conversation. However, current video-conferencing tools only allow for strict boundaries between small conversation groups, inhibiting fluid group formations and between-group conversations. This isolates small-group conversations from others and leads to inefficient transitions between conversations. We present FluidMeet, a virtual breakout meeting system that employs flexible conversation boundaries and cross-group conversation visualizations to enable fluid conversation group formations and ad-hoc, informal conversations. FluidMeet enables out-group members to overhear group conversations while allowing conversation groups to control their shared level of context. Users within conversation groups can also quickly switch between in-group and private conversations. A study of FluidMeet showed that it encouraged users to break group boundaries, made them feel less isolated in group conversations, and facilitated communication across different groups.

CCS CONCEPTS

• **Human-centered computing → Collaborative and social computing systems and tools**.

KEYWORDS

Remote Meetings, Breakout Rooms, Private Conversations, Proxemics

1 INTRODUCTION

Studies have shown that ad-hoc, informal conversations are key to creative innovations in social and professional contexts and are a critical factor when forming social bonds and building trust in a group [38, 48, 68, 84]. Such conversations often occur during *breakout meetings*, where small conversation groups can be created and conversation members can be quickly exchanged. These meetings enable smaller groups of people to have ad-hoc, informal conversations and form light-weight connections. For example, in-group participants may whisper to each other without being afraid of missing the ongoing group conversation because they can overhear the ongoing conversation. An out-group participant may also monitor and choose to join a conversation. However, unlike face-to-face breakout meetings, participants assigned to virtual breakout rooms may not be exposed to side conversations (in-group conversations) and their peripheral awareness of other breakout rooms may be diminished (between-group conversations), leaving them feeling unconnected and with a lack of conversation context after they have joined other rooms [60, 87].

To address these issues, some commercial platforms have been developed to support social virtual environments (e.g., Gather-Town [4], Mozilla Hubs [6]). Studies of these platforms in breakout meeting contexts (e.g., workshops at conferences, group discussions in online learning, etc.) have found that these platforms can create realistic scenes and afford users full flexibility to form versatile conversation groups [18, 19, 34, 87]. Inspired by the interactions that occur in physical settings, several studies [18, 19, 87] have investigated these platforms via proxemics frameworks [47, 87] and personal spaces - theories on people's social use of space. However, detecting such spatial relations constrains the flexibility within conversation groups and often comes at the cost of inefficiency, interruption, and privacy concerns [34]. The additional transition effort required between conversation groups can also create high-friction problems when switching breakout rooms or having private conversations. Therefore, the use of these platforms may lead to conversation initiation problems [34, 78], as out-group participants do not know the current conversation context.

In this work, we propose switching focus from enabling the *proximity of people* to exploiting the *proximity of conversations* by supporting more flexible, frictionless in-group private conversations and the peripheral awareness of ambient conversations in semi-permeable breakout rooms to enable in-group and between-group ad-hoc conversations.

We present FluidMeet, a videoconferencing system that facilitates ad-hoc and informal conversations by supporting flexible boundaries that vary the conversation visibility and frictionless transitions that occur between in-group, between-group, and private conversations. With FluidMeet, breakout groups can have private messages and calls within a group. FluidMeet also enables flexible between-group boundaries, i.e., conversations can be 1) *fully open* - out-group members can see, hear, and influence the conversation; 2) *semi-open* - others can either see the keywords extracted from the live conversation or see audio levels; or 3) *fully closed* - no information about the conversation is shared. We conducted a user study with 16 participants and compared FluidMeet with Zoom breakout rooms. Our findings illustrated that the enhanced awareness of within-group and between-group conversations in breakout meetings improves individual and group interactions and helps dismantle group boundaries by translating the benefits of controllable and frictionless whispering and overhearing into a virtual setting. We conclude that breakout meeting designs should focus on providing multiple alternatives of in-group conversations and supporting the connectivity of between-group conversation contexts, rather than only focus on the pure flexibility of group formation experiences.

The main contributions of this paper are 1) the concept, design, and implementation of FluidMeet, a novel virtual breakout meeting system with interpersonal and inter-group distances for enhancing ad-hoc and informal conversations, 2) findings from a user study evaluating the effect of FluidMeet on user experiences, engagements, and usability, and 3) design implications arising from the study and development of FluidMeet that can be used to guide the development of future virtual breakout meeting software.

2 RELATED WORK

We motivate our research by reviewing literature discussing how the concepts from physical environments and groups translate to virtual communication tools.

2.1 Supporting Small Group Conversations in Virtual Breakout Meetings

2.1.1 Challenges of Breakout Meetings. There has been a shift away from large in-person meetings to virtual meetings due to concerns about climate change and efforts to reduce carbon impact [52, 85] and the recent health risks introduced by COVID-19 that have transitioned education [72, 82] and academic conferences [20] to be held online. Many events and programs, such as conferences and workshops [87], synchronous online learning [23, 24], and online degree earning programs [79] use breakout meetings to support small group conversations and afford ad-hoc discussions and social encounters. In educational settings, in-class breakout groups have been used to support small subgroup discussions, help build connections and facilitate interactions between peers [24, 36, 59, 63, 70, 73]. However, recent research has shown that remote peers feel isolated in Zoom breakout rooms [60]. For example, group members often divide their attention between various tasks, resulting in a lack of investment in the current conversation and leading to silence and dissatisfaction during breakout sessions [2]. During virtual conferences and workshops, the shyness of initiating a conversation

for newcomers and the difficulty of deciding who to talk to often results in a lack of conversations occurring [78].

While the types of breakout meetings vary by setting, having ad-hoc, informal conversations and building lightweight connections are common goals when attending a breakout meetup [70, 79]. These goals motivated us to create a video conferencing platform that could support ad-hoc and informal conversations.

2.1.2 Technologies and Interfaces for Virtual Breakout Meetings. Current commercial and research platforms vary in their support of between-group boundaries during breakout meetings (Figure 1). Most videoconferencing platforms like Zoom [14] provide breakout rooms as bounded spaces with static boundaries (Figure 1: Static Boundary) where users can have focused in-group conversations and join other breakout rooms with an awareness of the other rooms' titles and membership. A few platforms such as Discord [3], Unhangout [12], and Remo [7] have provided advanced visualizations of other rooms' activities (i.e., icons next to the avatars or user names) to allow out-group members to identify the active speaker or the specific location of out-group members in the room. While these techniques do provide some additional context to out-group members, these visualizations may not be sufficient for out-group members to join an ongoing conversation.

Moreover, these videoconferencing platforms are designed for focused conversations, making it difficult to replicate *spontaneous conversations* and *ambient awareness* online [60]. One solution could be to use proximity-based virtual meeting platforms (e.g., [4, 6, 8, 10, 13]) that have less clear boundaries (Figure 1: No Boundary) such as Mozilla Hubs[1] [6] and Gather.Town[2] [4, 57]. With these platforms, users could roam around a virtual environment and form conversations with other nearby users in the virtual map. However, HCI researchers have identified several limitations of proximity-based virtual environments with respect to the forming of spontaneous or private conversations in breakout meetings like workshops [34, 58, 65, 87]. These systems require additional interpersonal friction and additional effort to transition from private to group conversations. For example, Erickson et al. [34] found that users were uncertain about how far away others could eavesdrop on their private discussions. Furthermore, they were afraid of missing critical information whenever they moved away to have a private conversation and later rejoined the main group. Most proximity-based platforms support both small bounded smaller spaces (with portals to travel between breakout rooms) and relatively unbounded larger spaces (for people to form smaller subgroups by proximity freely), however, several recent studies have found that users have difficulties when forming groups in larger spaces due to problems with controlling personal space and distances, and lack of between-group visibility in smaller breakout rooms [57, 87]. Furthermore, similar to platforms using static boundaries, the additional information provided by the movement and orientation of avatars within proximity-based systems does not represent the current conversation context so that these platforms fail to support users when they are deciding whether it is appropriate to join a group. This thus

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[1]Mozilla Hubs: a virtual environment platform that provided fully 3D virtual environments. In larger spaces, users could hear spontaneous conversations.
[2]Gather: a 2D map and location-oriented interface where each user was a virtual avatar and could roam around the interface.
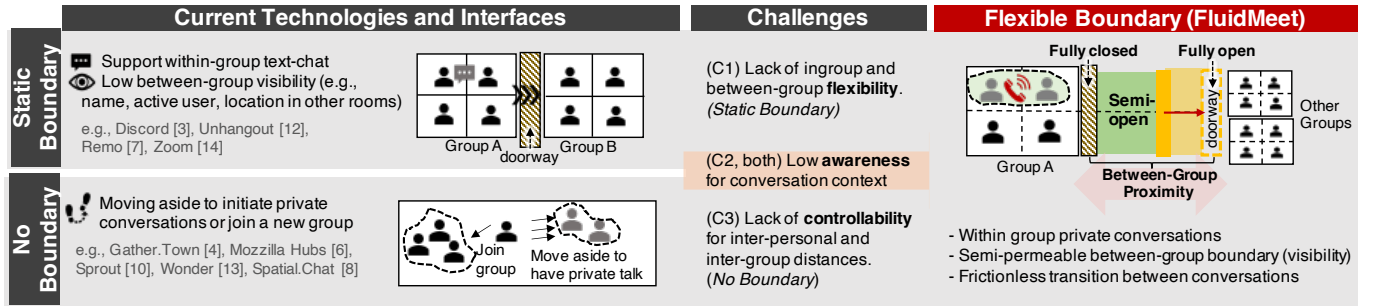
Figure 1: Overview of virtual meeting tools organized by boundary type (no boundary, static boundary, and flexible boundary).

leaves the problems that result from conversation initiation and shyness before joining a new breakout group unresolved [34, 78, 87].

