

AI-Driven Assistant for Worker Safety in Future Construction: Examining Opportunity and Challenges

Proceedings of the Human Factors and Ergonomics Society Annual Meeting 2025, Vol. 69(1) 2104–2107
Copyright © 2025 Human Factors and Ergonomics Society
DOI: 10.1177/10711813251358804
journals.sagepub.com/home/pro



Woei-Chyi Chang¹, Wei Zhou¹, and Sogand Hasanzadeh¹

Abstract

The integration of robots, particularly drones, into future construction sites introduces new safety challenges requiring enhanced situational awareness (SA) among workers. To address these challenges, this study explores the effectiveness of an AI-driven assistant designed to inform workers about dynamic environmental changes via auditory and visual channels. A mixed-reality bricklaying experiment was developed, simulating worker-drone interactions across three interaction levels: coexistence, cooperation, and collaboration. One hundred five construction-background students participated in tasks with and without the AI assistant, during which their eye-tracking data, productivity, and subjective perceptions were collected. Results indicated that the AI assistant significantly expedited workers' awareness of approaching drones but concurrently reduced bricklaying productivity. Although participants reported high perceived usefulness and low distraction by the AI assistant itself, findings revealed a trade-off: improved SA toward drones came at the cost of decreased task performance, likely due to increased attentional shifts toward drones. Furthermore, the effectiveness of the assistant varied depending on the interaction level with drones. This study highlights both the opportunities and challenges of applying AI-driven informational systems in future construction environments, offering critical insights for designing human-centered AI technologies that balance safety enhancement with productivity maintenance.

Keywords

worker-AI interaction, situational awareness, future construction

Introduction

Construction sites have been recognized as a safety-critical and dynamic workplace with the presence of various hazards. Workers are required to concurrently perform construction activities and maintain situational awareness (SA) of surrounding environment (Luo et al., 2024). However, future construction sites will potentially become more dynamic and unpredictable after introducing mobile robots (Chang et al., 2023). Among various types of mobile robots, the applications of unmanned aerial vehicles (a.k.a. drones) within the construction domain have been widely emphasized (Hatoum & Nassereddine, 2022). Previous studies have highlighted the latent risks associated with drones, compromising worker safety (Chang et al., 2024). Consequently, workers must allocate their attentional resources to tasks, hazards, and drones to ensure both productivity and safety on future jobsites. Such multitasking situation in future construction shed light on a need for effective strategies to reduce workers' workload during human-drone interactions. A potential solution is to develop an AI-driven assistant to provide workers with critical information regarding the dynamic environment (e.g., drone information) via specific communication channels (e.g.,

visual, auditory, and haptic). Hence, workers can concentrate on the designated tasks without sacrificing their SA of the surrounding environment. Though feasible, this AI-driven assistant, especially the visual-based ones, might latently be a distractor to attract workers' attention even when it is not providing information. It remains unclear whether an AI-driven assistant enhances worker safety by providing information or undermines task performance by causing distractions. Therefore, this study aims to explore the opportunities and challenges of an AI-driven assistant in future construction by simulating a futuristic worker-drone interaction scenario.

Background

As safety is a critical determinant of a successful construction project, literature has proposed solutions to enhance

¹Purdue University, West Lafayette, IN, USA

Corresponding Author:

Woei-Chyi Chang, Purdue University, 550 W Stadium Ave., West Lafayette, IN 47907-2050, USA.
Email: chang803@purdue.edu

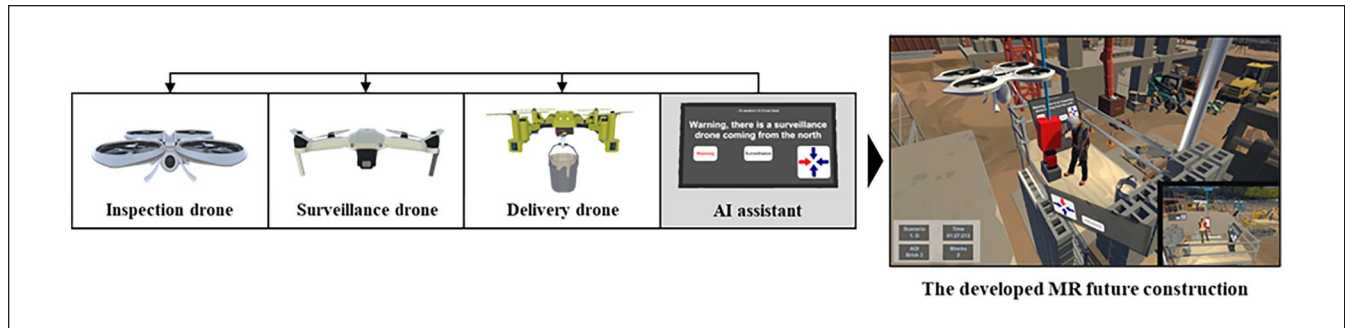


Figure 1. The developed bricklaying experiment in this study.

