2025 IEEE Conference on Virtual Reality and 3D User Interfaces Abstracts and Workshops (VRW) | 979-8-3315-1484-6/25/$31.00 ©2025 IEEE | DOI: 10.1109/VRW66409.2025.00397

Exploring Human Reactions to Telepresence Drones: A User Study on Safety and Trust Using A Simulated Drone in a VR Environment

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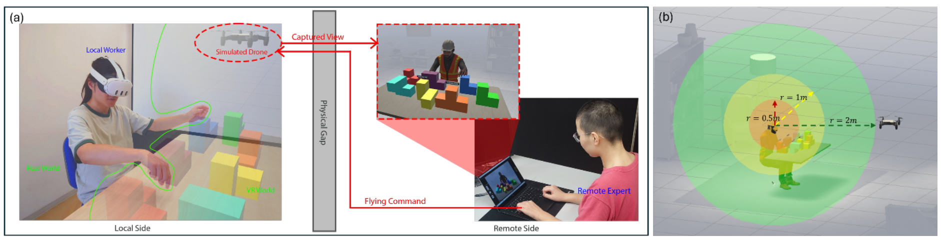

Figure 1: (a) An overview of the Virtual Reality (VR) remote collaboration system with a simulated telepresence drone. The local worker (left) is assembling Soma cubes, following the remote expert's (right) instructions. The simulated drone is located in VR with the local worker, capturing view through built-in virtual camera and send to remote expert's PC. (b) Transparent spheres of different colors were used to visualize the distance between the simulated drone and the heads of local workers.

Abstract

Telepresence using drones is a promising technology. This paper presents a user study within a simulated Virtual Reality (VR) remote collaboration system to shed light on users' perceived safety and trust regarding telepresence drones. We manipulated drone operation variables, including failure of drone, speed of flying, and distance restriction, to assess their impact on user perceptions. Quantitative and qualitative analysis shows that drone failures significantly reduce safety and trust for both local and remote users. Flying speed affects safety and trust for local workers but only impacts safety for remote experts. Distance restrictions enhance both safety and trust.

Index Terms: Telepresence drone, remote collaboration, virtual reality simulation, perceived safety and trust.

1 Introduction

Drones have been increasingly utilized in remote telepresence systems. However, telepresence using drones poses significant challenges, particularly when flying indoors and with humans around, which often leads to accidents [2]. As a result, local people who coexisted with drones frequently feel vulnerable, fostering fear and distrust towards drones. At the same time, remote operators of a drone may worry about the stability, responsiveness, and reliability of drones. These issues may cause operators to doubt the drone's capabilities and affect the successful completion of the mission. To develop more effective and user-friendly interfaces for telepresence drone systems, it is critical to first understand the attitudes of remote collaborators toward these devices, both local workers and remote operators.

Trust and safety are pivotal in ensuring the seamless integration of robots into the workplace. When users perceive drones as unreliable or unsafe, it may lead to increased anxiety, decreased productivity, and reluctance to use the technology [4]. The context of telepresence drones has not yet been explored despite their great potential.

This study examines local and remote users' perceptions of safety and trust in telepresence drones through a VR-simulated remote collaboration system. Local workers, guided by experienced remote experts, performed assembly tasks while wearing VR headsets. The simulation realistically mimicked a drone's size, sound, and behavior, enabling controlled and immersive interactions while ensuring participant safety. Using VR allowed us to explore human-drone interactions flexibly and risk-free, uncovering concerns influencing user trust and safety. This research provides insights to improve telepresence drone design and control methods, aiming to enhance their efficiency and usability in remote collaborative applications.

2 Method

We built a simulated VR remote collaboration system. Local workers and remote experts work together to assemble a specific shape using Soma cubes. As a telepresence of the remote expert in the local environment, the drone delivers the information needed during the collaboration process, including video capture of the work environment. By changing the operating status of the drone, we want to answer the research question: What factors influence collaborators' perceived safety and trust in telepresence drones?

2.1 Experimental Design and Procedure

The experiment followed a $2 \times 3 \times 4$ within-subjects design, resulting in 24 total conditions. We manipulated the failure of the drone (normal: the drone flew according to the command; and faulty: the drone flew uncontrollably, with fluctuating altitudes, unclear directions, and chaotic engine noises), speed of flying, including movement speed and rotation speed (high speed: 5 m/s, $100°/s$; middle speed: 2 m/s, $50°/s$; and low speed: 0.5 m/s, $10°/s$), and distance restriction of flying (3.6 meters, 1.2 meters, 0.45 meters, and no restriction) as the independent variable. The distance restriction levels are based on Hall [3]'s interpersonal distance zones: intimate (0–0.45m), personal (0.45–1.2m), social (1.2–3.6m), and public (>3.6m). These zones were adopted because people tend to

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979-8-3315-1484-6/25/$31.00 ©2025 IEEE
DOI 10.1109/VRW66409.2025.00397