Inspired by the work of Hollan and Stornett [50], which encouraged remote work to take unique advantage of telecommunication technologies to surpass rather than imitate face-to-face interactions, this research aimed to design a breakout meeting tool that supported private in-group conversations and enhanced ambient awareness for inter-group boundaries rather than imitate physical interaction. We believe that breakout meetings can benefit from enhanced awareness and between-group visibility, however, the current use of static or no boundaries results in platforms that lack the flexibility and controllability that is needed to support within-group and between-group awareness and conversation context. This motivated us to explore how to enhance interpersonal and inter-group awareness and ease the transitions between these conversations.

2.2 Supporting Awareness in Computer-Mediated Communication Systems

The challenges of feeling unconnected and losing conversation context occurs not only in breakout meetings, but also during meetings that are held using media spaces and computer-mediated communication platforms [17] that connect distributed teams and facilitate informal social interactions. Consequently, this lack of *awareness*, a mechanism noted by Dourish and Bly [29, 30] as "*an understanding of the activities of others, which provides a context for your own activity*", would lead to missed opportunities to collaborate and the inappropriate interruptions of others [37, 69, 74].

To enhance workspace awareness, earlier research studied groupware systems over time (i.e., synchronous or asynchronous) and space (i.e., face-to-face or distributed) constraints, focusing on asynchronous tools like email, shared databases, and synchronous tools such as audio or video conferencing and instant messaging [44–46]. Several studies defined the Open Conversation Space, where other groups' conversations could be overheard during text-based instant messaging [31, 32] and chat rooms or Multi-User Dungeons (MUD) [27]. Harnessing the importance of casual conversations during workspace collaborations [56], groupware systems created small social worlds or communities through large displays or personal workstations [40, 41, 64]. Such systems have the potential to enable new collaborations across distant teams by supporting shared video snapshots of offices (e.g., Portholes [30]), lightweight glances into

other offices with a sense of tele-proximity (e.g., Montage [80, 81], Piazza [51]), and transitions between asynchronous and synchronous work (e.g., Notification Collage [41], TeamView [40], Community Bar [64]). Many of these systems supported a digital "doorway" to ease transitions between synchronous and asynchronous, individual and group-based work within one technology, which Greenberg and Roseman [40] later adopted as the "Room Metaphor." They defined *Permeability*, as a feature of the Room (as "bounded space") that placed a doorway between rooms so that users could navigate between rooms without seeing what was going on in a room. In brief, this line of research enabled distant teams to transition from loose to tight collaboration couplings [37, 69, 74] by providing casual communication opportunities in a "semi-synchronous" manner.

The current research builds on the history of multiparty media spaces and workspace groupware systems to explore awareness in synchronous breakout meeting contexts. We bring attention to the high friction challenge of forming subgroups and sub-conversations and maintaining individuals' control of their group conversations in social and professional contexts. Unlike the *permeability* doorway concept [40], we support the notion of *semi-permeable* rooms that construct an additional space between breakout rooms. This additional space acts as an active conversation awareness facilitator to facilitate conversations and provide real-time group and individual self-disclosure.

2.3 Background Theory and Motivation

Our research leverages insights from three theoretical concepts: proxemics, F-Formations, and privacy regulation.

2.3.1 Social Proxemics among Remote Peers as a Conceptual Lens. This work builds on Hall's proxemics theory [47] related to the concept of distance. One of the main themes within Hall's work was that people maintain certain physical distances based on the types of relationships they are in and the types of interactions they have. Hall articulated four main distances, i.e., an *intimate distance* that allows for touch or whispers with the range of 0 to 45 cm, a *personal distance* that we naturally maintain with strangers, a *social distance* where we can catch other's gaze, and a *public distance* where people lose their sense of personal involvement with others, such as when one is public speaking. Hall described the broader set of spatial relationships that exist between particular arrangements of people and objects in environments, which we

argue can be applicable in co-located and remote environments. In co-located contexts, the concept of proximity has been used to examine users' relationships via the devices they carry (e.g., [39, 42, 62]). For virtual communication technologies, many researchers have found that perceived proximity is a crucial indicator of the effectiveness of such systems [66, 67, 69, 88], implying that the concept of virtual proximity could become an estimation of users' desires to communicate with others or others' groups during online conversations.
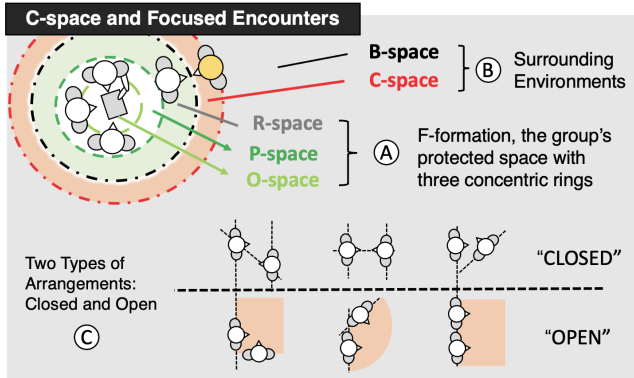

Figure 2: A walk-through of F-Formations: A) three concentric rings that form the group's protected space; B) beyond this, there is a *C-space* belt between the r-space and the b-space (public space); C) focused encounters can be open or closed based on their arrangements.

2.3.2 F-Formations and the Immediate Environment. The theory of F-Formations was based on observations of face-to-face conversations in public spaces and defined concentric circles relevant to protecting group interactions from non-member interference [55]. Initially, Kendon [55] suggested that there were three concentric rings (i.e., *o-, p- and r-space*)[3], which were part of the group's protected space (Figure 2A). Beyond that was the *B-space*, which was the rest of the group's perceivable (and public) space. However, if an outsider suddenly transitioned from the public space (i.e., *B-space*) to the group's protected space (i.e., *o-, p- and r-space*), then the group would have no time to prepare an appropriate behavioral response. Thus, Ciolek and Kendon [25] posited that there was a *C-space*, where there is minimal attention and awareness of people who soon might enter the protected space occurs (Figure 2B). Moreover, Kendon also found that people in close proximity to outsiders seem to avoid using "closed arrangements" (Figure 2C closed), which may indicate the need for visual control of the immediate environment and a certain level of readiness to cooperate with others who are nearby. By establishing concentrically nested spaces, people in an F-formation cope with other users' presence by sorting and accessing the events taking place outside the *o-space* without running the risk of sensory or information overload. Ciolek and Kendon concluded that *"there is a progressive transition from the*

domain that is most private, exclusive, and jealously guarded to the most public and most accessible one"* [25]. The *C-space* gives rise to FluidMeet's goal of giving off clues about what is happening within a group's protected space and simultaneously giving low-effort awareness to group members of potential outsiders who may be interested in joining for ad-hoc conversation.

2.3.3 Privacy Regulation Theory. In Altman's privacy regulation theory [15], privacy is an interpersonal process that regulates interactions between the self and the environment. Each person has their own privacy preferences that determine their initial desired privacy level and influence their specific dialectic between openness and closeness of self to others. Accordingly, when group privacy is considered, group norms change in response to group membership changes and are influenced by individual preferences. Palen and Dourish later [71] applied Altman's theory to sociotechnical environments to suggest new ways of thinking about privacy. They further conceptualized the interpretive framework of a disclosure boundary (i.e., privacy and publicity), an identity boundary (i.e., self and other), and temporal boundaries (i.e., past, present and future) to outline privacy as a dynamic dialectic process.

2.3.4 Using Theories to Motivate Virtual Meeting Design. Virtual meeting tools should support users' or groups' virtual proximity to mediate their interpersonal (*proxemics*) and intergroup (*C-space*) conversations and facilitate a flexible, frictionless handling of the privacy level of the group conversation (*privacy regulation*). Rather than taking inspiration from the spatial organization (e.g., interpersonal distances, orientation, and avatar movement) underlying the two human-human social theories (i.e., Proxemics and F-formations), this research enables for the *proximity of conversations* and constructs different conceptual distances between conversations. In particular, we construct the *C-space* in F-formations as a peripheral awareness of Room Panels to connect between-group contexts in real time. Within a group, we enable interpersonal interactions for efficient private conversations between pairs. Moreover, as breakout groups need various degrees of conversation management to control conversation disclosure, *privacy regulation theory* was used to situate how individual agency and group mechanisms can flexibly influence between-group boundaries or distances by managing the openness levels of conversation context.

3 FLUIDMEET DESIGN PRINCIPLES

FluidMeet was developed to explore how video-conferencing platforms can better support interpersonal and inter-group ad-hoc conversations during breakout meetings. The main design goal was based on two research questions: **RQ1: Enhancing Awareness:** How can we enhance the awareness of in-group and between-group conversations; **RQ2: Easing Transitions:** How can we ease the transitions between conversations (i.e., in-group, between-group, and private)? The "Enhancing Awareness" goal conceptually articulates two design properties - *Interpersonal Distances* (3.1) for in-group conversations and *Cross-Group Distances* (3.2) for between-group conversations, suggesting opportunities for nested and progressive proxemic zones (Table 1). The "Easing Transition" goal describes the design property of *Privacy-Interaction Flexibility* (3.4) which focuses on controlling within-group and between-group conversations (Table 2). The design properties are derived from the

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[3]Internal Arrangements of F-formation: *O-space* is the innermost space where people project their voices and gazes and is a small-scale interaction arena where overt and explicit actions are located. *P-space* interlocks the bodies and personal belongings of people and determines group membership. *R-space* is a space that buffers the group from the outside world.

