1. The Warfighter Effectiveness Research Center (WERC) at the US Air Force Academy

The WERC is a research laboratory at the United States Air Force Academy conducting basic and applied research to enhance warfighter effectiveness. The WERC conducts a wide range of research and design projects for operational customers. This research is based in the behavioral sciences and connected to a wide range of disciplines and collaborators across government labs, academia, industry, and military operators to generate the most innovative and effective solutions.

1.1 Facilities

The USAFA Research Center maintains seven dedicated research laboratory spaces (see **Figure 2**). Each laboratory is equipped with Ethernet, campus wireless internet, and commercial internet. Additionally, the laboratories are connected via local area network to select offices within the Research Center's footprint. This allows for any computer or robot connected to the local area network to be controlled remotely at several locations during Wizard-of-Oz Paradigms. The Research Center provides a shared office for Postdoctoral Researchers, Developers and Research Assistants located adjacent to the offices of the Principal Investigators.

1.2. Major Equipment

Across the three laboratories in the Research Center, each experimental station contains a desktop computer running experimental software, two computer monitors, and peripherals (keyboard, mouse, head-phones, etc.). The Research Center contains a battery of robots that can be programmed for experiments: Furhat Robot, Ghost v60 Robotic Dog, Pepper Humanoid Robot (Softbank Robotics; one (1) in Laboratory 2), Nao Humanoid Robot (Softbank Robotics; one (1) in Laboratory 3), Baxter Collaborative Robot (Rethink Robotics; 1 in Laboratory 1), Create 2 Programmable Robot (iRobot; four (4) in Laboratory 2), Cue Robot (Wonder Workshop; six (6) in Laboratory 1), and Cozmo Robot (Anki; six (6) in Laboratory 1).

Figure 1. Air Force Tesla Model X exterior (left) and interior (right) during earlier conducted parking studies (Tenhundfeld et al., 2019; 2020).

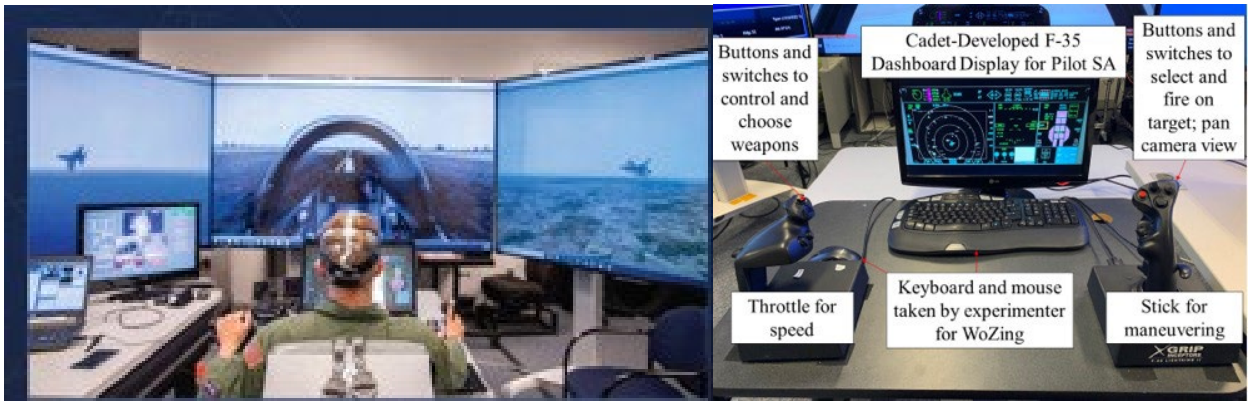
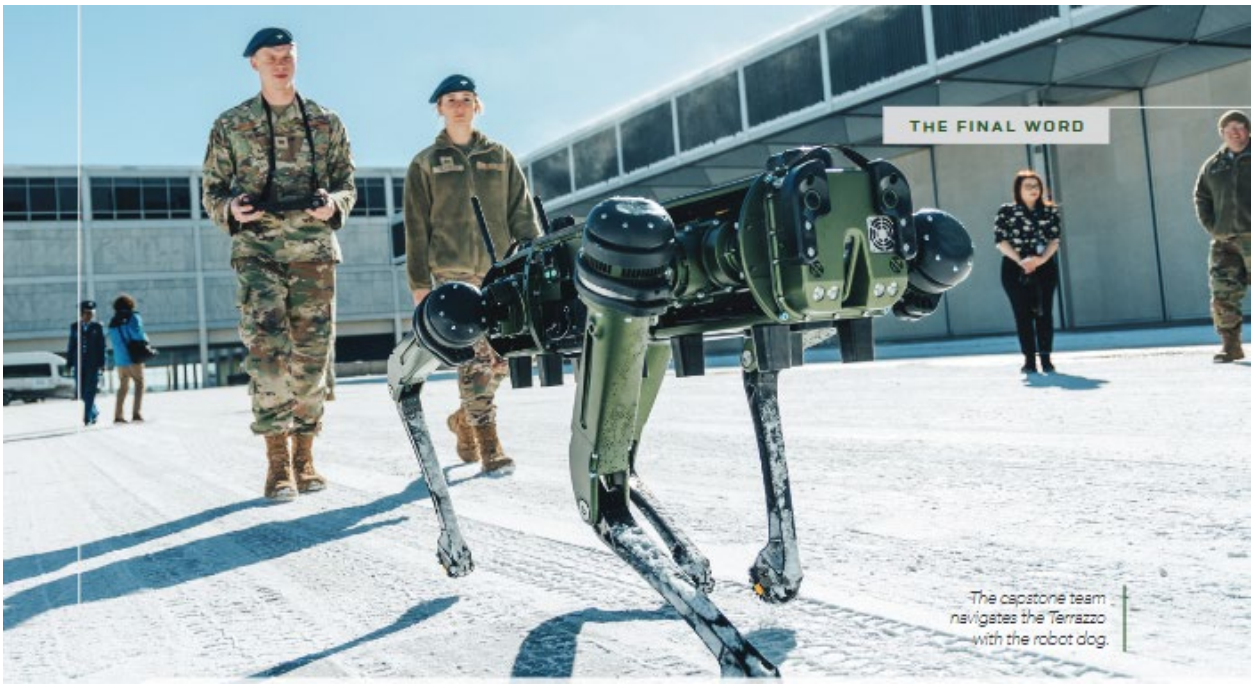


