

Distance Matters to Weak Ties: Exploring How Workers Perceive Their Strongly- and Weakly-Connected Collaborators in Remote Workplaces

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Workers tend to make inferences about one another's commitment and dedication to work depending on what cues are available to them, affecting worker relationships and collaboration outcomes. In this work, we investigate how remote work affects workers' perceptions of their colleagues with different levels of social connectivity, commonly referred to as strong ties and weak ties. When working remotely, workers' perceptions of weak ties may suffer due to the lack of in-person interaction. On the other hand, workers' inferences about their strong ties may also be impacted by losing richer communication cues, even though they had more connections with their strong ties than weak ties. This study explores how remote workers make inferences about engagement levels of and willingness to collaborate with weak ties compared to strong ties. We used a mixed-methods approach involving survey data, experience sampling, and in-depth interviews with 20 workers from different companies in Taiwan. Results showed that workers depended on one-on-one synchronous tools to infer the engagement level of strong ties but used group-based communication tools to infer the engagement level of weak ties. Interestingly, the absence of cues in remote workplaces exacerbated prior impressions formed in the physical office. Furthermore, remote work led workers to develop polarized perceptions of their respective ties. We discuss how characteristics of computer-mediated communication tools and interaction types interplay to affect workers' perceptions of remote colleagues and identify design opportunities for helping remote workers maintain awareness of weak ties.

CCS Concepts: • **Human-centered computing** → **Empirical studies in collaborative and social computing**.

Additional Key Words and Phrases: Perceived engagement; remote workplace; strong ties; weak ties; computer-mediated communication; remote collaboration

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1 INTRODUCTION

In workplaces, workers make inferences of one another's commitment and dedication to work based on available cues observed in the office [14]. Such perceived engagement, in turn, affects workers' relationships and collaboration with each other. When everyone is collocated, a colleague's unintended signals such as posture at their desk, tone of voice, or even their manner of chatting, whether it can be in the hallway or office, cause workers to make inferences about their work attitude, working status, and work contribution [18]. However, when workers must perform their work remotely due to uncontrollable circumstances such as an organizational restructure or the COVID-19 pandemic, there may be a limited amount of information available for workers to infer the engagement of their remote colleagues [42].

Despite a large body of research on remote work and communication technologies that attempt to support remote collaboration [33, 37, 49] and recent discussions around the impact of the pandemic on remote work [63], few studies have considered how remote work affects interaction patterns among workers and how workers' perceptions of their remote colleagues might vary depending on the social connectivity with one another. Recent studies revealed that the pandemic has harmed remote workers' productivity [21, 44, 55], well-being [55], the social connection among remote collaborators [20, 32], and the communication process when working from home [26, 56]. However, what is not yet clear is the impact of specific tie strength, which is an important [63] but often overlooked social factor, on remote workers' perceptions when all communication becomes mediated by technology during work from home (WFH). Our study extends prior understandings of remote collaboration by examining the perceived engagement of remote colleagues through the perspective of tie strengths (strong/weak tie), as perceived engagement affects workers' trait inferences and performance evaluations of one another [18].

In this work, we specifically focused on workers' perceptions of their strong ties and weak ties [16, 23] when their interactions became entirely mediated by technology. Strong ties in workplaces are commonly conceptualized as close-knit team members of a worker, with whom the worker also tends to have more frequent interactions [16, 23]. In contrast, weak ties refer to socially distant team members of a worker, with whom the social interactions tend to be infrequent [16, 23]. The literature of social networking in the context of work holds the view that co-workers of strong and weak tie strengths are both critical to individuals, carrying different functions and types of social capital [10, 17, 65]. However, remote work can inevitably disrupt how people perceive and treat their co-workers of strong versus weak tie strengths. When working remotely, casual encounters such as hallway conversations, which are important for building group relationships, trust, and mutual understanding [2, 6, 13], are significantly reduced [14]. Therefore, workers' perceptions of their weak ties may be more adversely affected by the lack of in-person interactions and the scarcity of social cues than their strong ties, leading to a polarized perception of workers' strongly- and weakly- connected colleagues. On the other hand, working remotely could also limit the ability of strong ties to use rich cues to draw inferences about one another [1, 66]. From a hyperpersonal perspective of communication [69], limited cues available in computer-mediated communication can reinforce how senders present themselves selectively and how receivers receive social information selectively, forming potentially biased impressions of one another. On the other hand, it is also possible that remote work leads workers to form a more leveled perception of their strongly- and weakly- connected colleagues, minimizing the difference between strong and weak ties when working remotely.

To understand whether remote work leads workers to form polarized or leveled perceptions of their strong and weak ties, we examined how workers interacted with and perceived their respective ties differently during WFH using a mixed-methods approach. We combined survey data, experience sampling with 19 workers (1 data point was excluded for incomplete participation), and in-depth interviews with 20 workers from different companies in Taiwan. Results revealed that remote work led workers to have a polarized perception of their strong ties and weak ties. Workers mainly depended on one-on-one synchronous tools (one-on-one direct messaging, always-on audio calls) to receive cues and infer the engagement level of their strong ties. In contrast, workers used group-based communication tools, such as group video call, public channel of the team, to infer how engaged their weak ties were. Interestingly, the absence of cues in remote workplaces appears to exacerbate workers' prior impressions of their respective ties formed in the physical office. Based on the findings, we highlight the need to further investigate how remote work poses challenges to weak ties and provide insights for designing communication tools to enhance workers' awareness of weak ties in remote workplaces.

The contribution of this study is twofold. First, by triangulating the results from an online survey, experience sampling, and interviews, we point out how remote work could pose challenges (e.g., being perceived as less engaged), particularly for weakly-connected collaborators, such as team members who share fewer interactions and newcomers to the team. Second, we highlight the need to support the awareness of weakly-connected collaborators when designing communication tools for remote work, because the lack of awareness can exacerbate prior impressions formed before remote work. This insufficient awareness could also prevent workers from updating their inferences about weakly-connected collaborators as frequently as for their strongly-connected collaborators, which leads to biased evaluations in remote work. With this study, we highlight tie strength as a key factor to consider in remote work, because tie strength affects how workers draw conclusions about their remote colleagues' behaviors. Future systems need to consider the impact of tie strength in designing holistic online collaboration and communication systems that serve all stakeholders [25]. We urge researchers to focus on designing tie strength-aware systems to mitigate the perceptual biases toward weak ties in remote workplaces as more organizations transition from collocated to remote work during and after the COVID-19 pandemic [4, 28].

2 BACKGROUND AND MOTIVATION

2.1 Perceived Engagement in Remote Workplaces

In workplaces, workers rely on many social cues to infer one another's engagement level in performing work, and such perceptions could impact inter-worker relations and the outcome of their collaboration [18, 41]. Workers' engagement in work can be inferred from their levels of enjoyment, dedication, and concentration in their work, depending on the available cues workers observe in the office or in non-work contexts such as in front of the elevator, candy bar, or tea room [14, 18]. Having a good understanding of co-workers' engagement in work can be helpful for assigning tasks, allocating resources, and maintaining the collaboration [3]. Furthermore, workers can also be inspired by sensing that their co-workers are engaged in performing their work [45]. In fully-distributed workplaces, however, workers have little control over the extent of their work practices being visible to other remote colleagues [38].

2.2 Computer-Mediated Interaction in Remote Workplaces

When working remotely, workers mainly rely on computer-mediated communication tools to interact with and make inferences about each other. Indeed, people tend to give more attention to and have positive impressions of those who join meetings in person [35]. This can be caused

by technological constraints in computer-mediated communication. For example, it is difficult for remote workers to find space to interrupt during a meeting, which might give other attendees the impression that they are not engaged in a discussion [35]. In hybrid workplaces, where some members may join a meeting remotely and some may be co-located, researchers have also found that it is difficult for remote workers to signal their engagement and it was easy for them to be perceived as not engaged from their co-located colleagues' viewpoint [73]. As the hyperpersonal model of communication suggests [69], people tend to form potentially biased impressions of one another due to the limited cues available in computer-mediated communication. Such biased impression is reinforced by people's selective consumption of social information transmitted from communication technology. Hence, it is likely that people misattribute and make wrong assumptions about their remote colleagues when interacting through technology.