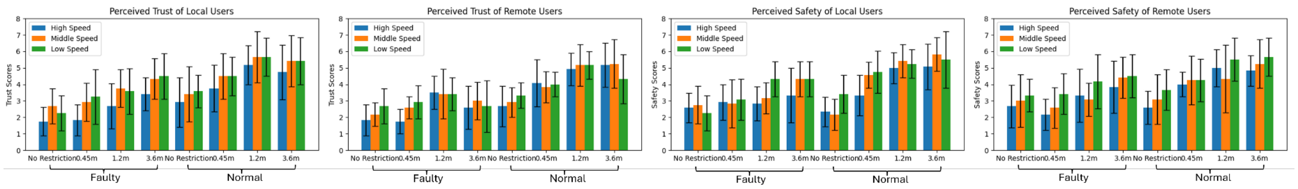

Figure 2: Results of quantitative measures on Perceived Trust and Safety towards telepresence drone. Error lines stand for ± 1 standard error.

maintain similar distances with robots as they do with other people [1].

Participants were randomly paired, with one person assigned the role of local worker and the other as remote expert. Participants were trained before the experiment. After the introduction of the tasks and experimental content, participants signed a consent form.

In the experiment, remote experts guided local workers in assembling Soma cubes by viewing the simulated drone's video feed on a PC monitor and providing voice instructions. Local workers performed tasks in VR. Each condition lasted 3 min, and the order was randomized. Participants rated **Perceived Safety** and **Perceived Trust** of the drone on a 7-point Likert scale and answered open-ended questions about drone safety and trust. Think-aloud protocols were used to document the process.

2.2 Setup and Apparatus

Fig. 1(a) illustrates the simulated work environment developed in Unity 3D. The local worker, wearing an HMD (Quest 3), interacts with 3D virtual Soma cubes on a virtual workbench using hand gestures or controllers. Their movements are synchronized with a virtual avatar using Final IK for enhanced observation. The simulated drone, modeled after the DJI Tello, features realistic engine sounds and an integrated virtual camera that streams workspace footage, including avatar movements, to the remote expert's PC. The expert controls the drone via a keyboard, enabling movement and rotation in various directions for dynamic perspectives. A distance-based visualization alerts the local worker when the drone approaches. A red sphere appears when the drone is within 0.45m of the worker's head, a yellow sphere for 0.45m–1.2m, and a green sphere for 1.2m–3.6m. Beyond 3.6m, no sphere is displayed (Fig. 1(b)).

2.3 Participants

We recruited participants in the school community. Interested individuals were asked to complete a questionnaire about demographics and prior experience with VR or drones. Individuals who lacked any knowledge of VR and drones were excluded. A total of 24 participants (16 male and 8 female) were selected for the study, aged from 21 to 31 (M=24.67, SD=2.91).

3 Results

3.1 Quantitative Results

The Shapiro-Wilk normality tests showed that overall residuals for both trust ($W = 0.997$, $p = 0.256$) and safety ($W = 0.997$, $p = 0.347$) followed a normal distribution. We analyzed participants' attitudes toward telepresence drones using ANOVA and post hoc tests (Fig. 2). Drone failure ($p < .001$) and distance restriction ($p < .001$) significantly impacted perceived safety and trust for both roles. Speed influenced safety for both roles ($p < .001$), but its effect on trust was significant only for local workers ($p = .003$). Interaction effects showed that failure combined with no distance limits heightened insecurity and distrust ($p < .01$). Tukey HSD post hoc analysis revealed higher safety and trust ratings during normal drone operation compared to fault conditions ($p < .001$). For local workers, speed differences affected safety ($p = .007$) and trust ($p < .01$). For remote workers, safety varied significantly between speed levels ($p < .05$). Most distance conditions showed significant differences ($p < .05$), except between 1.2m and 3.6m.

3.2 Qualitative Results

We collected qualitative data through think-aloud sessions and interviews, revealing insights beyond statistical results. Local workers feel unsafe when the drone is too close, often making evasive movements and pausing tasks. Remote experts struggle to operate drones accurately due to limited environmental awareness but need closer proximity for visibility. Active measures, such as distance limits and visual indicators, are crucial to balance drone operation and worker comfort. P1 said: "I feel like the drone hits my head, which is scary." P12 said: "I feel safer when the drone is 1–2m away." Drone speed impacts perceived safety and control accuracy. Slower speeds allow closer proximity but may reduce responsiveness, affecting trust. High speeds decrease control accuracy, increasing safety risks. P5 said: "At low speed, I can accept the drone being closer." P16 said: "Controlling a high-speed drone accurately is difficult." P15 said: "At slow speeds, it feels like the drone isn't moving." Drone malfunctions greatly reduce user trust and safety, making other factors like speed or proximity less relevant. P1 said: "When the drone is faulty, I'm afraid it will fall and hit me."

4 Conclusion and Discussion

This study explores perceived safety and trust in telepresence drones for remote collaboration using VR simulation. Key findings include: 1) Perceived safety: Drone failures reduce safety, while distance limits and appropriate speeds improve comfort. 2) Trust: Normally functioning drones enhance trust, while faults significantly undermine it; drone speed affects trust in local workers but not remote experts; minimum distance restrictions benefit trust for all users. Future work could increase the sample size to conduct a properly powered VR study. It should also evaluate how to implement measures to improve safety and trust.

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