Design Properties	Design Requirements	Descriptions of Design Requirements	Design Solution (FluidMeet's Features)
Interpersonal Distance *Within-Group*	*Visibility, in-group*	Users should be able to detect ongoing conversations and be peripherally aware of one-to-one or side conversations (noticeable but not distracting) [55]	Halo Widget: private conversations nested in a group conversation
	Interpersonal interactions	Users should have flexible interpersonal interactions, different proxemic distances (personal and social distances) should be nested and overlapped with each other.	
Cross-Group Distance *Between-Group*	*C-space* [22,54]	Flexible cross-group interaction is needed for people in a small group to monitor and perceive their surroundings.	Room Panels: create transitions of C-space
	Progressive Transition	C-space identifies the spatial zones as nested and progressive transition from private to public domains [22].	Five Cross-Group Distances (multiple visibility levels)
	Visibility, out-group	Similar to the interpersonal distance, visibility also applies in cross-group inter-actions. The between-group information should be peripherally noticeable [55].	Changeable sizes of room dimensions.

Table 1: Design properties and requirements for Enhancing Awareness and FluidMeet features supporting them.

theoretical conceptualization of virtual conversation spaces relating to proxemics, F-formations, and privacy processes and a critique of the state-of-the-art in contemporary video-conferencing systems.

3.1 Enhancing Awareness: Interpersonal Distances

Hall described interpersonal space as four distances between people that were divided into zones based on intimate, personal, social, and public encounters [47]. These zones could be nested and overlapped, suggesting that the intimate or personal distances (and social or public encounters) could co-exist within longer-range distances. While several virtual group meeting tools have been designed to facilitate these free-formed encounters by proximity, they rarely articulated how such features constrain action possibilities by sep-arating conversations that could have been nested and co-occur. For example, in systems with free-formed conversations defined by proximity (e.g., [57, 87]), to have a private talk (i.e., within inti-mate or personal distances), the users in a group conversation (i.e., social distances) have to move to unoccupied areas to avoid being overheard. This creates friction when moving between conversa-tions and makes switching conversation groups and having private conversations time-consuming and laborsome. By construing the design property as **interpersonal distance**, a nested conversation structure can be formed - users can have private conversations (i.e., personal distance) within the group conversation (i.e., social distance) without moving to other spaces or rooms (Table 1).

3.1.1 Halo. Within FluidMeet, interpersonal distance was reflected using the Halo. The design of Halo was inspired by peripheral awareness interfaces [22] and off-screen object visualization meth-ods [16, 43]. When a user initiates a private message or call with a member in the same group by clicking another member's video stream (Figure 3 C3), the messages and calls are visualized as col-ored bubbles in the corners of the receiver's video stream (Figure 3 C4). The information provided via Halos represents timely yet ephemeral side conversations. The Halo fades out in 20 seconds so that it does not require constant attention from the user. The private message is invisible if the user does not attempt further actions. The user can quickly close, reopen, or respond to the message/call by using quick access buttons (Figure 3B Halo Menu).
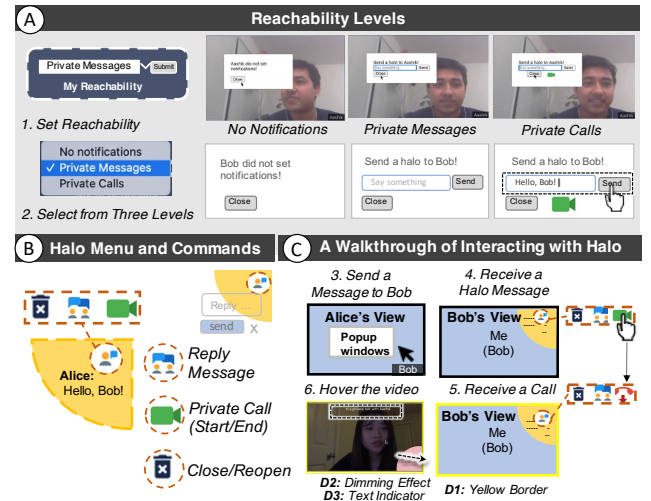

Figure 3: Halo Interface and Interaction. (A) The reachability level determines whether others can privately reach a user, only send text messages, or initiate a quick call. After a user sent a message (bottom) to Bob, (B) a Halo Menu appeared on Bob's view and contained the *Reply Message, (Close/Reopen) a Halo, (Start/End) a Private Call* commands. (C) Users can change their reachability level anytime (top). The Halo ap-pears at the corner of the receiver's video stream. If one is in a private call, a *(D1) Yellow Border* is shown around the person's video with *(D2) Dimming Effects* and *(D3) Text Indi-cator (bottom).*

3.1.2 Interacting with Halo. Halo has three reachability levels that enable users to regulate their interpersonal distance to other users in the same breakout room. Setting one's reachability level results in three different popup windows when other peers click on the user's video stream (Figure 3A: bottom). At the *No Notifications* distance level, users avoid all Halo messages and private calls, thus blocking all interpersonal side conversations from other users. Other users who are initiating a side conversation will see a "The user did not set notifications!" prompt (Figure 3A: *No Notifications*). At the *Private Message* distance level, sending private messages is an indirect
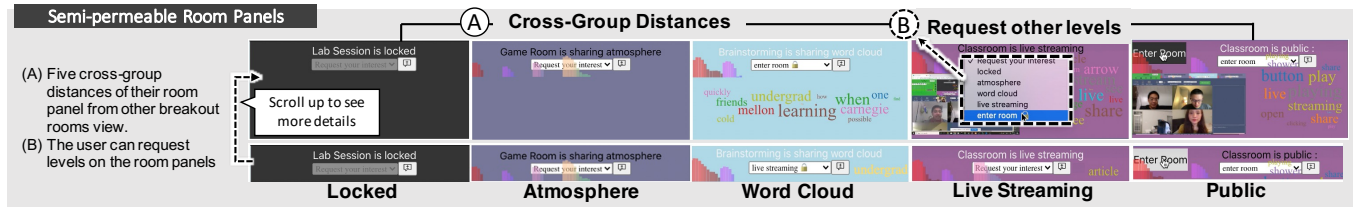
Figure 4: A depiction of the Room Panels. (A) Five Cross-Group Distances and (B) "request your interest" menu on Room Panels.

way to initiate a private call. At the *Private Calls* distance level, whenever a user clicks on another user's stream, a green video icon (Figure 3A: *Private Calls*) displays the user's availability to receive a private call. The user can also send a private message to check the user's availability to have a side conversation (Figure 3 C3). If a user did not enable the private call level, sending a private message can be an alternative way to check the user's availability to have a private video call.

A *Private Call* can be initiated by clicking on the video icon (Figure 3B) in the Halo Menu. When in a private call, visual indicators (i.e., Yellow Border, Text Indicator and Dimming Effect) let the user in the private call know they are in a private call and whom they are talking to (Figure 3C: D1-D3). Other members of the group cannot hear the user in a private call but will see still images to indicate the two users are "In a private talk" (Figure 6D).

Although current videoconferencing systems support private text chat within the public chat channel, it can be challenging to notice or discover either public or private chat messages, especially when viewers focus on a video stream channel. For example, before a speech begins, two people in a room may start a conversation that lasts until the speech begins. During the speech, they may whisper and comment about the speech's content and share materials. Although this side-channel conversation is typical in physical space, this one-on-one interaction experience is almost universally ignored in virtual video communication [86]. In some cases, this may prevent users from gaining access to remote peers due to the amplified nature of the public discussion channel. The ability to send private messages and calls within group situations via self-controlled reachability and a novel UI widget, i.e., the Halo (Figure 3B), overcomes users' limited interaction opportunities and enhances interpersonal conversational awareness. The within-group private messages and calls further support ad-hoc, reachable private conversations during breakout meetings.

3.2 Enhancing Awareness: Cross-Group Distances

According to the F-Formations literature [26], there is a C-space belt where people are monitored and are consciously perceived and reacted to. F-formation theory also specifies progressive and nested transitions from private to public domains. For example, empirical studies of the occurrence of verbal and gestural salutations between participants of an F-Formation and a passerby show that 96% of salutations take place within a range of ten paces (or six meters) from the F-formation system [26]. This design sensitivity to connect conversation context is particularly complementary to how existing

systems (e.g., Discord [3], Unhangout [12], Remo [7]) visualize members in other groups or active speakers to show member visibility in other rooms. Therefore, adopting conversation visibility under the umbrella of between-group visibility is essential to support conversation context. We conceptualize conversation visibility as levels of openness and closeness in an ambient conversation. Considering **cross-group distance** levels, we suggest having explicit design properties that can be used to enable out-group members to perceive progressive levels of conversation visibility without needing to join the conversation group (Table 1).

3.2.1 Between-Group Room Panels. Within FluidMeet, Room Panels contain five cross-group distances that support overhearing from other breakout rooms, resulting in different levels of conversation visibility (Figure 4A-B). The cross-group distances represent the different levels of openness of a breakout room as distances to other breakout rooms. The closer a group is to other groups, the more information members in other breakout rooms can perceive about its content and activities. The host or co-hosts of each breakout room can share their cross-group distances to show the current level of conversation visibility. The shared cross-group distances of each room are shown on a Between-Group Room Panel from other Breakout Room's views in real-time. Furthermore, the drop-down menu on each Room Panel (Figure 4B: Request your interest) enables individual users to unlock new cross-group distances for that breakout room.