Figure 2a-b. (a) The Autonomous Flight Testbed with cadet participant and (b) F-35 pilot's dashboard display.

The WERC has also established a mobile research laboratory known as HART (Human-Automation Research in a Tesla) mobile lab (see **Figure 1**). This mobile lab environment is set up in a 2017 Tesla Model X car, equipped with various automated features which include lane-following, adaptive cruise control (ACC), and automated parking. The car has been instrumented with several biometric collection devices.

One of our newest technologies, the Ghost Robotics Vision60, is making an impact at USAFA and a central feature of capstones in Model-Based Systems Engineering and human-machine teaming:



1.3. Other Resources

The United States Air Force Academy Research Office provides budget assistance and administration. The Academy also subscribes to Sona Systems, an online university research service that enables universities to recruit and manage research participants. Each year, USAFA cadets enrolled in Behavioral Sciences 110 and 310 have the option to participate in research studies through Sona in exchange for extra credit. Researchers at USAFA have access to a participant pool of two-thousand (2000) students per academic year.

2. Relevant Grants

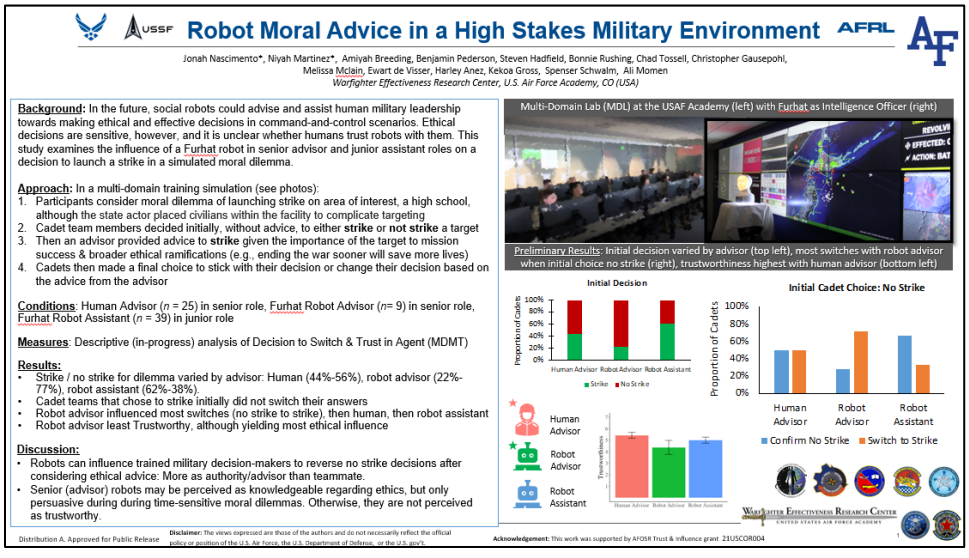
2.1. AFOSR Grant Research Overview and Approach