construction safety by applying digitalization technologies. For example, in the study focusing on improving safety inspection, the authors developed an augmented reality (AR) application to digitalize the entire inspection process (Ramos-Hurtado et al., 2022). Moreover, previous studies combined AI and digitalization to present the results of hazard-related image recognition in an AR device (Wu et al., 2022). These examples showcased the effectiveness of providing additional information to facilitate construction safety. However, the literature also suggests that digitalization technology may increase users' cognitive load and distract them from primary tasks (Buchner et al., 2022; Kim & Gabbard, 2022). For example, in the study that investigated the distraction of AR devices in driving, the authors reported their potential of visually and cognitively distracting drivers (Kim & Gabbard, 2022). In the construction domain, this issue might further compromise workers' productivity and influence their attentional allocation on jobsites. Therefore, understanding the positive and adverse impacts of AI-driven assistants on workers can offer insights into designing a human-centered informational system to enhance safety.

Methodology

Experimental Design

This study developed a mixed-reality (MR) bricklaying scenario where workers needed to interact with drones during the bricklaying task. Workers must utilize a real-world robotic tool (i.e., MULE) to execute the bricklaying task. MULE can automatically lift heavy concrete blocks, while workers had to manually apply mortar and move MULE to correct positions. Three types of drones were included in the developed environment, representing three interaction levels: coexistence (i.e., sharing workspace), cooperation (i.e., sharing workspace and goal), and collaboration (i.e., sharing workspace, goal, and object). Specifically, the inspection drone aims to examine workers' progress and behaviors by hovering overhead. The coexistence nature of this interaction was explained by the fact that workers only shared a

workplace with the inspection drone without any shared goal or object. The surveillance drone was designed to convey the message of design change for workers to accurately complete the bricklaying. Since the workers shared a workplace and a goal with the surveillance drone without sharing an object, this interaction referred to a cooperative interaction. The delivery drone collaborated with workers by delivering a new mortar bucket (i.e., a shared object), allowing them to continue bricklaying. Additionally, an AI assistant was developed to inform workers about drone types and their incoming direction during approaching, aiming to reduce workload on jobsites. The information was presented through both auditory and visual modes using an augmented interface. This AI assistant can refer to AI-powered wearable sensors like smart watches and AR glasses in real-world situations. Figure 1 presents a graphical overview of the developed environment.

Data Collection

This study recruited 105 current students with construction backgrounds, representing the next generation of workforce, to attend the experiment. They were asked to complete two 7-min bricklaying tasks with and without the AI assistant, while the rest of the environment was identical. The order of these two conditions was counterbalanced to minimize the impact of order bias. In both experimental conditions, participants needed to interact with each of the three types of drones once. Participants' eye-tracking data and bricklaying productivity were collected during the experiment, and their subjective perception (i.e., usefulness and distraction) of the AI assistant was recorded through an interview after completing both conditions. This study considered the following metrics to comprehensively examine the effectiveness of the AI assistant: (i) time to first fixation on drones (*how many seconds participants took to start noticing drones during approaching*), (ii) productivity rate (*number of bricks completed per minute*) and (iii) the perceived usefulness (*to what extent participants think AI assistant was helpful to make them more prepared for drones*) and visual distraction (*how*

often participants checked the AI assistant when it is not providing drone information) of the AI assistant on a five-point Likert scale.

Findings

Results

This study conducted within-subject analyses using t-tests on various performance metrics. The time to first fixation on drones was shorter when information was provided by the AI assistant (Mean \pm STD = 7.340 \pm 6.093), compared to when no information was given (Mean \pm STD = 13.317 \pm 7.666). The statistical result supported the effectiveness of the AI assistant to enable workers' earlier awareness of drones' approaching ($t=5.660$, $p=.000 < .05$). Moreover, participants demonstrated higher bricklaying productivity without the AI assistant (Mean \pm STD = 22.219 \pm 5.740) than with it (Mean \pm STD = 16.086 \pm 4.598). The significant effect of the AI assistant on productivity was verified by the t-test ($t=8.504$, $p=.000 < .05$). Apart from objective metrics, participants reported a high score of usefulness (Mean \pm STD = 4.372 \pm 0.648) and a low score of visual distraction (Mean \pm STD = 1.849 \pm 0.497). Overall, the results indicated that the AI assistant effectively help workers maintain SA of approaching drones but may compromise their productivity on the primary task.