- **Locked.** The default distance to a breakout room is "locked" (Figure 4A Locked), similar to current videoconferencing systems like Zoom [14]. A "locked" breakout room cannot be accessed or overheard. As it can be thought of as a conversation group with the greatest distance to all other conversation groups, the only information that can be seen is the group's presence.
- **Atmosphere.** The atmosphere distance utilizes a social visualization of the aural group conversation to capture the group's voice pattern. The design is inspired by table visualizations (in-person) [53, 54, 76], which enable a group to see their conversation visualized on the table surface as they speak and understand who is the dominant speaker. In FluidMeet, two types of information are captured and visualized. The number of members in a conversation is visualized as the number of audio visualizers, with different colored audio visualizers representing different users. The pitch and amplitude of the voices are also visualized as a set of bar graphs.
- **Word Cloud.** In physical space, whenever a user moves closer to, or actively follows, a conversation at a certain distance, they can overhear several split words from the conversation. Similar to this, at the word cloud distance, the top ten frequency words

Design Properties	Design Requirements	Descriptions of Design Requirements	Design Solution (FluidMeet's Features)
Privacy-Interaction Flexibility *Within-Group* (in-group)	**C1)** self, desired, in-group, output	The user (self) should be able to flexibly control their output (e.g., private and group conversations). Hence, an individual (self) should be able to switch between different interpersonal levels.	Switch Handler: a transition from private to group conversations.
	C2) others, desired, in-group, input	Privacy can be analyzed as an individual's privacy. A person has privacy preferences that determine their desired privacy level and dynamically change the openness of their interpersonal conversations.	Reachability: enable privacy preferences.
Privacy-Interaction Flexibility *Between-Group* (in-group, out-group)	**C3)** self v.s. others, desired v.s. actual	To fulfill the self's and others' actual and desired levels of openness to one another, the group (self) should be able to control their desired openness to others	Slider: dynamically change distance levels.
		The group should be able to observe the user's desired level and accept or decline the request.	Square Brick (Red Grid).
	C4) self, desired	This desired level of openness (self) will result in the actual levels of others' distance to the group. Hence, to achieve an optimal privacy level, users should be able to actively request their desired distances levels to other groups.	Request Menu: request their desired levels to other rooms.
	C5) self and others	Members of a group (self) should be able to invite their others to the group and invited users should be able to accept/reject these invitations.	Invite individuals from other groups.

Table 2: The design property and requirements for Easing Transition and the FluidMeet features supporting them. In the Design requirements column, the listed words under C1) - C5) were constructed in Section 3.4.

from members in the breakout room are visualized and updated every 20 seconds [28].

- **Live-streaming.** At the live streaming distance, if a user is actively following a conversation before joining the breakout room, they can view a muted video but cannot influence it. The live-stream is paused by default to avoid distracting the current conversation of the live-stream viewers. The video stream offers additional information and context about the conversation because the video contains stronger socially significant information like human faces and their expressions, which is similar to standing in a hallway and looking into a meeting room through a glass window. As noted by social translucence work [33], humans are perceptually attuned to information like movement and human faces. When showing a live video with socially significant information, people are willing to notice and react to faces more readily than other levels of information (e.g., words).

- **Public.** At the public distance, a hyperlink is shared with other breakout rooms on the Room Panel. Users can click on the hyperlink to enter the shared breakout room. The addition to the previous distance (i.e., Live-streaming) is that this hyperlink enables out-group members to influence the group conversation.

Based on the "progressive and nested transition" design requirement from private to the public domain, all of the levels are nested such that the subsequent distance will always include previous distances. For example, if a breakout room is sharing a live-stream, all of the previous distances (i.e., Atmosphere and Word Cloud) should be shared as well.

The lack of connectivity can be a disruptive experience for current breakout meetings, as one must fully exit one space before gaining awareness of the conversation state of the new space. To provide a sense of connectivity of breakout room contexts similar to large physical spaces, it is crucial to be able to view other breakout rooms' contexts before traveling to them [87]. FluidMeet uses visibility levels of different distance metaphors to support between-group conversations and foster a sense of connectivity between breakout rooms.

3.3 Enhancing Awareness: Summary

With the "Enhancing Awareness" goal and the set of design features introduced, there is a need to adopt a stronger sensitivity to combine the **interpersonal distance** and **cross-group distance**. Virtual meeting tools should enable short-range interpersonal distances nested with other long-range distances to reduce the friction of switching between different conversations. Systems should also expand between-group visibility to enhance the flexible proximity of conversations so that a user can overhear a conversation without traveling to another room.

3.4 Easing Transitions: Privacy-Interaction Flexibility

To regulate one's privacy (i.e., social interaction), individuals or groups may use various behavioral mechanisms such as verbal or non-verbal behavior or territoriality and personal space [15]. Extending privacy theory to sociotechnical research, Palen and Dourish [71] stressed how the active process of privacy management takes place in the context of the *possibilities* that are offered by one or another technology. If the design features for controlling this process or switching between privacy and interaction levels are not flexible and easy to use, it would be challenging and frustrating for users to successfully control the process and change the distance. In this case, the system would fail to fulfill the needs of individuals or groups to *regulate* the privacy process, nor would it achieve their optimum level of privacy. Hence, the "Easing the Transition" goal aims to achieve a flexible, smooth, and dynamic process to regulate individuals' or groups' privacy and interaction and construct frictionless transitions between various conversations.

To address the in-group and out-group structure, the design property of **Privacy-Interaction Flexibility** is adapted to the two awareness properties (i.e., interpersonal distance and cross-group distance to achieve different goals and states of awareness). The design property emphasizes how users can flexibly control the process of obtaining their desired *interpersonal distances* and *cross-group distances* respectively. Table 2 describes how the design property was constructed to ease the transition for within-group
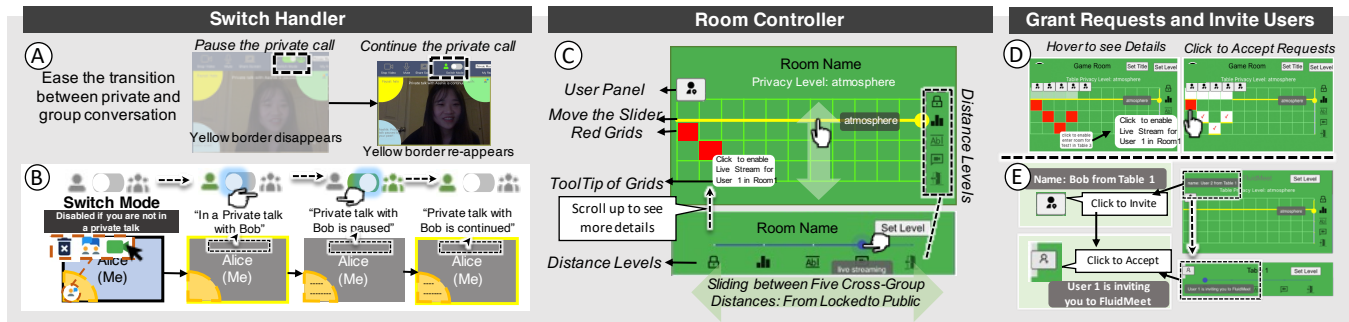
Figure 5: Users can Ease Transitions between private and group and group-to-group conversations by using the (A-B) Switch Handler or (C-E) Room Controller.

and between-group dimensions, the five concepts **C1)** - **C5)** from five properties of privacy regulation theory [15], and how these concepts map within FluidMeet:

C1) Self vs. Others: *The way that one's actions or utterances are designed with respect to the actions of others.*

C2) Desired vs. Actual: *The desired level of privacy is the amount of privacy required to serve a person's needs and role requirements. The actual level refers to the amount of privacy that a person achieves.*

C3) Input vs. Output: *A bi-directional property that involves input from others (e.g., noise) and output to others (e.g., oral communication).*

C4) Individual vs. Group: *Individuals have their own privacy preferences that determine their initial desired privacy level and influence their privacy dialectic. For a group's privacy, group norms change in response to changes in group membership.*

C5) In-Group vs. Out-Group: *Both in-group and out-group members consider in-group and group-to-group boundaries to achieve optimal levels of privacy.*

Privacy-interaction flexibility allows users to control their within-group interpersonal interactions smoothly and between-group (cross-group) distance.

3.4.1 Switch Handler. The Switch Handler is a within-group flexibility technique (Figure 5 A-B) that is enabled after a private call has been initiated. It enables flexible switching from private talk to group conversations and vice-versa. As users in a private call can still hear the group conversation, it enables group members to meet the urgent and immediate needs of primary conversations. For example, when someone from a group mentions a user who is in a private call, this user (addressee) does not need to stop their current private talk to move back to the general group conversation. Rather, they can quickly switch back to the group conversation without stopping the private call. When the user clicks on the Switch Handler (Figure 5A: left), the private call is temporarily paused (Figure 5B) and the user they were talking to is notified. In addition, the visual indicator (i.e., Yellow Border) in both users' views will disappear until the private talk is continued (Figure 5B).

3.4.2 Regulating Distances via the Room Controller. Prior research has stressed the importance of representing involvement levels with respect to conversations [77, 83]. Most implementations have focused on knowing who is currently viewing the ongoing conversations and do not specify various levels of involvement. For example,

Babble [35] used a visual representation called "social proxy" to visualize levels of involvement. They depicted people as marbles in and around a circle, representing a conversation. In Communico [31], the degree of involvement depended on how aware a participant was of a conversation and whether or not they participated in the conversation. Inspired by such chat-based tools, FluidMeet uses a *Room Controller* as the "social proxy." The cross-group distance to the current group is displayed as four rows of square bricks (Figure 5C), with participants depicted as a column of grids. The participant icons behind the "locked" square brick represent users who are logged in but are in other breakout rooms or in the lounge (Fig 5C: User Panel). Both hosts and co-hosts can control the *Room Controller* by moving the slider and breakout room access can be granted on a per-user basis. If a user outside the breakout room requests access beyond the current cross-group distance level, their request appears as a red grid on the Room Controller (Fig 5D: Red Grids). Any member of the breakout room can see the requester's username by hovering to see the tooltip of the red grid and clicking on the red grid to grant them access (Fig 5D: Left). Once per-user access is granted, the access is shown as a white box (Fig 5D: Right).