Despite the design of various computer-mediated communication and team communication tools to make remote collaboration more effective, such as supporting awareness-checking [5, 46] and using telepresence robots to initiate informal conversations across distance [36, 37], remote workers still face social isolation [33], social stigma [35], and have difficulties in maintaining social relationships with their remote colleagues [1]. When all social interactions are mediated by technology, it becomes unclear how workers access the observed cues from these communication technologies to infer remote colleagues' engagement levels, especially when workers with various types of social connections (e.g., co-workers who meet five times a week, co-workers who have only communicated once in the last month) all rely on mediated cues to make inferences of each other.

2.3 Challenges of Remote Work when Collaborating with Different Types of Social Connections

Rich literature about remote work has studied how the relationship between workers affects remote collaboration. For example, Olson & Olson pointed out that the coupling of work, which determines how frequently workers interact with their remote collaborators, could dramatically affect remote collaboration outcomes [49]. Although most of such studies focused on supporting remote collaboration among strongly-connected collaborators [33, 37, 49], few studies have focused on collaboration among those who are weakly connected to each other.

Meanwhile, in the area of social network analysis, the contrast between 'strong ties' and 'weak ties' has been studied extensively [9, 23, 65]. Strong ties indicate that there is frequent social interaction and an intimate relationship between two social contacts, while weak ties are two relatively loose social contacts who have infrequent interaction with, and feel less intimate with each other [16, 23]. Strong ties are important for successful collaboration because they have strong mutual understanding, trust, and shared resources with each other [9, 65]. In contrast, weak ties are identified as being able to bring in new sources of information and perspectives, new connections between two groups, and novel opportunities for a group, which are important for group innovation and network expansion [10, 17, 23].

In this study, although we are not focusing on the social network, we borrow the concept of tie strength to help us analyze how the tie strength between remote collaborators affects perceived engagement and willingness to collaborate. We define strongly- and weakly-connected colleagues by workers' perceived intimacy and interaction frequency with their respective ties within their current collaborative projects.

When working remotely, weakly-connected colleagues might suffer from a diminished awareness of each other due to infrequent interactions compared to strongly-connected colleagues, leading workers to have vastly different perceptions of their strong and weak ties. The physical proximity and social presence available in a physical office allows workers to initiate informal conversations

and sense their colleagues' work status (e.g., availability to initiate conversations, types of work they were working on) [34, 62], which may compensate for the infrequent interactions among weakly-connected colleagues that enhances group coherence and the collaboration process [13, 71]. However, such informal interactions cannot easily occur when everyone is working remotely, which can become a barrier for workers to access sufficient cues for inferring the engagement level of their weak ties. On the other hand, since working remotely limits the ability of strongly-connected colleagues to use rich cues to draw inferences about one another [68], computer-mediated cues can also affect workers' perceptions of their strong ties. Hence, it is also possible that remote work leads workers to form a more leveled perception of their strongly- and weakly-connected colleagues.

2.4 The Current Study

Taken together, in this study, we set out to examine whether workers' perceptions of their strong and weak ties becomes polarized or leveled in remote workplaces, where everyone faces the challenge of being "out-of-sight and out-of-mind" [51, 68], i.e., potentially failing to capture co-workers' work status (e.g., availability, task progress). Specifically, we tackle the following three research questions:

RQ1: How do workers interact with strong ties and weak ties when working remotely?

RQ2: What cues do workers rely on to form perceptions of their strong ties and weak ties when working remotely?

RQ3: How does insufficient awareness in remote workplaces affect workers' perceptions of the engagement level of and willingness to collaborate with their strong ties and weak ties?

3 METHOD

3.1 Participants

We recruited 20 workers currently living in Taiwan¹ during the study period (12 women and 8 men). Prior research on remote work and remote collaboration suggests that it is possible to derive insights on remote work interactions with approximately 20 participants [30, 52, 53]. We approached participants by posting the call-for-participants registration form on several Facebook groups where people share their work experiences. In the post, we described the goal of the study, which was to understand the experience during working from home. To minimize the influence of different cultural backgrounds, we adopted a convenience sampling approach² by limiting the workers' nationality to the same country during the study period.

We were interested in understanding how remote work affected the workers' perceptions of their teammates. The WFH policy deployed by many organizations due to the pandemic in February 2020 was a chance for us to reach a large pool of candidates who suddenly changed from co-located collaboration to remote collaboration. When sampling workers to participate in this study, we set criteria for recruiting workers (1) who worked in the office before their organizations implemented WFH policy; (2) who started working from home at least two months before the study began (early June 2020); and (3) whose work required collaboration with more than two colleagues in their organization. The workers' jobs varied and included software engineering, design, sales, product management, and consulting (see Table 1). Four of them transferred jobs and joined a new company after the WFH policy was administered. Their ages ranged from 20 to 35 years old (mean = 29.25).

¹By focusing on an Eastern context, an unconventional choice by CHI and CSCW standards [39], our study is able to contribute to diversifying international perspectives in HCI.

²We followed the common monocultural approach in CHI and CSCW research—the majority of has been restricted to specific cultural backgrounds. In past research, findings focused on contexts exclusively in one country as an initial step to explore research questions about workplaces [24, 35, 47].

Table 1. Background information of each remote worker. All of them used to work in office but were forced to work remotely due to the COVID-19 pandemic in 2020. Note: Worker 03, 11, 13, 16 joined their current organizations as new hires remotely.

Worker ID	Gender	Industry	Worker's position	Position of S	Position of W	When to start WFH
P01	F	Technology	Software engineer	Project manager	Designer	Feb., 2020
P02	F	Bio-medical	UX researcher	Team member	Engineer	Mar., 2020
P03	F	Technology	UX researcher	Project leader	Boss	Mar., 2020
P04	F	Technology	Marketing	Team member	Engineer	Jan., 2020
P05	M	Game	Data analyst	Project leader	Team leader	Mar., 2020
P06	M	Technology	UI designer	Team leader in Team A	Team leader in Team B	Mar., 2020
P07	F	IT	Human resource	Boss	Subordinate	Mar., 2020
P08	M	Technology	Sales	Boss	Team member	Feb., 2020
P09	F	IT	Product manager	Project manager	Designer	Feb., 2020
P10	M	Education	Consultant agency	Team member	Boss	Mar., 2020
P11	F	Service	Business development	Boss	Engineer	Mar., 2020
P12	M	Transportation	Software engineer	Team member	Product manager	Mar., 2020
P13	F	Auto driving	Procurement staff	Boss	Product manager	Feb., 2020
P14	M	IT	Software engineer	Senior team member	Team member in another product unit	Mar., 2020
P15	M	IT	Human resource	Boss	Subordinate	Mar., 2020
P16	F	Technology	Front-end engineer	Boss	Back-end engineer	Apr., 2020
P17	M	Technology	Assistant	Boss	Administrative staff	Feb., 2020
P18	F	IT	Data analyst	Boss and mentor	Manager	Feb., 2020
P19	M	OTT streaming	Software engineer	Team member	Senior team member	Apr., 2020
P20	F	Technology	Software engineer	Team member	Team member in another engineering unit	Mar., 2020

3.2 Study Design

To capture the complex work practices and workers' activities and perceptions at various time points during WFH without the researchers' physical presence, we adopted a mixed-methods approach. The study consisted of three phases: an online survey, five-day experience sampling, and an online interview. The mixed-methods approach allowed us to triangulate the data we collected in each phase (Fig. 1). All workers were first invited to answer the survey; then, they participated in the five-day experience sampling study and proceeded to complete a semi-structured interview. Each phase served a unique role in collecting workers' reflection, perceptions, and observations during WFH. We describe the details of each phase below.