Discussions

This study presented the following findings based on participants' subjective and objective performance. First, a trade-off between worker SA of drone and productivity was identified. Although the AI assistant provided workers with a warning regarding drone's approach, it conversely encouraged them to allocate more attentional resources to drones, indirectly impacting productivity. This finding contradicted the literature that mentioned the positive impacts of SA on productivity (Jiang et al., 2024). A plausible explanation is the fact that drones must be viewed as another source of distraction (Chang et al., 2025). While participants reported minimal visual distraction from the AI assistant, they could still be distracted by drones after noticing their approach. Second, some participants decided not to allocate attention to drones after the AI assistant provided the information. This observation occurred more frequently in the interaction with the inspection drone (*coexistence*). This interesting finding revealed that the effectiveness of the AI assistant might be reshaped by the interaction levels of the drones. In other words, workers might ignore the information and focus on their tasks if they do not anticipate direct communication with the drones. These findings further emphasize the need to consider AI assistants and drones together to optimize the design of information delivery.

Conclusion

It is expected that future construction will become more dynamic and safety-critical due to the introduction of mobile robots to jobsites, highlighting an importance to ensure worker safety. AI-driven assistants that can provide workers with hazard-related information exhibit the potential to facilitate their rapid understanding of surrounding environment, while it may pose distraction concerns on workers. To address this issue, this study developed a MR future construction scenario to collect participants' subjective and objective performance during interaction with the AI assistant and drones. The results illustrated that the AI assistant can effectively expedite workers' SA of drones but simultaneously stimulate their distraction by the drone, compromising productivity. This study contributed to examining the effectiveness of AI-driven assistants in enhancing safety in future construction while also considering their potential negative impacts on workers. On the other hand, there remain some limitations and future directions to address. First, this study recruited current students who represent the next generation of the workforce in the experiment; however, more experienced workers can also be recruited to replicate this study. Second, future studies are suggested investigating how to design AI assistants to balance the trade-off between workers' safety performance and productivity.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: This study was supported by the FW-HTF award from the National Science Foundation (2310210 and 2128970). Any findings and recommendations in this material are those of the authors and do not necessarily reflect the views of NSF.

References

- Buchner, J., Buntins, K., & Kerres, M. (2022). The impact of augmented reality on cognitive load and performance: A systematic review. *Journal of Computer Assisted Learning*, 38(1), 285–303. <https://doi.org/10.1111/jcal.12617>
- Chang, W.-C., Borowiak, A., & Hasanzadeh, S. (2023). The importance of situational awareness in future construction work: Toward the effects of faulty robot, trust, and time pressure. In *Proceedings of the 2023 ASCE international conference on computing in civil engineering* (pp. 821–828). American Society of Civil Engineers (ASCE). <https://doi.org/10.1061/9780784484852.103>
- Chang, W.-C., Esmaceli, B., & Hasanzadeh, S. (2024). The impacts of physical and informational failures on worker-autonomy trust in future construction. *Journal of Construction Engineering Management*, 15102(4), 04025011. <https://doi.org/10.1061/JCEMD4.COENG-15241>

- Chang, W.-C., Yu, L.-F., & Hasanzadeh, S. (2025). Exploring worker-drone interaction in mixed reality: Balancing distraction and situational awareness. In *Proceedings of the 2025 IEEE Conference Virtual Reality and 3D User Interfaces (VR)*. IEEE Transactions on Visualization and Computer Graphics. <https://doi.org/10.1109/TVCG>
- Hatoum, M. B., & Nasserredine, H. (2022, July 15). The use of drones in the construction industry: Applications and implementation. In *Proceedings of the 39th international symposium on automation and robotics in construction (ISARC 2022)*. International Association for Automation and Robotics in Construction (IAARC) <https://doi.org/10.22260/ISARC2022/0077>
- Jiang, L., Shen, H., & Zhang, J. (2024). Study on labor productivity improvement based on situational awareness and improved value stream mapping. *Buildings*, *14*(5), 1253. <https://doi.org/10.3390/buildings14051253>
- Kim, H., & Gabbard, J. L. (2022). Assessing distraction potential of augmented reality head-up displays for vehicle drivers. *Human Factors: The Journal of the Human Factors and Ergonomics Society*, *64*(5), 852–865. <https://doi.org/10.1177/0018720819844845>
- Luo, Y., Yang, Q., Seo, J., & Ahn, S. (2024). Theoretical framework for utilizing eye-tracking data to understand the cognitive mechanism of situational awareness in construction hazard recognition. *Journal of Management in Engineering*, *40*(4), 04024027. <https://doi.org/10.1061/JMENEA.MEENG-5905>
- Ramos-Hurtado, J., Muñoz-La Rivera, F., Mora-Serrano, J., Deraemacker, A., & Valero, I. (2022). Proposal for the deployment of an augmented reality tool for construction safety inspection. *Buildings*, *12*(4), 500. <https://doi.org/10.3390/buildings12040500>
- Wu, S., Hou, L., Zhang, G. (Kevin), & Chen, H. (2022). Real-time mixed reality-based visual warning for construction workforce safety. *Automation in Construction*, *139*, 104252. <https://doi.org/10.1016/j.autcon.2022.104252>