3.4.3 Flexible Size Changes of Group-to-Group Dimensions. The Room Controller (Figure 5C Top and Bottom) and Room Panels (i.e., cross-group distances: Figure 4A and Requesting commands: Figure 4B) constitute a group-to-group dimension. To avoid distracting the primary breakout room discussions, FluidMeet situates cross-group dimensions at the periphery. FluidMeet makes other Room View Panels unobtrusive by minimizing their view during a group discussion (Figure 4A: Bottom; Figure 5C: Bottom). If users are actively following another breakout room, they can scroll up to see an enlarged, more detailed cross-group dimension (Figure 4A: Top; Figure 5C: Top). If users do not attend to other breakout rooms, they may only capture some fragmented information, even if they are close to other groups. Hence, the only cross-group distances they may feel in the minimized cross-group dimension are the audio visualizations and several split words (e.g., a phrase or a word).

3.4.4 Requesting Cross-Group Levels from Other Breakout Rooms. The goal of privacy-interaction flexibility is to allow users to smoothly and dynamically activate the next state of interpersonal or cross-group distance. For interpersonal distance, individuals can set their Halo reachability to regulate their interpersonal privacy-interaction flexibility (Figure 3A). Similarly, hosts or co-hosts can regulate the

cross-group distance of their conversation. Individual users can initiate an enhanced awareness of another room by requesting a closer cross-group distance or a higher visibility level. Hence, aside from group boundaries, individual to other group flexibility is enabled, regardless of an individual's group distance to other groups. In other words, as the cross-group distance is set external to the user, it limits how the user can approach or distance themselves from other groups. Users themselves, however, can assert their agency over their group's authority by requesting access to other levels of interactions in other breakout rooms (Figure 4B). By default, if a breakout room is locked, the drop-down menu of possible distance levels will be disabled (See Figure 4A: Locked) to avoid unwanted distractions. Moreover, individuals can opt out of unwanted distances by filtering and disabling the unlocked breakout room distance level (Figure 4B). Hence, this feature augments the actions and flexibility a user can have to regulate their privacy and interactions with other conversations (i.e., unlock and lock levels of distance), regardless of the current cross-group distances of their breakout room.

3.4.5 Inviting Users from Other Breakout Rooms. Within the Room Controller, group members can see each user as a small icon in the groups that are not in the locked dimension (Figure 5C: User Panel). When a user hovers over an icon, they can see the name and location of the user from other groups (Figure 5E: Top). Users can also click an icon to invite users from other breakout rooms. An invited user can learn which breakout room and person has invited them by hovering over the invitation icon (Figure 5E: Bottom).

Current systems support either locked or fully permeable doorways to enter the system, resulting in a lack of privacy and interaction flexibility. An initial group privacy level may rely on the context of the breakout meeting, varying the degree of privacy (i.e., focused encounters) versus interaction (i.e., loosely-coupled gatherings). For example, in an online lecture with focused subgroup discussions, there could be more control exerted for the between-group boundary to avoid interruptions while showing a certain level of openness to other breakout conversations. Teachers or teaching assistants could perceive breakout room contexts without joining the group. They may jump into different groups upon their acceptance. In this case, the group could prepare an appropriate behavioral response and maintain their group privacy with a certain level of flexibility. Alternatively, in social scenarios like virtual conferences and poster sessions, which involve more frequent group-to-group transitions and loosely-coupled gatherings, the need for interaction might override a group's privacy. When employing flexible boundaries, these different breakout meeting settings' need for privacy and interaction implies a different initial privacy level.

3.5 Summary

The three design properties (i.e., *interpersonal distance*, *cross-group distance*, *privacy-interaction flexibility*) show how this research goes beyond previous work by integrating existing frameworks and prior research. To put these design properties into action, we implemented a working system with a set of features that demonstrates how to pragmatically realize levels of awareness and virtual distance. Furthermore, by seamlessly integrating ad-hoc conversations with frictionless transitions, this articulation and emphasis on

conversation awareness and flexibility opens up new possibilities for virtual meetings systems.

4 PROTOTYPE IMPLEMENTATION

FluidMeet consists of a web interface, a back-end authentication server, and a back-end signaling server. The front-end web interface was built using React, Javascript, HTML, and CSS. The back-end authentication server was built using Node.js and has a MariaDB database. The signaling server was built using the Socket.io Javascript API, which allows for a bi-directional events channel for peer-to-peer (P2P) connections. The front-end and back-end communicates using a WebSocket to transmit data and HTTPS requests to access the APIs. To enable communication with more than one peer, the Simple-Peer library [1] was used. This library builds P2P WebRTC video/audio communications and data channels and allows Fluid-Meet to create a mesh network of six peers in one room. The system can run on any device that can support the Chrome web browser.

As FluidMeet enables individual breakout rooms to share Word Cloud with other breakout rooms depending on the privacy settings of that breakout room, FluidMeet uses the React Speech Recognition API [9] to detect spoken language and transcribe each conversation. The resulting transcript is then synthesized and parsed to obtain the keywords with the highest frequency, ignoring common words such as articles, prepositions, auxiliary verbs. The signaling server was used to share the Word Cloud and Atmosphere with other breakout rooms, send public messages to the same breakout room, show interest in other breakout rooms, invite individuals to one's breakout room, and send private messages between peers. To live-stream breakout rooms to others, the *Simple-Peer* library [1] was used within the signaling server.

4.1 FluidMeet Overview

4.1.1 Lounge. When logged in, users are placed in the virtual lounge where they can browse the conversational dynamics of all the breakout rooms and browse the cross-group distances of each breakout room (Figure 6: Lounge). Users can then create a new breakout room or join it via its breakout room identification number (i.e., a universally unique identifier) if others invite them. On the other hand, when users in the lounge find a breakout room that is interesting and is public, they can directly enter it. If that breakout room is not public, users will need to request permission to join the breakout room through the drop-down list "request your interest" (Figure 6B). Users can request interest levels even if they are in the lounge, which will also result in a red grid appearing on that breakout room's Room Controller (Figure 6A).

4.1.2 Breakout Rooms. Each breakout room consists of three components that are always visible (Figure 6: Breakout Room): 1) *Video streams* show the live video of users with real-time private messages (Figure 6C), private calls (Figure 6D), and the flexibility to control user's reachability levels. 2) *A Room Controller* (Figure 6A), which enables a host or co-hosts to share cross-group distances and allows the group members to be aware of all the requests from members of other breakout rooms. 3) *Breakout Room Panels* (Figure 6B) show the current virtual distance (e.g., word cloud) with a request menu for members of that breakout room to unlock new features. *Video*
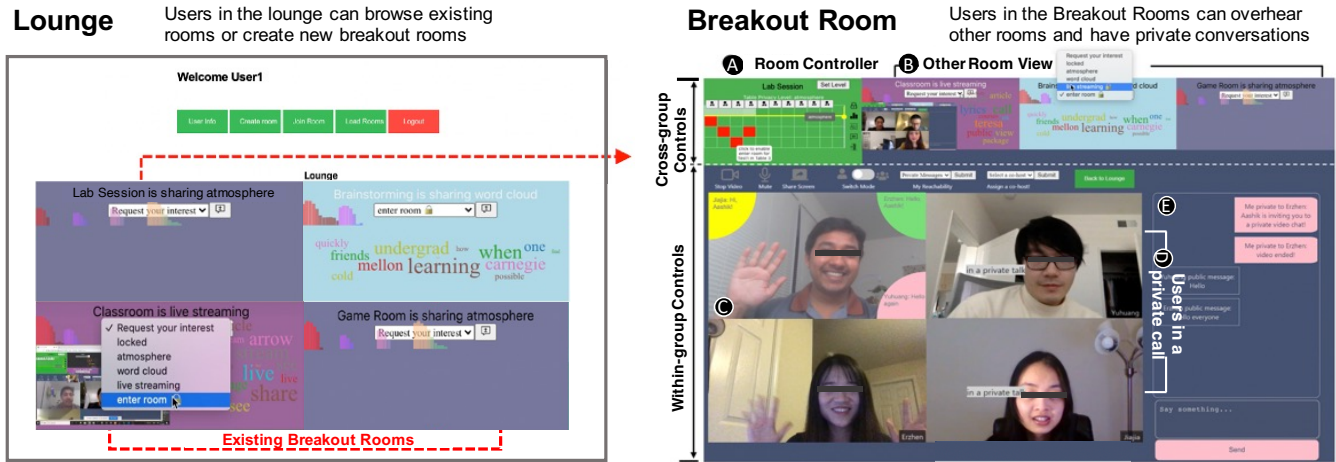
Figure 6: The FluidMeet User Interface: the Lounge and a Breakout Room.

streams (Figure 6C) and *Group Message Windows* (Figure 6E) mimic typical interfaces within video conferencing platforms.

5 USER STUDY

The Halo Widget and Room Panel are awareness designs and a means for in-group and between-group communication channels. A user study was conducted to compare FluidMeet to a *baseline* condition (i.e., a Zoom breakout room feature with default settings) to investigate 1) if these features increase awareness and improve conversational interaction (**RQ1**) and 2) how the added flexibility between different conversation distances ease in-group and group-to-group transitions (**RQ2**). The study was conducted as a two-part study to avoid confusion between in-group and between-group awareness. The study was approved by the institutional review board of the University of Virginia.

5.1 Participants

Sixteen participants (8 female and 8 male) with an average age of 26.3 were recruited from the local campus community. The participants were grouped into eight groups of three, with two deployments of four groups. Since we intentionally recruited participants who had experience with videoconferencing tools, their familiarity with such tools was high (Median=6, IQR=1; 1-7 with 1 being no experience). Most participants used videoconferencing tools a few times a day (n=11) or week (n=5). All participants had experienced Zoom breakout meetings. Six participants had used Gather.Town in online lectures (6/6) or virtual conferences (4/6) for group discussions. The study took approximately 90 minutes per participant and each participant was compensated with $30 USD.