In the **survey phase**, we asked workers to identify two collaborating colleagues in their projects, one being the strong tie and the other being the weak tie. In line with the definition of the strength of ties [16], we asked the workers to designate two individuals from their own teams, one with whom they interacted the most as their "strongly-tied colleague," and the other with whom they interacted the least as their "weakly-tied colleague." We refer to these two types of colleagues as "strong ties" and "weak ties" in the rest of the paper. Note that "weak tie" here refers to a coworker that one still has to collaborate with, but with less interaction frequency compared to a "strong tie." After indicating the respective ties, workers were asked to rate their intimacy level with each tie, which was used as a manipulation check of tie strength on a seven-point Likert scale, where "1" indicated a very low intimacy level, and "7" indicated a very high intimacy level. Finally, we asked the workers to write down the top three communication tools they used to interact with their remote colleagues and how frequently they used each tool with their respective ties during WFH.

In the **experience sampling phase**, our goal was to understand the relation between workers' interaction patterns with their strong and weak ties and their inference about the respective ties. To implement the experience sampling method, we sent our mobile probe three times a day (once in each time window: 11 AM–noon, 2 PM–3 PM, and 5 PM–6 PM) via a LINE account³. Two workers worked for European companies but worked from home in Taiwan. Thus, we sent the mobile probe for these two workers at different time points to match their working hours correspondingly. Overall, workers received three probes per day for five consecutive days, resulting in 15 probe responses from each worker. In each mobile probe, we asked workers to report whether they had any interaction with each tie in the past few hours and what communication tools they had used. We also asked them to indicate the levels of engagement they perceived for each tie and rate their willingness to collaborate. Based on prior work [60], we adopted three constructs to measure one's engagement level: interest, concentration, and enjoyment. We presented these three constructs to the workers and asked them to rate the engagement level of their respective ties on a seven-point Likert scale (described below). We then asked the workers to report the sources and cues they relied on to make those inferences. Next, we asked them to rate how positively and negatively they thought of each tie as a teammate on a seven-point Likert scale, which was an index for "willingness to collaborate" (described below). On average, it took less than five minutes to answer each probe. None of our participants informed their colleagues that they were inferring their engagement levels.

In the **interview phase**, we interviewed the workers based on the content they provided in the survey phase and the experience sampling phase. In the interviews, we focused on probing details of specific events that happened during WFH, including the cues they relied on to judge the engagement level of strong and weak ties and the differences in their perceptions of strong and weak ties. We provided workers the corresponding data they reported during the experience sampling phase as cues for them to recall any specific events. This retrospective approach allowed

³One of a popular mobile messaging applications in the country where the study took place

workers to reconstruct their behaviors, rationales, affective reactions, and responses for specific events they reported during experience sampling without interrupting too much of their ongoing work [50]. Each interview lasted about 40 minutes. The interviews were conducted remotely using video-conferencing software and were recorded for transcription. The study was approved by the Institutional Review Board from one of the authors' institution.

Altogether, 20 workers answered the survey and participated in the online interview. 19 workers' experience sampling data were analyzed - the data of one worker was removed due to incomplete participation. All workers were compensated for their full participation with USD \$92 after the study ended.

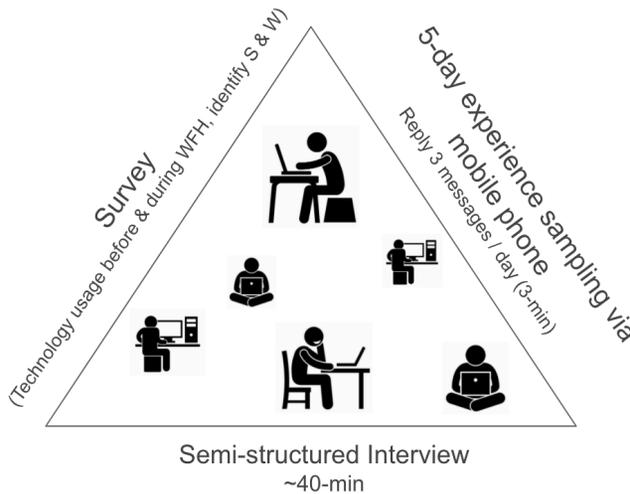


Fig. 1. Study overview. The study complement the findings with mixed-methods: survey, five-day experience sampling, and online semi-structured interviews.

3.3 Procedure

Due to the unforeseen coronavirus pandemic, the whole study was conducted online. Before the study began, we scheduled an online introduction session with each worker in order to inform them of their rights while participating and to explain the background of the study. In the introduction, they were instructed to add a designated LINE account to receive our probe. They were told that they would receive three push notifications a day and were asked to answer the questions within one hour after receiving a notification. During the survey phase, we explained the definitions of strong and weak ties and asked them to write down the nickname of one strong tie (referred to as "S" hereafter) and one weak tie (referred to as "W" hereafter) in their teams. In the survey form, we gave the following instructions to the participants: "Please indicate one colleague who has the most frequent interaction with you (strong tie) and one who has the least frequent interaction with you (weak tie) in your current collaborative project" (see A). In the experience sampling phase, all workers received probes three times a day through the LINE account for five days. Each time the workers received the probe, they evaluated their respective ties with the same set of questions (see examples in Supplementary section). After the five-day experience sampling study, workers scheduled an online interview with one of the authors. All of the interviews were conducted within a week after the experience sampling phase.

3.4 Analysis

3.4.1 Communication Media Used During WFH. To investigate how workers used communication media differently when communicating with their respective ties during WFH, we asked the workers to report the three communication media they used most frequently to interact with the respective ties and to indicate the percentage of each media usage in their interactions with each tie (for example, 80% face-to-face, 10% email, 10% text messaging) in the survey phase. These communication media were: face-to-face, video calls, audio calls, text messages, email, collaborative tools used in each organization, and others (e.g., social media).

3.4.2 Types of Interaction. Once the LINE account prompted the questions in the experience sampling phase, we asked workers to report the types of interaction they had with their strong and weak ties most recently. To answer this question, workers could select from three choices: direct interaction, indirect interaction, or no interaction. Direct interaction meant workers had synchronous, reciprocal interactions with their coworkers, for instance, interacting via online video-conferencing, audio calls, or real-time text messaging. Indirect interaction meant workers received information or cues about the remote colleague asynchronously without having reciprocal interaction with that person. For example, workers may have seen their coworker's message on a public channel; saw their coworker attending the same meeting with them without talking to them; received emails from their coworker, including those that were not personally addressed to them; or observed their coworker's online activities on a shared public workspace. If workers did not receive any cues at the time of answering to the probe, they could select "no interaction." We counted the frequency of each interaction type to see whether there was any difference between the amount of cues workers received from their strong and weak ties.

3.4.3 Perceived Engagement. During the experience sampling study, the workers were reminded of the strong tie ("S") and weak tie ("W") they had reported in the survey, and were asked to make inferences about the perceived engagement of these two specific remote colleagues throughout the study. In the mobile probe, workers were asked to infer the perceived engagement of "S" and "W" by rating the following three questions on a seven-point Likert scale, where "1" indicated a very negative perception and "7" indicated a very positive perception: "How would you estimate "S" and "W"'s interest for work?" "How would you estimate "S" and "W"'s concentration at work?" "How would you estimate "S" and "W"'s enjoyment for work?" In line with [60], we averaged the scores of the three items and used this as an index of perceived engagement.

The engagement scale adopted from [60] was originally developed based on flow theory developed by Csikszentmihalyi [15]. Flow theory suggests that when people are engaged in an activity, they experience a state of concentration, interest and enjoyment. It has been applied to understanding workers' engagement in workplaces [48]. Therefore, we decided to appropriate this scale in our study.

3.4.4 Willingness to Collaborate. Also during the experience sampling study, to examine whether the workers' willingness to collaborate with "S" and "W" would be affected by their perceived engagement levels in the field, we asked the workers to answer what was their feeling towards S/W as a team mate to work with in the probe. A seven-point Likert scale was used, where "1" indicated having a very negative perception and "7" indicated having a very positive perception.