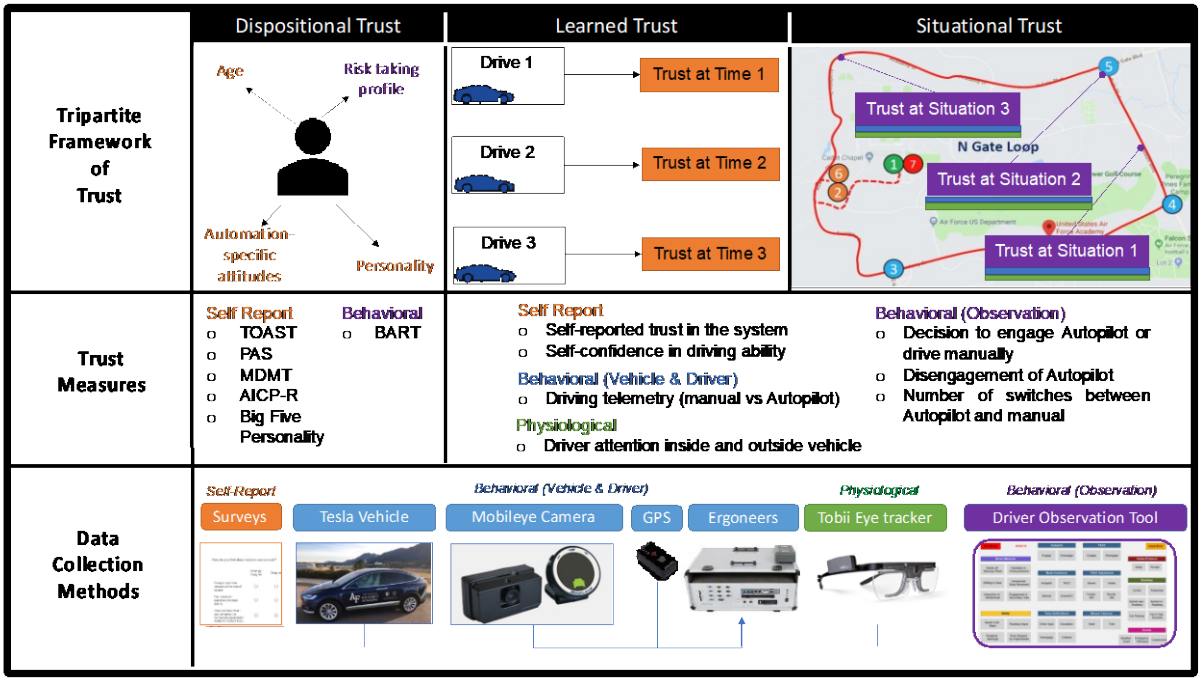
The issue of trust in autonomy and AI will be at the forefront of successful technology integration into future military operations. It is unclear if more advanced technologies will exacerbate trust, attentional, and resource allocation challenges or help improve these systems. Furthermore, the high-stakes environment in which AI and autonomy will be deployed in the military, such as remotely-piloted aircraft and the F-35, increase the potential for costs (or vulnerability) to the human-AI system. Therefore, foundational studies are needed to understand the influence of these technologies on decision making, ethics, and overall performance outside of lab environments. We proposed a series of studies along two research aims to examine human-intelligent agent trust