5.2 Study Design

The experiment used a within-subject design. The independent variable was the enhanced presence of interpersonal and inter-group awareness (i.e., present (*FluidMeet*) or absent (*Baseline*)). For dependent variables, we measured Social Presence, Conversation Experience, and usability to understand the effect of the Halo and

Room Panels on user experiences and co-presence with the additional in-group and between-room awareness. We also measured the usability of FluidMeet in terms of mental effort and levels of focus to understand if the flexibility eases the transitions without extra effort. Zoom was chosen as the baseline because it supports breakout rooms and is the most familiar meeting tool for users.

5.3 Tasks and Procedure

The study was divided into two parts with two different use case scenarios to evaluate within-group (*Part 1*) and between-group (*Part 2*) tasks. Before each part of the study, the researchers explained the purpose and procedure to participants for 15 minutes. Following the instructions, participants then engaged in the baseline and FluidMeet study conditions. The order of the conditions was counterbalanced across deployments. Before the study, the researchers demonstrated the use of FluidMeet features for private conversations and between-group distance control over a video call. Participants were given a demonstration of FluidMeet via video calls. The research team then shared a link to a 5-minute tutorial video that highlighted key features of the system. Participants were encouraged to visit the prototype website and explore the interface and become familiar with the FluidMeet features before the study.

5.3.1 Study Part 1: One Lie and One Truth (Within-group Interactions: 30min). For each condition, participants were divided into groups of four. The experimenter instructed two group participants to think of one statement about themselves in a private chat/video: they first needed to decide who was the liar and then say the statement to the group. Others could ask questions about the statements for two rounds and they then discussed and decided which person was the liar. The other pairs then took turns. After each condition, they completed Likert-based questions (on Networked Mind Measure of Social Presence [49], Usability, Single Ease Question (SEQ) [75], and the Subjective Mental Effort Question (SMEQ) [89], see Appendix A.1.1). This task was chosen because it resembled a breakout meeting (for the within-group dimension) where some

users may be having side conversations or back-channel discussions.

5.3.2 Study Part 2: Fun Fair (Between-Group Interactions: 50min).
The scenario mimicked an online Fun Fair or Camp Expo where three breakout rooms completed three tasks: "*Survival Games*", "*fortunately-unfortunately*", and a chat room for users to chat with each other randomly. In addition, there was one experimenter in each room to moderate the task. Initially, participants were randomly assigned to one of three different breakout rooms and then they decided the between-group distances of their room and started the task. Breakout tasks remain the same for the two conditions with different topics introduced and counterbalanced across conditions for the Survival Games and the stimuli topics for *Fortunately-Unfortunately*. After each condition, they completed Likert-based questions (on Networked Mind Measure of Social Presence [49], Usability, Single Ease Question (SEQ) [75], and the Subjective Mental Effort Question (SMEQ) [89], see Appendix A.1.2).

- *Survival Games*: Participants were be assigned in discussion sessions to one of two popular team-building tasks called *Lost at Sea* [5] and Survival on the Moon [11]. The ordering of the tasks was counterbalanced across all groups. After receiving their scenario, each participant ordered their own list (seven items). Participants then individually ranked seven items (with one being the highest rank) within five minutes and then discussed with other participants in the breakout room to rank the top three items across all the ideated items within ten minutes.
- *Fortunately-Unfortunately*: In this room, users were randomly assigned to play a telling-a-story game called "fortunately-unfortunately", where each sentence must start with either "fortunately" or "unfortunately", constantly alternating. In addition, a slide deck of stimuli was provided to spark ideas.
- *Chat Room*: Participants would have a conversation with the experimenter. The conversation topics were pre-prepared.

After the first round, which lasted for a maximum of 15 minutes, was completed, the second round of Study *Part 2* began. It provided more transition opportunities for participants because they could either go to the other two rooms based on their interest or open a new breakout room. The tasks mimicked the between-room dimensions common in breakout meetings (e.g., poster sessions, job fairs or workshops, lectures with breakout groups) where different breakout rooms have different tasks. Moreover, by enabling three different tasks, we tried to motivate participants' need to travel between different rooms or groups after the first round and to investigate the transition from between-group awareness to conversation. At the end of the study, a final questionnaire collected user preferences, subjective feedback, and gave participants an opportunity for further comments. There was also an interview session for participants who were willing to attend.

5.4 Data Collection and Analysis

5.4.1 Data Collection. Two types of data were collected during the study:

1) Questionnaires: After each condition in *Part 1* and *Part 2*, all participants completed the Likert items (on SEQ, SMEQ, CE, and SP, see *Part 1*: Appendix A.1.1 and *Part 2* Appendix A.1.2 for more details). Participants also completed a final questionnaire that

probed their preferred condition and the reason for the preference (see Appendix A.2).

2) Interviews: To complement the survey data with a qualitative understanding of the users' experiences and preferences, semi-structured interviews were conducted with ten participants (i.e., 4 females, 6 males). Each interview session lasted about 20 minutes. The interview probed participants use of FluidMeet features like the Halo and Room Panels, their thoughts on the influence of FluidMeet on the way they interacted with others and conversation groups, and their experiences, thoughts, and feedback about FluidMeet.

5.4.2 Analysis. To analyze the responses to the five open-ended post-task survey questions (see Appendix A.2) and the follow-up interviews, a thematic analysis method following that of Braun and Clarke was used [21]. An inductive approach to thematic analysis was used, where codes and themes were developed from the data content. All the transcribed survey open-text responses and interview comments were reviewed and compiled into one document. Each section of the document contained answers to a single question or a survey and interview question that were related. A sentence was the smallest meaningful unit. The researchers first examined the data set before manually developing a set of initial research codes. In terms of the coding process, the researchers explored the data set to become familiar with it. The data were read and reread several times, iteratively being coded three times: 1) initially coded using broad codes, 2) focused on to identify patterns of meaning, and 3) finalized to create and refine the themes. We reread and re-evaluate to determine whether the emerging themes captured the data set.

6 RESULTS

6.1 Questionnaire Data

A one-way ANOVA ($\alpha = 0.05$) was used to analyze the task difficulty, mental effect, enjoyment and level of focus, conversational and social experiences results (Figure 7). For Study *Part 1*, we found that tasks performed with FluidMeet ($Median = 5$, $IQR = 2$) were easier than the Baseline ($Median = 4$, $IQR = 3$; $F(1, 30) = 5.21$, $p < 0.01$). FluidMeet ($Median = 6$, $IQR = 0$) was also more enjoyable than the Baseline ($Median = 5$, $IQR = 1$; $F(1, 30) = 4.80$, $p < 0.05$). There were also two significant differences for *Conversational Experience* questions. Participants also thought that FluidMeet was more interactive ($Median = 5$, $IQR = 0$) than the Baseline ($Median = 4$, $IQR = 3$; $F(1, 30) = 5.57$, $p < 0.05$; Question 5) and FluidMeet ($Median = 6$, $IQR = 3$) also enabled them to selectively attend to one person at a time than the Baseline ($Median = 4$, $IQR = 5$; $F(1, 30) = 4.72$, $p < 0.05$; Question 7).

For *Part 2*, participants were able to selectively attend to one room at a time with FluidMeet ($Median = 5$, $IQR = 2$) than the Baseline ($Median = 4$, $IQR = 2$) ($F(1, 30) = 4.39$, $p < 0.05$; Conversation Experience: Question 7). We also analyzed the sub-scale of the Social Presence questionnaires that includes Co-Presence (CP), Attentional Allocation (AA), and Perceived Message Understanding (PU). We found significant differences in favor of FluidMeet for the overall CP (FluidMeet: $Median = 6$, $IQR = 2$, Baseline: $Median = 3$, $IQR = 4$; $F(1, 30) = 8.44$, $p < 0.01$), but no significant difference for the AA and PU questions. There were no significant

differences for the other metrics between the two conditions in *Part 1* and *Part 2*.

For overall preference and usefulness, 10 out of 16 participants preferred FluidMeet Halo to the Baseline during *Part 1*. Thirteen participants perceived FluidMeet as more useful than the Baseline in their experiences in *Part 1*. For *Part 2*, 11 participants preferred FluidMeet to the Baseline. Twelve participants perceived FluidMeet as more useful than the Baseline.
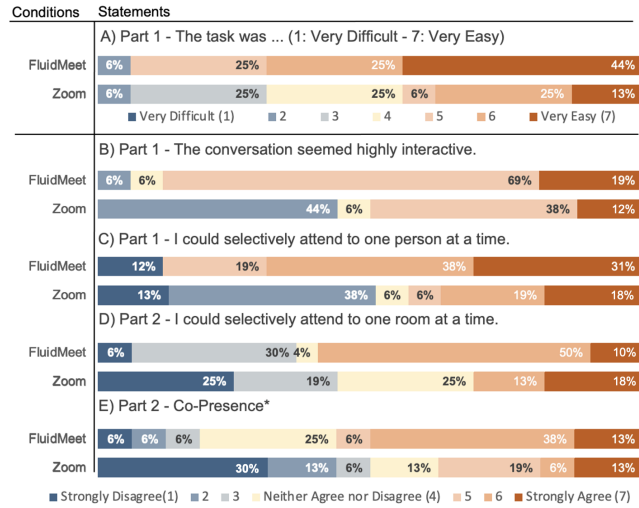

Figure 7: Summary of Significant Survey Results. *Note: Overall Co-Presence combines two statements "*I think (Members from other breakout rooms) often felt as if we were in the same room together.***" and "***Other rooms' presence was obvious to me.***"**

6.2 General Feedback

Herein, we report on the responses to the five open-ended survey questions (n = 16, see Appendix A.2) and interview results (n = 10).