3.4.5 Semi-structured Interviews. All the interviews were audio-recorded and transcribed for analysis. Following the thematic analysis method [8], one of the authors open coded all relevant concepts and assigned labels that featured the concepts. Next, all of the authors repetitively discussed the grouping of the labels and assigned labels to different categories. Finally, the identified categories

were exhaustively compared among all workers until no new themes that were related to the research questions emerged.

4 RESULTS

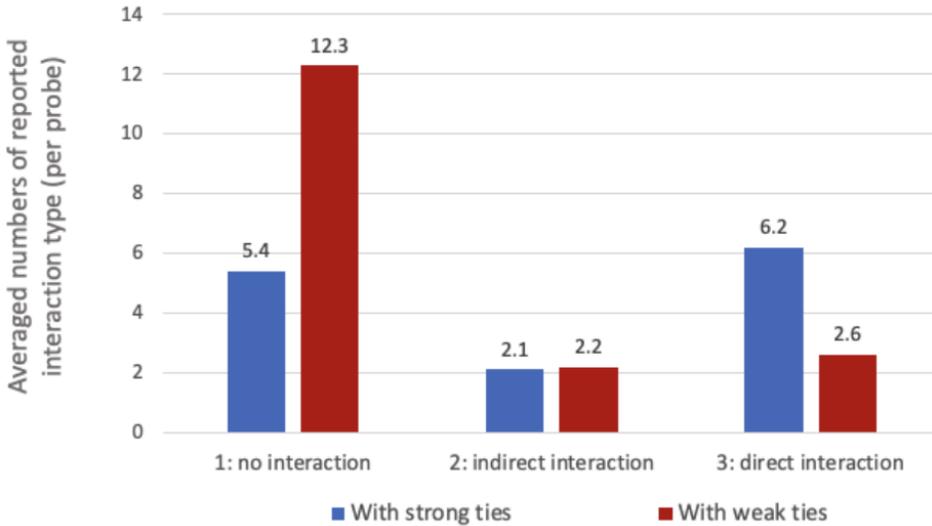


Fig. 2. Types of interactions workers had with each tie. The y-axis is the averaged frequency of each type of interaction reported by all workers through the experience sampling method. The x-axis shows three different types of interactions, *no interaction*, *indirect interaction*, *direct interaction*. The bars in blue indicate workers' interactions with their strong ties, while the red bars indicate workers' interactions with their weak ties.

In this section, we present our findings in order of the proposed research questions. First, we show manipulation check on workers' perceived intimacy level and interaction frequency with respective ties to verify whether workers' self-identified tie strengths were consistent with our study's definition. Then, to answer RQ1 about workers' interactions with strong and weak ties during WFH, we examine the data collected from the survey results, experience sampling, and interviews (section 4.2.1). Next, to address RQ2 about the sources workers rely on to form perceptions of their strong and weak ties, we reflect on the interview data (section 4.3). Finally, to address RQ3 about how insufficient awareness in remote workplaces affects workers' perceived engagement and willingness to collaborate with their respective ties, we describe the trends derived from the experience sampling study (section 4.4).

4.1 Manipulation Check of Respective Tie-strength

In the survey, the workers indicated the relationships with strong and weak ties, and rated the intimacy level with the respective ties on a seven-point Likert scale. Workers' strong ties included their team members, team leaders, and project leaders, whereas their weak ties mainly consisted of team members who did not work on the same projects, colleagues working on the same projects but in other departments, and senior managers in upper or distant hierarchies.

As expected, workers felt higher intimacy with S than W ($t[18]=6.03, p<.01$). Regarding interaction frequency, we compared the types of interactions workers had with their respective ties from the five-day experience sampling study, including times with direct interaction, indirect interaction,

and no interaction. Chi-square analyses showed the workers indeed engaged in different types of interactions with their strong versus weak ties during WFH ($\chi^2 = 57.4, p < .00001$). As Figure 2 shows, workers reported having more "direct interaction" with strong ties than with weak ties, whereas the frequency of "no interaction" with weak ties was higher than with strong ties. The above analysis confirms that the strong and weak ties selected by our participants followed the definition of strong and weak ties as we instructed them [16, 23].

4.2 The Influence of Communication Patterns and Interaction Frequency with Respective Ties when Working Remotely (RQ1)

4.2.1 Workers had Different Communication Patterns with Respective Ties when Working Remotely.

The interview data showed that all workers frequently updated their working status and had discussions with strong ties through one-on-one video/audio calls or text messaging. Working status here includes workers' current working progress, short-term goals to achieve, availability, whom they were collaborating with, and attitudes about the current projects they were working on together. On the other hand, workers could only know of their weak ties' working status through regular group-based video-conferencing or by overhearing their discussions with other colleagues via a public online workspace indirectly, such as public channel of Slack ⁴ or comments left on Notion ⁵ or Github ⁶. Moreover, survey data also confirmed that workers used different communication tools to communicate depending on strong and weak ties (Fig. 3). The descriptive statistical data revealed that workers interacted with strong ties via text messages (52%) more than weak ties (32%), but used email more to contact weak ties (12%) than strong ties (9%).

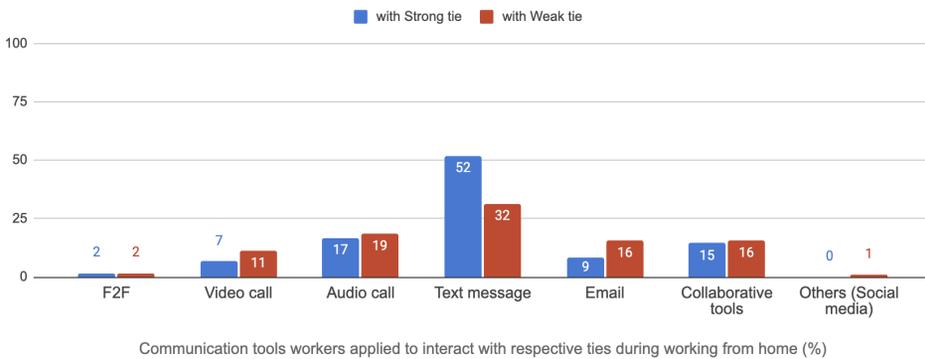


Fig. 3. Different usage of the communication media between workers and strong/weak ties during WFH (Blue: with strong ties; red: with weak ties). The number shows the percentage of each communication media being used with respective ties.

According to the interviews, the workers often collaborated with their strong ties on pieces of large-scale software development, or belonged to the same project and worked on different subtasks (e.g., a worker was responsible for the development of iOS while his/her strong tie works on Android development for the same function). When collaborating on these highly-interdependent tasks,

⁴Slack is a channel-based online communication platform that supports audio call and text messaging with teammates. <https://slack.com/>

⁵Notion is a web application that supports individual and team members to create, coordinate, and share notes. <https://www.notion.so/>

⁶Github is a platform for developers to manage and maintain source code for individual or collaborative projects. <https://github.com/>

workers frequently updated their ongoing project status with their strong ties to coordinate the details of how to merge functions and ideas with each other. In addition to checking in with their colleagues to align their collective goals, workers also reported that they often asked questions and provided feedback to their strong ties during their discussions. To maintain collaboration quality when everyone was working remotely, some workers shared that they would constantly connect with their strong ties (e.g., always turning on live video and audio) to approximate the interaction they previously had in the office (P14, P15). Workers would also immediately initiate conversations via text messages or video calls when they wanted to clarify or seek feedback from strong ties (P7, P9, P14, P15). The following example shows how a male software engineer kept connected with his specific strong tie, who was his senior team member, to immediately exchange their thoughts with each other:

P15-Software engineer: When S, who was a senior team member, found some bugs and couldn't solve them, we talked about it immediately. [...] We would leave the audio call on all the afternoon to remain connected, so we could instantly share and discuss any issues or interesting things that came up.