development, maintenance, and repair in real-world environments. The first research aim, Adaptive Calibrated and Effective human-autonomy and algorithmic Systems (ACES), is a three-year set of capstones for cadets, faculty, and collaborators to understand the symbiotic relationship between humans and intelligent technologies. This aim focuses on issues of explainable AI, transparency and how these designs affect trust calibration and repair, especially in situations of high uncertainty and in cases where the algorithm outperforms humans. The research is executed in our customized research testbeds including the F35 simulation as well as the Tesla Model X research vehicle (see **Figure 1**). The second research aim is to investigate the influence of a socially intelligent and ethical mission assistant (SIEMA), which is envisioned to either be virtual or a robotic agent, on human-autonomy team performance. Given the proliferation of many types of intelligent machine agents, including physical robotic systems and virtual agents, and the commitment of the DoD to develop and deploy them widely, there is a need for these agents to exhibit a degree of *ethical competence*. We are investigating SIEMA's ability to provide ethical advice and 2) its ability to effectively communicate ethical decisions and information in a human AI-teaming context. The research is executed in testbeds that have been adapted for ethical scenarios and critically examine the relationship between ethical and effective human-AI team performance. Outcomes of both projects are extending theories of trust and human-machine teaming by identifying relevant contextual and design factors, uncovering the social influence of intelligent technologies on humans, and defining team ethical performance metrics applied to ecologically-valid tasks and environments.

2.2. Human-Machine Teaming Research Emphasis

To date, our grant has been extremely productive in terms of both the high-quality scholarly output as well as the productive collaborations we have established. Since the start of the WERC, we have published 15 manuscripts including 12 journal papers and 3 conference proceedings in high quality outlets with an additional three journal publications currently in revision (see **Appendix**). To highlight some successes, we published one paper (Tossell et al., 2022) in the Proceedings of the National Academies of Sciences (PNAS, impact factor 12.78). This work that was also covered by





the Economist and Time Magazine. Additionally, we received a best-paper award for our work on creating and evaluating the trustworthiness of a GPT-enabled moral robot advisor at the HICSS conference (Momen et al., 2023). The study of ethics in human-machine contexts is a new emphasis (see above poster). We have also pioneered an entirely new autonomous driving methodology to assess trust in automated driving that has resulted in several publications (Madison et al., 2021; Hsieh et al., 2022; Momen et al., in revision). Through this grant, we have established numerous productive collaborations leveraging the unique status of the USAFA-WERC as a hub including with Beth Phillips at George Mason University, Jonathan Gratch at the Institute of Creative Technologies, Nathan McNeese at Clemson University, Tom Williams at the Colorado School of Mines, Leanne Hirschfield at the University of Boulder, Marlena Fraune at New Mexico State University, Tony Hsieh at Texas A&M University, Stephen Fiore at the University of Central Florida, Gregory Funke at AFRL Dayton Ohio, Anthony Ries at ARL, Adolfo Escobedo at Arizona State University, Nancy Cooke at Arizona State University, and Nathan Tenhundfeld at the University of Alabama Huntsville.