6.2.1 Overall Perception of Design. Overall, participants reported that the design of the Halo and Room Panels were easy to learn (Halo: *Median* = 5, *IQR* = 1, Room Panel: *Median* = 6, *IQR* = 1) and easy to use (Halo: *Median* = 5, *IQR* = 1, Room Panel: *Median* = 6, *IQR* = 1). Most participants did not find Halo and Room Panels hard or distracting to use. Most participants (13/16) found the Halo Widget to be useful as its peripheral location is easier to notice than the Baseline (9/10). Participants liked the look and feel of the Halo ("*I liked the color and location that make direct messages obvious.*", P2) and how accessible it was ("*more easily accessed than the Zoom's direct message.*", P1). The majority (12/16) of participants also liked how the location of Halo made it easier for them to distinguish private messages from group messages, which is often difficult in current systems (e.g., P9 stated how she accidentally "*replied classmate's private message to the public chat in Zoom.*").

For cross-group distances, most participants (13/16) appreciated the distances that revealed more information (e.g., "*... Word Cloud and Live-Streaming give you information about what is exactly going on.*", P2). A few participants preferred to see adequate and easier-to-digest information due to attention allocation concerns. Four

participants preferred the Word Cloud to Live-Streaming (P4, P5, P8, P9) because it offered a quick overview of the conversation topic (e.g., "*you might have no time to observe Live-Streaming; with Word Cloud, you can see clearly...*", P8). P9 preferred Atmosphere over Word Cloud and commented that "*you need to see every word in Word Cloud, and it's constantly changing; for Atmosphere, I just need to see the color (in audio bars), which is easier to see than split words.*" P9 also pointed out that the lower-level distances may sometimes be overlooked in the presence of higher-level information (nested) on the Room Panel - "*when the Live Streaming occurred, I didn't notice the audio bars (Atmosphere), I relied heavily on the video.*" Most participants (9/10) valued the "public" distance for the efficient navigation it offered (e.g., "*the ability to jump from one room to another very quickly with one click*", P5). While P7 liked the freedom provided at the "public" distance, she was concerned that "*leaving the current group may distract current group members.*" These comments highlight how the Halo's peripheral location and size meet participants' needs as a message display to enhance their awareness of one-to-one interaction. The preference for between-group distances and the **right amount of information** was highly context-dependent. The Atmosphere distance was found to be immediately easy to understand yet contained limited information. The Word Cloud and Live-Streaming distances would still be adequate conversation initiators for users to join other groups.

6.2.2 Facilitating Side Interactions. Participants noted that their conversation experience was highly interactive (Figure 7B) and that they could selectively attend to one person at a time (Figure 7C). They found that the task was easier to complete using Halo Widget than the Baseline (Figure. 7A). In particular, they emphasized the benefits of having private calls to facilitate lightweight and timely one-to-one conversations (e.g., "*... efficient for immediate and ad-hoc confirmations.*", P5). Several participants (4/10) noted the convenience and availability of private calls might help them learn about each other better and build potential connections, e.g., "*...private video channel connects us much closer than text messages.*" (P1). One participant appreciated that the private talk option avoided being eavesdropped on by others: "*...in a physical room, it may be overheard*" (P4). In particular, participants responded favorably to the transitions in private channels, e.g., P9 noted that "*Halo is quite convenient for short conversations. It leads to a private call smoothly if a longer conversation is needed.*" This indicates that the interactivity and the transition from messages to calls appears to be a reasonable mechanism for people to transition from the enhanced awareness of ad-hoc, lightweight messages to conversations.

6.2.3 Awareness of Others' Off-Task Behavior. Participants liked observing private calls and still images in FluidMeet because they conveyed a sense of connectivity and presence of what was going on - "*private calls seem to have some sort of inclusion, it is like your classroom that you are sitting at your table, you can see other people, you are like directly involved.*" (P1). Two participants (P4, P9) had mixed feelings about having others see the text indicator ("In a private talk") as it was "*too straightforward and embarrassing.*" Participants liked the still images in FluidMeet during private conversations because without it, "*...others will misunderstand that you are multitasking*" and "*when having a private call in FluidMeet,*

others will at least know that your attention was still in the meeting."
(P5).

6.2.4 Comprehensive Context of Other Breakout Rooms. All participants appreciated the presence of other breakout rooms provided by the Room Panels, which helped their understanding of the context and feelings of the "room atmosphere." Participants agreed that they felt like they were in the same room with members from other breakout rooms (Figure 7E Co-Presence). For example, P9 commented - "*I can see other rooms' content. I can enter any room and catch the session.*" Moreover, most participants would like to learn more about people from other breakout room in FluidMeet (13/16). Participants rated the enhanced ability to selectively attend to one room at once with FluidMeet (Figure 7D) and not being too distracted when using minimized Room Panels: "*I mainly focused on the meeting, but I can feel the minimized Room Panels; it is not distracting as it is information rather than notifications.*" They liked that they could see information from other rooms without traveling there. For example, P13 stated - "*I can see what is happening elsewhere, like in a job fair or such, and I can easily switch, instead of looking for links.*" Participants also reported that FluidMeet provided a sense of connectivity and belongingness. P6 described her experience of jumping between Zoom breakout rooms during a school event, which cost extensive manual and mental effort, i.e., "*joining (breakout room) was a struggle; I do not know what is happening there and I feel disconnected. I hesitated to join.*" These comments suggest that the Room Panels enabled a sharing of information across conversation rooms, connecting room contexts and encouraging users to join other rooms. This is in line with our intention to promote between-room visibility in breakout meetings to foster more ad-hoc conversations.

6.2.5 Avoiding Interruptions and Exerting Control Over Group Membership. Participants also liked that hosts and room members could handle individual requests using the Room Controller. A majority of participants appreciated being able to have direct control over the number of people in their session, e.g., "*I think the most beneficial part is that I can control my own session efficiently by the number of people I let in.*" (P2). Some participants who had used Zoom breakout sessions in classes and poster sessions shared their thoughts on using the Room Controller in such scenarios. For example, P1 suggested that the Room Controller may avoid unanticipated jump-ins from late-comers, which often happens in virtual meetings ("*...there was a silence in our room, and the professor just jumped in, and it was pretty awkward.*", P1). P10 was concerned about formal scenarios for having the between-room visibility (e.g., "*FluidMeet's room chatting is good for social networking. But I may be disturbed by others. To discuss serious things, the Zoom breakout rooms are better.*"). In addition, two participants were concerned about the delay in their requests being granted by other groups. P10 said, "*It took nearly ten minutes for my request for Word Cloud to be granted.*" Although the Room Controller was designed for awareness control, the added benefits of controlling for group size and facilitating more efficient conversation could also be useful for conversation group management.

7 DISCUSSION

Based on the results from the survey, two main themes surrounding the design of high-awareness and low-friction meeting software emerged, i.e., enhance awareness for in-group and between-group conversations and the tensions that exist between flexible user agency and distractions. We also discuss how the use of FluidMeet in the study aligns with the theory and design principles and the design implications for high-awareness and low-friction meeting systems.

7.1 Enhancing Awareness for In-Group and Between-Group Conversations

7.1.1 Enhancing Within-Group Interactions. The study investigated how the implementation of *Halos* combined with the *Switch Handler* could provide presence awareness about others and smooth and efficient transitions between primary and side discussions. In general, the Halo's practice matched the design principle of *Interpersonal distances*. The progressive and nested transitions between interpersonal distances via quick messages to private calls provided a favorable and smooth channel from awareness to the conversation, supporting the need for lightweight one-to-one connections in loosely-formed subgroup conversations. Furthermore, participants enjoyed private calls as they perceived the sense of connectivity when they found the evidence of others in a private call as engaged in the meeting. However, they perceived the evidence of typing private text messages as multitasking and doing things unrelated to the meeting. They also had concerns that others might observe their facial expressions when typing private messages during the meeting. The finding is consistent with a study on multitasking during remote meetings, where the assumption that a peer was involved in a "personal or related to other work" task brought about negative interpersonal perceptions [61]. With FluidMeet, it seems that the enhanced presence of others' activities (i.e., the still image and the text indicator) offered activity transparency and provided a sense of connectivity.

Design Implications: The opportunities afforded by having the message information resources on the Halo display (i.e., awareness) were realized by its functionality, where the transition between different interpersonal distances helped avoid overlooked opportunities. The Halo incorporated a communication channel with a progressive and lightweight transition from private messages and calls (*Interpersonal distances*) that succeeded in *tightly coupling* the enhanced awareness (e.g., location and color of Halo) and "the means for communication." Designers and developers should thus consider implementing such a private channel to alleviate the lack of one-to-one conversations by enhancing private channels' noticeability in virtual meeting systems. Integrating such a feature into an existing meeting system requires careful consideration of how it would afford the transition from awareness to foreground interaction, from private to group conversations.

7.1.2 Constructing Between-Group Visibility and Ambient Awareness. FluidMeet Room Panels as a whole embody the *C-space* theory for one to share a certain level of visibility and openness to others to communicate one's readiness to collaborate. The presence of the Room Panels affected users' focused and unfocused interactions,

as evidenced by the strong sense of co-presence ratings from participants. Participants may have glanced at the minimized room panels to selectively maintain awareness of one breakout room, scroll up to see the full view, and unlock or request further contextual information. This matches the theory that the information was presented so that participants were able to take full advantage from awareness to interaction. With the line of activities presented, participants' attention could switch from focused to unfocused interactions as addressed by C-space [55]. However, the richness of constantly changing information and nested cross-group distances on Room Panels was a mixed blessing, as richer information (e.g., Live-Streaming) may have overshadowed the lower-level distances (e.g., Atmosphere) as participants reported that they may have neglected other levels using lesser forms of presence information. This does not exemplify the design properties of a nested transition from private to public domains implied by F-formations. This mismatch to the theory might be because whenever a participant is paying attention to the between-room dimension, the design sensitivity of cross-group distances may cause them to exert more visual demand over other arrays of channels (e.g., hear, smell and touch). In addition, the highly subjective nature of information saliency for users and their context may also play a role. Participants did, however, perceive the Room Panels with "closer proximity" as providing a sense of the conversation group's interaction availability, which exemplifies what Kendon [55] noted about various arrangements of F-formations, i.e., "*to be only partly engrossed in our activity and to indicate (by an "open" arrangement) that we are also taking into account the others around us.*" This transition between cross-group distances on the Room Panels thus implies a conversation potential for out-group members, with the richness of information sources and awareness, appeared on the Room Panel.