On the other hand, much of the workers' communication with weak ties mainly consisted of discussing project status updates and sharing goals with each other in group-level meetings, sometimes accompanied with sharing issues and solving them together. Workers reported that their encounters with weak ties mostly happened during regular group video/audio calls in the beginning of the workday (50% of workers, n=20). Because workers had relatively fewer work-related interactions with weak ties compared to strong ties, regular group meetings were one of the rare opportunities for workers to know of their weak ties. However, workers shared that it was hard to find a chance for initiating informal conversations with remote colleagues in a group video/audio call, which prevented them from maintaining personal relationships with their weak ties. As a worker shared in the interview:

P04-Marketing [when talking about her interaction with weak tie, who was an engineer in her team]: When we were in the office, I would occasionally asked him, 'what did you eat for lunch?', 'what were you drinking?'. But now [when WFH], I had no chance to chit-chat with him, even though we met each other in regular group meetings, we just talked about work.

Some workers said they would only receive information about their weak ties once every few days, if they were not required to join the same group meeting with weak ties. Other than the group video/audio meetings, workers received information about their weak ties from email, text messages, or collaborative platforms (i.e., Slack, Teams, Notion, Trello ⁷) adopted by the company. For example, a worker who was a consultant in an overseas agency noted below:

P10-Consultant [when talking about his interaction with weak tie, who was his boss]: When I discussed with other colleagues, I also CCed him (specific weak tie) in the email. Sometimes he would reply if he had some comments. I judged his status [availability and engagement] by how long he took to reply to me. For example, if I sent an email at 9AM and got a reply around 10AM, I would guess he was not very busy then.

4.2.2 The Impact of Insufficient Cues and Infrequent Interactions on Weak Ties.

Unable to Explain Observed Behavior. Several workers (60% of workers) mentioned that the lack of cues and infrequent interactions with the weak ties made it hard for them to stay fully aware of the weak ties' behavior and make inferences about their engagement level. The observed behavior, such as late replies, non-responses, and unexplained outcomes (e.g., uncertainties about why they took longer than expected to complete a task or why they gave the task less priority) prevented workers from finding any evidence to explain the colleague's behavior and outcomes when working

⁷Trello is an online task management tool for individual or team project management: <https://trello.com/en-US>

remotely. Although such uncertainty can occur even with strong ties, workers talked about such uncertainty most of the time when they were talking about interactions with their weak ties. The following quote shows an example of a worker's reaction when not receiving a reply from the specific weak tie during working from home:

P07-Human resource [when talking about a case in which her weak tie (her subordinate) did not respond]: I didn't know, and I didn't even ask. I just waited for his reply. Actually I had no idea whether he received my message or not. And I was not sure if he understood what I wanted him to do. Even if he received it, I was not sure whether he read it, or he had read it but just didn't want to do it, or he'd read it and would do it later. I didn't know what the situation was.

Workers Became Distant with Weak Ties during WFH. Several workers (40% of the workers) reported explicitly that the sudden change to remote work made them feel more distant from their weakly-connected colleagues compared to their previous experience of being in the same office. Unlike their frequent interactions with strong ties, there was no spontaneous timing for workers to initiate informal conversations with weak ties while working from home. When working in the same office, it was natural to have impromptu conversations when they arrived early at a meeting room, walking back to their seats after a meeting, or at coffee spaces. Nonetheless, these natural timings were missing when everyone was distributed. As a data analyst shared about the contrast of his interaction with his weak tie between before and during WFH:

P05-Data analyst [when talking about his interaction with weak tie, who was his team leader]: I felt we didn't chit-chat like before [as in the office] ... because in the office, I could talk to W just by turning my head, or if I saw something funny, I would directly talk to people around me, and then we would laugh or chit-chat for a while. Under that situation, it was easy to feel close to each other or talk about something funny. But now when it's at home, everyone just focuses on the meeting. After the meeting, everyone starts to do their own task... there is no chance to chat.

Newcomers, Who Were Weak Ties to All, Were Hard to Know Invisible Social Connections in the Organization. From the interview, we also found that it was hard for remote workers who joined the organization as newcomers to understand the invisible organizational structure of their company. Among all workers in this study, four joined their organization when the company had begun implementing WFH. Newcomers to the company, who could be seen as the weak tie to many existing workers, relied heavily on their strong ties to understand the big picture of their work projects, relationships among other colleagues, and job assignments. One newcomer described not being able to understand the hierarchy and relationships within their organization:

P11-Business development: There is a difference between working at home and in the office. In the office [at my former job], I clearly knew everyone's relationship with each other. The relationship was not only about the hierarchy of the colleagues, but also about how close they are and their relationships with each other. But when working alone from home, I couldn't sense anything about this.

Similar comments were also shared by P16, a female front-end engineer who said she could only know who was knowledgeable about certain topics if other newcomers posted their self-introductions on the public Slack channel of the organization. In another example, one newcomer relied on her strong ties to understand the structure of the organization and job assignments bit by bit during every discussion:

P03-UX researcher: I knew little about who knows what and who is responsible for what [in our company]. Not very complete... S would tell me something about that in our discussion. Yeah, I relied on him [to understand these points] most of the time.

In summary, survey data and interview results showed that workers had more one-on-one video/audio calls and text messaging with their strong ties, but had more group-level video/audio

calls and used more asynchronous tools with their weak ties. Missing cues and infrequent interactions with weak ties appeared to lead workers to have greater uncertainty when interpreting the observed behavior, and hard to maintain previous relationships formed in the office. Missing cues and infrequent interactions can also make remote newcomers unable to know the invisible social connections in the organization as found in the interviews.

4.3 Workers' Perceptions of Respective Ties can be Affected by Both Available and Unavailable Cues (RQ2)

4.3.1 Available Cues Acquired from Direct and Indirect Interactions (Often Among Strongly-connected Colleagues). Our second research question asked what cues workers relied on to form perceptions of their strong and weak ties when working remotely. In the interviews, the workers reported relying on available cues received from both direct and indirect interactions with remote colleagues to update their inferences about their engagement levels. Direct interaction referred to situations where workers had synchronous and reciprocal interactions with each other via video/audio calls and text messages, whereas indirect interaction referred to situations where workers received information or cues about the remote colleague asynchronously without having reciprocal interaction with that person.

Based on the interviews, cues in direct and indirect interactions that workers utilized to make inferences about co-workers fall into three general categories: (1) *task-oriented cues* (e.g., quick/slow reply, abstract/concrete comments, new/no ideas being proposed, questions being asked/answered, digital traces in online workspaces), (2) *availability-oriented cues* (e.g., daily routine, work schedule, availability, progress and plans for their tasks), and (3) *contextual cues* (e.g., background environments or background noise). We elaborate how workers relied on each type of cues to make inferences of respective ties below:

(1) *Task-oriented cues* were information or clues that workers gleaned from work to infer remote colleagues' engagement levels, such as response latency, comment quality, reactions in the discussion, and digital traces left in online workspaces. According to the interviews, when communicating with remote colleagues, workers reported that they tended to infer co-workers' engagement levels by seeing how fast and frequent they received responses from remote colleagues (e.g., waiting time in text messaging). If workers received a response within a short period of time, they would have more confidence that the remote colleague was relatively engaged.

P08-Sales [when talking about his interaction with strong tie, who was his boss]: I usually sent messages to update him about the current progress and asked his opinion. Sometime he replies immediately, and sometime he just quickly replied with 'I'm working on other task now, will get back to you later' [...] Sometime S would explicitly shared on the channel that he had to handle something else and would be offline for an hour or so. [...] If I sent him message without getting a reply, I thought he must be busy working on other tasks.

