# DESIGNING SUCCESSFUL HUMAN COLLABORATION WITH CYBER-PHYSICAL SYSTEMS

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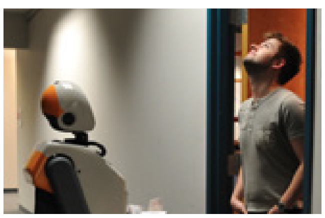
Mobile telepresence systems enabled remote workers to live and work with local coworkers almost as if they were physically there. Workers' mental models of the systems influenced emerging norms of use and workplace adoption.



This robot increased rapport, engagement and cooperation by personalizing its service over time.

People handed over objects to the above robot more efficiently when it utilized human physical collabora-tion cues.

**Background/Motivation.** People are increasingly expected to work through or with cyber-physical systems, such as mobile telepresence robots that let physicians meet patients remotely, autonomous cars, or assistive robots for older adults. Making these cyber-physical systems successful poses theoretical and practical challenges. We lack a theoretical understanding of the causes of and people's responses to the successful adoption of these cyber-physical systems. We need empirically validated design principles that shed light on the impact of design features in individual, social, and organizational contexts.

My two research threads aim to build a coherent body of knowledge and design principles for cyber-physical systems, so that technology may be used to **support people without overpowering human autonomy and control**. In my first research thread, I seek to illuminate organizational and social-psychological factors that lead to successful adoption of novel cyber-physical systems in the workplace. Receiving Best Student Research in the Vanderbilt agency conference, my long-term field studies with a robotic receptionist [1], a mobile telepresence system for distributed teams [2], and a workplace delivery robot [3] revealed that people hold different mental models about these robotic systems which influence the formation of workplace usage norms. In my second research thread, I design complex cyber-physical systems to be able to successfully collaborate with people, improving people's rapport, cooperation, and physical collaboration with the systems. I evaluate the new designs with users through controlled laboratory and field experiments. As the leader of an interdisciplinary team, I used human-centered and service design approaches to design and implement a social robot and its service [4], and evaluated it through two-month long field experiment [5]. When modeled after the handover processes of 27 pairs of people, the robot that utilized human physical collaboration cues worked with people more efficiently [6]. Service robots that made mistakes were most tolerated and accepted when they used human-politeness and social strategy [7].

**Proposed Research**. Moving foward, I propose three interconnected research areas to tackle the following critical challenges in making human cyber-physical systems collaboration successful. Across these research threads, my goal is to go beyond the HRI field's current focus on user perceptions of intelligent systems to link these perceptions with meaningful work outcomes and task performance.

**What are the impacts of cyber-physical systems on user decision making?** Increasingly, people work with and make decisions on other people through cyber-physical systems. Physicians diagnose patients through telemedicine systems; soldiers use drones to rescue victims; managers oversee remote workplaces using mobile telepresence systems; surgeons use robotic surgical tools to operate on remote patients. In these novel settings, decision makers need to make decisions on remote people, who used to be collocated before the development of the technologies. I propose to investigate how the psychological distance created by these robotic telepresence systems. A series of laboratory experiments will investigate the impact of these new technologies on diverse decision making outcomes – risky taking, dehumanization, care, impression formation, and omission bias – in medical and everyday advice giving scenarios. Physiological and brain activity sensors will be used to understand the underlying mechanism. We will then use this understanding to design interaction features to mitigate or influence the decisions.

**How much control should be shared between users and cyber-physical systems?** I'd also like to investigate the role of human control and autonomy in cyber-physical systems that learn about users and autonomously execute tasks. Literature on automation has focused on industrial, expert tasks such as flying an airplane. My previous research on smart home [8] suggests that the dynamics between human and system autonomy will be influenced not only by cognitive factors but also by social psychological factors. I plan to advance this field by exploring the social and cognitive impacts of varying levels of automation in cyber-physical systems such as, assistive robots or autonomous cars.

**How can we establish the right level of trust on and reduce biases with cyber-physical systems?** My previous work suggests that individuals form either social or utilitarian mental models of the systems, when systems are autonomous, as part of their sensemaking efforts. Previous psychology research suggests that these mental models can influence people's trust and expectation on cyber-physical systems. I propose to use different design features that promote either individuals' social or utilitarian mental models in order to reduce complacency biases in automation, cognitive load, and establish the right level of trust, using the task of driving an autonomous car.

**Potential Impact in Cyber-Physical Systems.** The proposed research will generate theoretical undersgandings on human responses to and decision-making with cyber-physical systems, in particular, in the domains of autonomous cars and assistive robots, and mobile telepresence robots. It will also generate a systematic set of design principles that lead to successful human and cyber-physical system collaboration.

## REFERENCES


[1] **Lee, M.K.**, Kiesler, S., & Forlizzi, J. (2010). Receptionist or information kiosk? How do people talk with a robot? In *Proc. of the ACM Conference on Computer Supported Cooperative Work*, 31-40.

[2] **Lee, M.K.** & Takayama, L. (2011). "Now, I have a body": Uses and social norms for mobile remote presence in the workplace. In *Proc. of the ACM/SIGCHI Conference on Human Factors in Computing Systems*, 33-42. **Best Paper Honorable Mention**

[3] **Lee, M. K.**, Kiesler, S., Forlizzi, J., & Rybski, P. (2012). Ripple effects of embedded social agents: Field study of a social robot in the workplace. In *Proc. of the ACM/SIGCHI Conference on Human Factors in Computing Systems*, 695-704.

[4] **Lee, M.K.**, Forlizzi, J., Rybski, P.E., Crabbe, F., Chung, W., Finkle, J., Glaser, E., & Kiesler, S. (2009). The Snackbot: Documenting the design of a robot for long-term human-robot interaction. In *Proc. of the ACM/IEEE International Conference on Human Robot Interaction*, 7-14.

[5] **Lee, M. K.**, Forlizzi, J., Kiesler, S., Rybski, P., Antanitis, J., & Savetsila, S. (2012). Personalization in HRI: A longitudinal field experiment. In *Proc. of the ACM/IEEE International Conference on Human Robot Interaction*, 319-326.

[6] Strabala, K. W., **Lee, M. K.**, Dragan, A. D., Forlizzi, J. L., Srinivasa, S., Cakmak, M., & Micelli, V. (2013). Towards seamless human-robot handovers. *Journal of Human-Robot Interaction, 2*(1), 112-132.

[7] **Lee, M.K.**, Kiesler, S., Forlizzi, J., Srinivasa, S., & Rybski, P. (2010). Gracefully mitigating breakdowns in robotic services. In *Proc. of the ACM/IEEE International Conference on Human Robot Interaction,* 203-210. **Best Paper Award**

[8] **Lee, M.K.**, Davidoff, S., Zimmerman, J., & Dey, A.K. (2006). Smart homes, families and control. In *Proc. of the International Conference on Design & Emotion*. **Best Paper Award**