Design Implications: Designers should thus consider implementing between-room visibility to ease the absence of group-to-group connections and the hesitation and shyness of joining other rooms. Integrating such a feature in scalable breakout meetings systems such as virtual conferences may take the form of recommending a person's information or topic of interest by analyzing the history of breakout rooms the person has already browsed, requested, or joined. Another direction could be to enable a manual filter of the current breakout conversations (in the lounge or breakout rooms) based on the topic of the moment. These approaches could solve the problem of information overload and build systems "beyond being there."

7.2 Tension Between Allowing Flexible User Agency and the Distraction

The privacy management allows users to manage their conversation distances to others, in-group members to control the size of a group to enable more efficient conversations, and out-group members to see certain levels of visibility provided by the group. The mismatch here is that, due to the strict in-group conversation management and the time-delay of granting out-group members' requests, out-group members felt isolated from the group's boundary and their group-to-group transitions were restrained. Our findings suggest that the central issue seems to be a tension between group ownership and the tendency to transition between breakout rooms, where the

initial or optimal privacy level is highly context-dependent. The study also found that the room privacy control could be helpful in controlling group size to maintain the efficiency of in-group "information exchange."

Design Implications: There seems to be a disparity between perceived opportunities arising from what is visible (i.e., current cross-group distances/openness) versus how users are limited from pursuing these opportunities by an item (the design of Request Menu) 's actual functionality. One possibility could be that the "closer proximity" to a conversation often motivates out-group individuals to actively join or request higher-level visibility. These results speak to the principle of initial privacy and the flexibility ranging from privacy and interaction. Designers or meeting organizers should thus consider the appropriate degree of conversation management to balance an *individual*'s need for group-to-group transitions (interaction) and the *group*'s ownership (privacy) on a per scenario basis. For meetings with frequent transitions, providing a lower level of privacy can ease the effort of granting permission in such scenarios, e.g., enabling the "enter room" button at other visibility levels and anticipating users to rely on a social protocol. Yet, as our findings demonstrated, providing a specific control to hosts for group size is beneficial for subgroup conversations, which Gutwin and Greenberg [44] mentioned as a trade-off between *"meeting the needs of individuals and meeting the needs of the group as a whole."*

8 LIMITATIONS AND FUTURE WORK

The user study provided a few insights into participants' experiences when using FluidMeet features, along with potential directions to improve virtual breakout meeting experiences to facilitate informal conversations. However, the study had several limitations, including the small number of participants. While the participants did not have difficulty using FluidMeet, a single-day session may not be sufficient to build trust with the system and fully familiarize them with the FluidMeet features, which could have hindered the discovery of some essential benefits and challenges. Therefore, a more thorough evaluation with a larger group of participants, of various backgrounds, in more scenarios, may provide more in-depth insights about the ability of the FluidMeet features to enhance awareness and frictionless transitions in breakout meetings.

9 CONCLUSION

This paper presented FluidMeet, a virtual breakout meeting system that enables frictionless transitions between in-group, between-group, and private conversations. With FluidMeet, users can quickly have private talks without leaving their main group conversation, similar to how they would whisper to another person during an in-person meeting or glimpse over at other groups' conversations and overhear others. Users can also quickly control others' access to themselves and their groups, similar to how they can maintain distances to others in physical settings. The evaluation of FluidMeet demonstrated how FluidMeet can help meeting attendees better understand other groups' atmosphere and discussion subjects without making interactions and notifications challenging to use or distracting.

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A APPENDIX

A.1 Intermediate Questions

A.1.1 Questionnaire - PART I. Intermediate Questions after every search task (i.e., after every condition) on a 7-point Likert scale. We changed the terms in [FluidMeet/Zoom] based on the condition.

Q1. Based on Part 1 Tasks, thinking back on your experience in [FluidMeet/Zoom] (1: Strongly Disagree - 7: Strongly Agree):

- I enjoyed the experience.
- I was able to focus on the task activities.
- The system was easy to use.
- The system was easy to learn.

Q2. Rate your experience in [FluidMeet/Zoom] based on the scale provided on Mental Effort (0 - 150: 0 = Not at all hard to do)

Q3. Overall, the task with [FluidMeet/Zoom] was...(1: Very Difficult - 7: Very Easy)

Q4. Thinking back on your Experience/Interactions with your Breakout Rooms in [FluidMeet/Zoom] (1: Strongly Disagree - 7: Strongly Agree):

- My group members' presence was obvious to me.
- I think (My group members) often felt as if we were in the same room together.
- I was easily distracted from my group members when other things were going on.
- My group members did not receive my full attention.
- My actions were often dependent on (my group members)
- What I did often affected what (my group members) did.

Q5. Thinking back on your conversation experience with [Fluid-Meet/Zoom] in Part 1: (1: Strongly Disagree - 7: Strongly Agree)

- I was able to talk and express myself freely.
- I was able to take control of the conversation when I wanted to.
- There were too many inappropriate interruptions.
- This was an unnatural conversation.
- The conversation seemed highly interactive.
- There were many unnatural and uncomfortable pauses.
- I could selectively attend to one person at a time.
- I knew when people were listening or paying attention to me.
- I found it difficult to keep track of the conversation.

Q6. Any quick feedback about [FluidMeet Halo/Zoom text channel]? [open text]

A.1.2 Questionnaire - PART II. Q1. Based on Part 2 Tasks, thinking back on your experience in [FluidMeet/Zoom] (1: Strongly Disagree - 7: Strongly Agree):

- I enjoyed the experience.
- I was able to focus on the task activities.
- The system was easy to use.
- The system was easy to learn.

Q2. Rate your experience in [FluidMeet/Zoom] based on the scale provided on Mental Effort (0 - 150: 0 = Not at all hard to do)

Q3. Overall, the task with [FluidMeet/Zoom] was...(1: Very Difficult - 7: Very Easy)

Q4. Thinking back on your Experience/Interactions with other Breakout Rooms in FluidMeet (1: Strongly Disagree - 7: Strongly Agree):

- I think (Members from other breakout rooms) often felt as if we were in the same room together.
- Other rooms' presence was obvious to me.
- I was easily distracted from other rooms when other things were going on.
- Members from other rooms did not receive my full attention.
- My actions were often dependent on Members from other rooms.
- What I did often affected what members from other rooms did.

Q5. Thinking back on your conversation experience with [Fluid-Meet/Zoom] in Part 2 (1: Strongly Disagree - 7: Strongly Agree):

- I was able to talk and express myself freely.
- I was able to take control of the conversation when I wanted to.
- There were too many inappropriate interruptions.
- This was an unnatural conversation.
- The conversation seemed highly interactive.
- There were many unnatural and uncomfortable pauses.
- I could selectively attend to one person at a time.
- I knew when people were listening or paying attention to me.
- I found it difficult to keep track of the conversation.

Q6. Any quick feedback about FluidMeet Room Panels? [open text]

A.2 Post-Task Questionnaire

Section 1: Think back on your experience in Part 1 when doing "One Lie and One Truth."

Q1. Based on your experience with Halo in FluidMeet, please rank the following three conditions in order of your preference - 1 being the most preferred to you: (Drag the items to rank)

- FluidMeet with a Halo Design
- Zoom's Direct (i.e., Private) Text Message

Q2. Which part do you like the Halo design, compared to Zoom's direct message? [open text]

Q3. Which part do you dislike the Halo Design, compared to Zoom's direct message? [open text]

Q4. How likely would you be to use the following methods for side conversations in a virtual breakout room? (1: Not at all - 7: Completely)

- I'd like to use Halo to send instant private messages.
- I'd like to use Halo to start a private talk (the green video icon).
- I'd like to use private text message within the group message like Zoom.

Section 2: Think back on your experience with the Fun Fair in Part 2. The scenario mimicked an online Fun Fair or Camp Expo where three breakout rooms are playing several different games (e.g., fortunately-unfortunately, survival games, and chat rooms)

Q1. Based on your experience with the Fun Fair in two conditions, please rank the following three conditions in order of your preference - 1 being the most preferred to you: (Drag the items to rank)

- FluidMeet with Room Panels (showing five discrete levels of other rooms)
- Zoom's Breakout Room (showing no visibility)

Q2. Please rank the following two conditions in order of your perceived usefulness - 1 being the most useful to you: (Drag the items to rank)

- FluidMeet with Room Panels (showing five discrete levels of other rooms)
- Zoom's Breakout Room (showing no visibility)

Q3. Which part do you like the FluidMeet's Room Panel design, compared to Zoom breakout Rooms? [open text]

Q4. Which part do you dislike the FluidMeet's Room Panel design, compared to Zoom breakout Rooms? [open text]

Q5. Breakout meetings support a smaller group of people to have ad-hoc and informal conversations and form a light-weight connection.

Q6. What do you think of the FluidMeet system in terms of supporting ad-hoc and informal conversations (1: Not at all - 7: Completely)

- Halo design in FluidMeet support within-group ad-hoc and informal conversations.
- I'd like to learn more about people from other rooms in FluidMeet.
- I'd like to share our rooms' visibility (e.g., word cloud, live streams) to other breakout rooms in breakout meetings.

Q7. Other Feedback about the FluidMeet system: [open text]