Unintentionally perceiving online activities in shared workspaces appeared to help workers update their inferences on respective ties, which included noticing stickers being added to public Slack discussion threads, receiving message notifications from group chatrooms, seeing someone's file editing and updating history from Github or shared documents, expecting to receive an immediate reply when noticing their online status next to the profile image changed from "on the call" to "not on the call", or viewing others' discussion threads on Slack, Notion or Email threads. These digital traces left in online shared workspaces provided useful clues for workers to be aware of their remote colleagues' working status. As one software engineer shared, he felt his strong tie was engaged in performing a development task by noticing his unusual commenting behaviors in a discussion thread:

P12-Software engineer's inference about S's engagement level: One day our CTO raised several issues [about our product] on Notion [Notion is a collaborative software used as a bulletin board in P12's company]. I remembered it was about how to improve its certain functions. I seldom check every notification sent by Notion, but I remembered at that time I saw the notification email showing S (team member) commented for about 300 words. I felt S must be focusing on that project very much, because he rarely comments something that long on Notion.

Unable to see remote colleagues' online activities also influence workers' inferences on the engagement of performing tasks. As a worker shared that she was unable to explain her weak tie's inactive on Slack channel:

P04-Marketing [when talking about her interaction with weak tie, who was an engineer in her team]: Recently our team were discussing something about "payment process" on Slack channel, me and other engineers all shared our ideas. But I didn't see any response from W. It's fine he didn't share anything, but I felt at least he could add a funny sticker or something to echo us.

(2) *Availability-oriented cues* are clues that enable workers to infer whether their remote colleagues were available to reach out during work, such as knowing one another's work routine, daily schedule, number of ongoing tasks, and future plans for collaborative tasks. Interview results revealed that workers could receive rich information about their strong ties' availability given the relatively more frequent direct interactions still available during WFH. The relatively more frequent interactions also created opportunities for informal conversations, allowing workers to continuously infer the strong ties' attitudes and understand when they were facing temporary ups and downs in their work, which may also contribute to the inferences of availability for engaging in work and collaboration. Knowing remote colleagues' situations enabled workers to find attributions for the observed behaviors and show understanding even if they sensed that their colleagues were not engaged at certain points. As a product manager shared that she sensed her strong tie did not want to have further discussion by listening to her private complaint:

P09-Product manager [when making inference about S' engagement level]: [during WFH] when we were not busy, we would talk about our current situation, like what bad thing we encountered today, what made us unhappy, etc. For example, S (project manager) would say: "oh, I feel very tired today, I don't want to respond to any message for now", or "today he (another colleague) asked me lots of questions, it's so annoying, I don't want to reply." Then, I would know she didn't want to work on it right now. I can expect that she is not in the mood to work in the next 1 or 2 hours.

(3) *Contextual cues* are information being noticed in the background, such as background noise or family members caught on camera during an online meeting. A UX researcher reported feeling a remote colleague might not be very engaged when s/he was both late for a project discussion and the background noise also indicated s/he was on public transportation. Some said they felt remote colleagues might be hard to concentrate on work because of their working environment. As a software engineer shared, he felt remote colleagues had to deal with lots of family tasks by seeing their family members passing by during the video call:

P19-Software engineer [when talking about his perceptions of remote colleagues' task performance]: Some of my colleagues were fathers. When we were in the office, I won't be able to see their family members and children. But now during our online group meeting, I could see their family members walking behind them. In such an environment where they had many [family-related] tasks to handle, it must be difficult to concentrate on work...I could sense the stress.

4.3.2 Prior Impression Dominates Inferences about Co-workers when Cues were Unavailable (Often Among Weakly-connected Colleagues). When there was no interaction at the moment of being asked to make an inference, 50% of workers said they used prior impressions formed in their face-to-face interactions, as well as recalling what they saw in recent interactions, to update the inference. Thus,

for weak ties with low interaction frequency and no recent interaction, the workers inevitably had to rely on the impressions that were formerly formed in the office.

Interestingly, the lack of cues about their colleagues seemed to not only make the workers rely on the impressions they formed in the past, but also reinforce those impressions:

P03-UX researcher [when making inference about W's engagement level]: Because I met W (boss) before, and I felt he was more focused than S. But since I didn't have many chances to interact with him [during WFH], I couldn't give him a high score [like 6 or 7]. But anyway, I feel he is SUPER engaged and always very ambitious.

When P03 talked about her weak tie colleague, she used "super" engaging to describe her weak tie's engagement level with her tone emphasizing "super" and "ambitious". The positive impression was maintained even if P03 did not have many direct interactions with her weak tie during WFH. In contrast, if the impression of the colleague is relatively negative, insufficient cues due to the lack of interaction during WFH could exacerbate the negative impression. P17 mentioned several times in the interview that he did not have many cues to sense his weak tie's general status during WFH, which made his prior impressions from the office dominate his inference:

P17-Assistant's inference about W' engagement level: hmm... W (administrative staff) always put up an unhappy face, so I guess she is not very happy about this job. Yes, ... I saw her always being unhappy in the office.... I guess she is less engaged [when working from home], but it is just my feeling. My impression of her is that she is very conventional, like not paying attention to the work, procrastinating as much as possible, and spending a long time cleaning the room, something like that.

To summarize, from the interviews, workers took diverse cues from direct and indirect interactions into account when inferring respective ties' engagement levels and interpreting their behaviors. Task-oriented, availability-oriented, and contextual cues all together helped workers make inferences about remote colleagues' engagement level. Frequent interactions with strong ties enabled workers to make more confident inferences of their strong ties (80% of the workers). Even when workers received a late response from their strong ties, these cues in combination with the relatively stronger pre-existing relation appeared to help avoid ungrounded attributions. However, such attributional adjustment seemed difficult for workers to infer weak ties' engagement levels, due to the lack of opportunities to obtain a variety of cues. When there was no interaction, which was frequently reported when inferring weak ties, workers' positive and negative prior impressions were reinforced due to insufficient cues for updating their impressions of remote colleagues.

4.4 Weak Ties Were Perceived as Less Engaged and Less Worthy to Collaborate with than Strong Ties (RQ3)

Our third research question asked how insufficient awareness in remote workplaces affect workers' perceptions of the engagement level of and willingness to collaborate with their strong and weak ties. From the experience sampling study conducted in the field, we compared workers' real-time perceived engagement of their respective ties at each of the 15 data points - three points per day, captured from a total of five days of experience sampling. Paired t-tests showed that workers perceived weak ties as significantly less engaged than strong ties ($t[14]=7.88, p<.01$). We further compared workers' perceived engagement of strong and weak ties at the beginning, middle, and the end of the workday. Results of a one-way ANOVA showed that workers' perceived engagement of strong ties did not change throughout the day ($F[2, 18]=2.1, p=ns$), while their inferences about weak ties' engagement levels significantly diminished from the beginning to the end of the day ($F[2, 18]=5.27, p<.05$) (Fig. 4, left).

Similar trends were found when workers assessed their just-in-time willingness to collaborate with strong and weak ties during the experience sampling study. Paired t-test showed that workers had less willingness to collaborate with weak ties than with strong ties ($t[14]=13.1, p<.01$). When

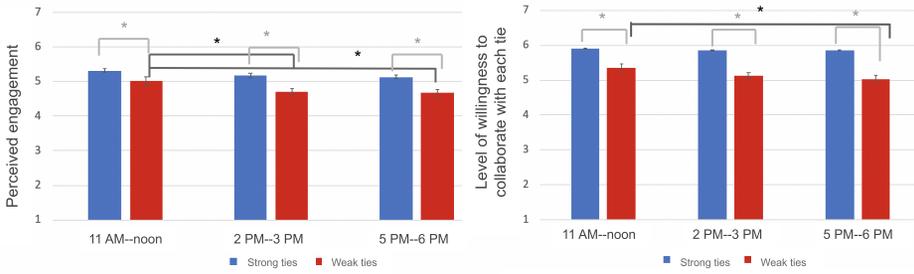


Fig. 4. Workers’ perceived engagement and willingness to collaborate with their selected strong and weak ties. Left: Perceived engagement. The y-axis shows the level of perceived engagement by worker. The higher the score, the higher the perceived engagement. Workers perceived weak ties as less engaged than strong ties, and their inferences about weak ties’ engagement level decreased throughout a day. Right: Willingness to collaborate. The y-axis shows how positively the worker feels about forming a collaboration with each tie. 7 is very positive, while 1 is very negative. Workers showed less willingness to collaborate with weak ties than strong ties.

further comparing the willingness to collaborate at the beginning, middle, and the end of the workday, results of the one-way ANOVA revealed that workers’ perceptions of their strong ties did not change significantly ($F[2, 18]=0.21, p=ns$). But for weak ties, workers’ willingness to collaborate appeared to diminish from the beginning of the day to the end of the day ($F[2, 18]=3.17, p=ns$) (Fig. 4, right). Multiple comparisons by LSD showed that workers’ willingness to collaborate with weak ties significantly decreased from the beginning to the end of the workday ($p<.05$).

To find out whether workers’ inference of engagement toward their respective ties relates to workers’ willingness to collaborate with them, we further analyzed the correlation between workers’ perceived engagement of each tie and workers’ willingness to collaborate. Correlation results showed that, for strong ties, there is no significant correlation between perceived engagement and willingness to collaborate ($r[18]=0.34, p=ns$). But for weak ties, there was a significant positive correlation between perceived engagement and willingness to collaborate ($r[18]=0.68, p<.01$). This correlation result suggests that what they perceived from weak ties’ perceived engagement level can predict, and may potentially affect, workers’ motivation to form collaborations with them. As for strong ties, a worker’s willingness to collaborate with a strongly-connected colleague is independent of the worker’s perceived engagement of this person.

Overall, the results from the experience sampling study complemented the interview findings in previous sections 4.2.2 and 4.3.2, suggesting that lacking of in-person interaction and insufficient awareness when working remotely could have led workers to form the perception that weak ties were less engaged than strong ties. Workers’ perceptions of their strongly- and weakly- connected colleagues become polarized rather than leveled when working remotely. Table 2 summarized all findings in section 4

5 DISCUSSION

In the following sections, we discuss each finding to illustrate how and why distance matters especially to weak ties in remote workplaces.

Table 2. Summary of the findings for each research question.

Research Questions	Main Findings
RQ1: How do workers interact with strong ties and weak ties when working remotely?	<ol style="list-style-type: none"> (1) With strong ties (S): more one-on-one, synchronous communication media; With weak ties (W): more group-based, asynchronous media. (section 4.2.1) (2) Remote work poses several challenges to weak ties due to insufficient cues and infrequent interactions, compared to strong ties. (section 4.2.2)
RQ2: What cues do workers rely on to form perceptions of their strong ties and weak ties when working remotely?	<p>Both available and unavailable cues affect workers inferences of remote colleagues' engagement levels: (section 4.3)</p> <ol style="list-style-type: none"> (1) Available cues: Workers updated their inferences through a combination of (a) task-oriented, (b) availability-oriented, and (c) contextual cues. (2) Unavailable cues: When there was the absence of the cues, prior impressions dominated workers' inferences of remote colleagues.
RQ3: How does insufficient awareness in remote workplaces affect workers' perceptions of the engagement level of and willingness to collaborate with their strong ties and weak ties?	<ol style="list-style-type: none"> (1) Workers perceived W as less engaged, and less worthy to collaborate with than S. (section 4.4) (2) Correlation results suggested a worker's willingness to collaborate with S is independent of the worker's perceived engagement. (section 4.4)

5.1 The Impact of Different Communication Patterns and Characteristics of Communication Tools on Workers' Perceptions of Respective Ties

The differences in technology usage combined with different communication patterns with strong and weak ties may lead workers to infer each tie's engagement level differently. One-on-one interactions, which often happened with strong ties, allowed workers to have more chances to build mutual understanding with each other. In contrast, workers often reported having more group-level interactions when interacting with their weak ties. In such group online meetings, it is hard to initiate informal conversations with weak ties. Because it is often difficult for people to find the right timing to interrupt and share their thoughts [35] and unequal participation could easily occur [63] in remote workplaces, this could make remote workers become even more distant from their weak ties. Failing to actively participate in regular group meetings, an already rare chance

for workers to connect with their weak ties, could further exacerbate perceptions of how engaged weak ties are in the workplace.

In addition to interaction patterns, our result also showed the characteristics of communication tools played a part when workers made their inferences of remote colleagues' engagement levels. Email has been identified as having fewer communication cues, such as lacking co-presence, simultaneity, and sequentiality, for establishing common ground [12]. Such characteristics of the communication tools could lead workers to misattribute their weak ties. For example, workers could misinterpret the response latency of an email as a late reply rather than considering the fact that it takes longer to exchange emails than instant messages. Different from the interactions with weak ties, workers used more instant messaging with their strong ties during working from home (see Fig. 3). The characteristics of the synchronous communication channels, such as visibility, audibility, simultaneity, and sequentiality, allow workers to stay connected and maintain a high awareness of strong ties.

The results of our study suggest that workers and organizations need to be aware of the characteristics of the communication tools they are using to communicate with strongly- and weakly-connected collaborators while working remotely so that workers can adjust their expectations when communicating with different social connections. We suggest that in addition to enhancing awareness by making the communication process transparent [5, 22, 29, 46, 67], showing extra information about the media characteristics to workers who used them to interact with various social connections is also important. For example, indicating that it is difficult to interrupt an ongoing conversation in a group audio/video call with weak ties, or highlighting that workers are using an asynchronous communication tool when exchanging messages with weak ties. Such information could help workers better attribute the behavior they observe when interacting with different social connections through various communication technologies.

5.2 Prior Impressions Dominate Inferences of Engagement Levels When Cues are Absent in Remote Workplaces

When workers could not receive any cues from their direct interactions with a colleague or from the collaborative shared workspaces, workers' prior impressions dominated the inference process. If prior impressions formed in the office or from the last interaction were positive, then insufficient awareness could enlarge these positive impressions. Similarly, if prior impressions of the remote colleague were negative, the absence of cues during remote work could also enlarge these negative impressions (see section 4.3.2).

This finding echoes and extends the concept of overattribution described in the hyperpersonal model proposed by Walther [7, 64, 70]. Following the prediction of the hyperpersonal model, weakly-connected remote colleagues have formed perceptions of one another based on the limited social cues they received via computer-mediated communication tools when working remotely. In the absence of cues, workers based their perceptions of each other on their initial impressions, a process Walther and colleagues [69] refer to as "overattribution". A series of related studies found that people's perceptions of their unacquainted partners' personality traits became intensified in CMC [27], and people formed exaggerated perceptions of their remote partners' during CMC, compared to face-to-face interaction [7]. Consistent with previous research on the overattribution process, our data showed that workers had exacerbated perceptions of their remote weak ties when there were insufficient cues during WFH (see section 4.3.2). One possible explanation is that insufficient interactions and awareness prevented workers from updating their impression of their remote weak ties, so they filled this gap in cues with their prior impression of their remote coworkers. This finding begins to extend CSCW's understanding of the overattribution process by showing that, even when remote coworkers have established prior understandings and relationships with one

another *offline*, overattribution can still occur due to infrequent interactions and unavailable social cues *online*. Further studies are needed to examine how enhancing interactions and awareness among remote workers changes the way workers explain the observed behaviors of their coworkers.

5.3 Enhancing Social Awareness among Weak-ties in Remote Workplaces

Many CSCW researchers have proposed socially translucent systems by making distributed workers' activities visible to each other [19, 40]. For example, researchers have used physical surrogates to sense and coordinate remote workers [58] and designed global views to highlight which distributed workers were performing what tasks [72]. Providing such social awareness among distributed workers helps workers initiate conversations [19], check the availability of their coworkers [5], and coordinate tasks with each other [46]. Our study expands the current understanding of supporting social awareness for remote workers by highlighting the need to support social awareness among *weakly-connected colleagues*. Our results showed that workers relied on digital footprints left in different online collaborative tools (e.g., Teams, Github, Slack) to make inferences about their weak ties. One potential way to support the awareness of remote weak ties is to take advantage of the digital footprints left in shared public workspaces, such as commit time, comment behavior, and file uploading time left by distributed workers. These pieces of information are already visible in most collaborative tools for supporting co-presence and enhancing task coordination. Consistent with the suggestions made by [11], remote workers in our study were willing to share their location and current tasks they were working on during working hours with their collaborators. Such information was also identified as useful for collaborators to sense each others' working status [11]. Public digital footprints have been widely adopted in supporting mutual understanding in workplaces. For example, study of software developers also showed that developers depended on online activities to assess other developers, e.g., active open source involvement, numbers of contributions and side projects [43]. Future collaborative tools could add an automatic digital footprint tracing function to collect all public but unnoticed digital traces left by distributed workers while working, and then visualize their online activities in an abstract manner among those who are weakly connected. Once the system identifies two distributed workers who are weak ties to each other, the system could share the activity visualizations after getting each worker's approval. Such awareness support can serve as extra channels for remote colleagues to update their impressions and enable workers to explain their coworkers' behaviors observed from diverse sources.

One noticeable challenge we found from workers' weak ties is that remote newcomers, who are weak ties to all existing members in a distributed team, are unable to understand the invisible organizational structure and interpersonal relationships in remote workplaces. Helping remote newcomers understand invisible organizational structures could support them in forming more positive perceptions of engagement and building relationships. In line with recent studies on the remote onboarding process of software engineers, which showed that new hires find it challenging to build social connections with other colleagues during remote work (e.g., smaller networks within the organizations and fewer messages being exchanged, compared to in-person work prior to the pandemic) [54, 63], we found that the lack of one-on-one discussion and insufficient awareness made it difficult for remote newcomers to bond with other team members, ask questions, and understand group dynamics. Meanwhile, scholars have proposed that visualizing how knowledge flows within workplaces can guide workers to reach out to the right colleague when seeking specific information [74]. Therefore, enhancing social awareness by visualizing the social and knowledge networks within the organization could not only help remote newcomers understand interpersonal connections better, but also guide them to find the right person to ask for help when there are insufficient interactions in the remote workplace.

6 LIMITATIONS AND FUTURE DIRECTIONS

We are aware that many factors come into play when studying remote workplaces, e.g., the coupling of work, colleagues' power relationships, organizational hierarchies, etc. Working remotely during a pandemic also adds complexity, e.g., stress. In the current study, we revealed that workers' existing impressions of strong and weak ties become polarized during WFH. Studying the influence of these nuanced factors on workers' perceptions of their co-workers is beyond the scope of the current study. Regardless of the various factors and diverse work conditions both workers and their respective ties faced in the study period, our empirical data showed that workers' inferences and impressions of each tie still differed due to the available and unavailable cues during WFH. Future studies are needed to understand the wider array of factors and processes potentially affecting workers' perceptions and collaborations with their co-workers in remote workplaces.

Another limitation of the current study is the absence of verified engagement levels from workers' respective ties. In a follow-up study, it is worth exploring how distance affects both workers' inferences and their remote colleagues' perceptions; how self-assessment and other-perception match or differ; and what strategies workers use to maintain perceptions of their engagement levels when suddenly forced to work remotely.

Although all of our participants were from Taiwan and came from an Eastern cultural background [57], our findings around perceived engagement are consistent with studies conducted in globally distributed organizations e.g., [14]. For example, Cristea *et al.* found that remote workers expend extra effort to signal their commitment to their managers and get a better job assignment. In line with their findings conducted with majority Western workers, our findings with Taiwanese workers also revealed the universal effect that workers' perceptions of their remote collaborators' behaviors have on how they assess each other. Meanwhile, we also acknowledge that there are rich cross-cultural studies indicating that people from Western and Eastern cultures have different communication styles [57], collaboration styles [59], ways of information processing, and ways of attribution [61]. For example, researchers found that Western workers are less attentive to indirect social cues in work settings than Eastern workers [57]. Asians were also found to use emoticons to express emotions more frequently than North Americans [31], which could lead to different interpretations of remote workers' use of reactions/stickers in text chat. All of these cultural factors could lead Western and Eastern workers to make different inferences about remote colleagues based on computer-mediated social cues. Our study revealed that workers show polarized perceptions of their respective ties, but how the extent of such polarization differs by culture will require further research.

Finally, further research regarding the effect of remote work on remote newcomers of a team is essential. Newcomers could be considered a weak tie to most of the members of a remote team, as identified in section 4.2.2. Future work on fully distributed workplaces should focus on supporting newcomers in understanding the invisible relationships among other collaborators, establishing mutual understanding and trust with other existing members who have already formed close relationships, and building rapport remotely.

7 CONCLUSION

Perceived engagement has a direct impact on the evaluation of work performance and the relationship among collaborators. In this research, we aimed to examine how workers interacted with and perceived the engagement of their co-workers with different tie strengths when working remotely. By triangulating an online survey, experience sampling, and in-depth interviews, we found that workers' perceptions of their weak ties would be affected by remote work more than perceptions of their strong ties. Unlike most remote work studies focusing on supporting common

ground building among strongly-connected collaborators, we focus on how insufficient awareness in remote workplaces could harm weakly-connected collaborators. The lack of available cues could harm the way weak ties are perceived and their relationships with other colleagues in remote workplaces. The infrequent, asynchronous interaction with weak ties and the absence of cues altogether can exacerbate the negative impressions workers have of weak ties. Our findings point out the importance of considering tie strengths when designing and applying various computer-mediated communication tools in remote workplaces, especially since weak ties who bring new perspectives to a team could be in a disadvantaged position during remote work.

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A SUPPLEMENTARY MATERIALS

A.1 Items being asked in the online survey (translated from Chinese to English)

- Job related questions. (E.g., What is your occupation? Which industry do you belong to? What is your position in the company? How long have you been working in this company?)
- Tie strength related questions:
 - Please indicate one colleague who has the most frequent interaction with you (strong tie) and one who has the least frequent interaction with you (weak tie) in your current collaborative project.
 - How close are you and the S / W tie? (1-7 Likert scale)
 - What are the top three communication media you adopt most frequently to interact with S / W?
 - Please indicate the percentage of each media usage when interacting with S / W (for example, 80% face-to-face, 10% email, 10% text messaging).

A.2 Questions being used in experience sampling phase

We asked workers to answer the following questions based on their observations and perception of strong (S) and weak ties (W).

- (1) Did you have a chance to interact or receive information about S in the past three hours?: interacted / received information from S / no interaction.
 - If yes, what media did you use? (video conferencing, phone, chatting, SNS, others?)
- (2) How would you estimate S's interest at this moment? (1-7 Likert scale)
- (3) How would you estimate S's concentration for work at this moment? (1-7 Likert scale)
- (4) How would you estimate S's enjoyment for work at this moment? (1-7 Likert scale)

- (5) (optional) What made you think this way? Reasons for 2,3,4. (e.g., the way s/he acted, the words s/he said, etc)
- (6) What is your feeling towards S as a team mate to work with? Negative <--> Positive (1-7 Likert scale)

The same set of questions were also asked while workers were making inferences of their weak ties.

A.3 Outline of the questions being asked in semi-structured interview

We followed this outline to initiate conversations with each worker, but the questions we asked were not limited to what were listed below. We would probe further depending on the events workers shared during the interview and the instances they reported in the experience sampling to understand more about the context.

- Could you share what kind of projects you are working on with S and W?
- Regarding the observed changes of your S / W's engagement (interest, concentration, enjoyment) in experience sampling phase, what makes you think this way? E.g., what kind of practice/activities did you observe? Any instance about information sharing, meeting, online activities, etc? (workers' responses in experience sampling phase are provided for them to recall the details and contexts.)
- How does this affect any aspect of your work / collaboration?
- Regarding your colleagues' engagement, what's the difference you observed between before and after working from home?
- How confident are you when you are estimating S / W's engagement? Compared with W / S? What's the difference? In what situation the confidence level would change?

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