Example WERC Publications 2021-2023

1. [Conference Track Best Paper Award] [C] Momen, A., de Visser, E., Cooley, K., Walliser, J. & Tossell, C. (**2023**). Trusting a Robot With Moral Questions: Perceptions of Moral Competence and Humanlikeness in a GPT-3 Enabled Moral AI. *Hawaii International 56th Conference on Systems Sciences.*
2. [J] Lucas, G., Mell, J., Boberg, J., Zenone, F., de Visser, E. J., Tossell, C. & Seech, T. (**2023**). Virtual Context Does Virtual Context Matter?: The Case of Military versus Civilian Framing of a Virtual Negotiation Skills Trainer. Submitted to *Computers in Human Behavior*.
3. [J] Walliser, J.C., de Visser, E.J. & Shaw, T.H. (**2023**). Exploring System Wide Trust Strategies with Multiple Autonomous Agents. Submitted to *Computers in Human Behavior*.
4. [J] Momen, A., Hugenberg, K., & Wiese, E (**2022**). Robots engage face-processing less strongly than humans. *Frontiers in Neuroergonomics*, 29.
5. [J] Textor, C., Zhang, R., Lopez, J., Schelble, B., McNeese, N., Freeman, G., Pak, R., de Visser, E. J. & Tossell, C. (**2022**). Exploring the Relationship Between Ethics and Trust in Human-AI Teaming: A Mixed Methods Approach. Submitted to the *Journal of Cognitive Engineering and Decision Making*.
6. [J] Hsieh, S. J., Wang, A., Madison, A., Tossell, C. & de Visser, E. J. (**2022**). Adaptive Driving Assistant Model (ADAM) Framework for Adaptive Autonomous Driving Assistance. *Transactions on Interactive Intelligent Systems,* 12(3): 1-28.
7. [J] Kim, B., de Visser, E., & Phillips, E. (**2022**). Two uncanny valleys: Re-evaluating the uncanny valley across the full spectrum of real-world human-like robots. *Computers in Human Behavior*, 107340.
8. [J] Tenhundfeld, N., Demir, M., & de Visser, E. J. (**2022**). An Argument for Trust Assessment in Human-Machine Interaction: Overview and Call for Integration. Submitted to Journal of Cognitive Engineering and Decision Making.
9. [C] Momen, A., & Wiese, E. (**2022**). The Inversion Effect as a Measure of Social Acceptance of Robots. In *Proceedings of the 2022 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 919-921).
10. [J] de Visser, E. J., Topoglu, Y., Joshi, S., Krueger, F., Phillips, E., Gratch, J., Tossell, C. & Ayaz, H. (**2022**). Designing Man's New Best Friend: Enhancing Human-Robot Dog Interaction through Dog-Like Framing and Appearance. *Sensors*, *22*(3), 1287.
11. [J] Tossell, C., Gomez, A., de Visser, E.J., Donadio, B., Metcalfe, A., Rogan, C., Davis, R. & Atran, S. (**2022**). Spiritual over Physical Formidability Determines Willingness to Fight and Sacrifice through Loyalty in Cross-Cultural Populations. Submitted to *Proceedings of the National Academies of Sciences*.
12. [J] Fraune MR, Leite I, Karatas N, Amirova A, Legeleux A, Sandygulova A, Neerincx A, Dilip Tikas G, Gunes H, Mohan M, Abbasi NI, Shenoy S, Scassellati B, de Visser E and Komatsu T (**2022**). Lessons Learned About Designing and Conducting Studies From HRI Experts. Submitted to *Frontiers in Robotics and AI.*

13. [C] Madison, A., Arestides, A., Harold, S., Gurchiek, T., Chang, K., Ries, A., Tenhundfeld, N., Phillips, E., de Visser, E.J. & Tossell, C. (**2021**). The Design and Integration of a Comprehensive Measurement System to Assess Trust in Automated Driving. In *2021 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE.
14. [J] Haring, K. S., Satterfield, K. M., Tossell, C. C., de Visser, E. J., Lyons, J. R., Mancuso, V. F., Finomore, V.S. & Funke, G. J. (**2021**). Robot Authority in Human-Robot Teaming: Effects of Human-Likeness and Physical Embodiment on Compliance. *Frontiers in Psychology*, *12.*
15. [J] Kohn, S. C., De Visser, E. J., Wiese, E., Lee, Y. C., & Shaw, T. H. (**2021**). Measurement of Trust in Automation: A Narrative Review and Reference Guide. *Frontiers in psychology*, *12:* 604977.

Some WERC Publications 2017-2020

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2. [Department Best Paper Award] [C] Schellin, H., Oberley, T., Patterson, K., Kim, B., Haring, K. S., Tossell, C. C., ... & de Visser, E. J. (2020, April). Man's New Best Friend? Strengthening Human-Robot Dog Bonding by Enhancing the Doglikeness of Sony's Aibo. In *2020 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE
3. [C] Kim, B., Bruce, M., Brown, L., de Visser, E., & Phillips, E. (2020, April). A Comprehensive Approach to Validating the Uncanny Valley using the Anthropomorphic RoBOT (ABOT) Database. In *2020 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE
4. [C] Bellas, A., Perrin, S., Malone, B., Rogers, K., Lucas, G., Phillips, E., ... & de Visser, E. (2020, April). Rapport Building with Social Robots as a Method for Improving Mission Debriefing in Human-Robot Teams. In *2020 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 160-163). IEEE
5. [C] Donadio, B. T., Gómez, Á., Atran, S., Novak, J., Wheeler, M., Marquez, C., ... & Tossell, C. C. (2020, April). Simulating Combat to Explore Motivations Behind Why Military Members Make Costly Sacrifices. In *2020 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE
6. [C] Hetrick, R., Amerson, N., Kim, B., Rosen, E., de Visser, E. J., & Phillips, E. (2020, April). Comparing Virtual Reality Interfaces for the Teleoperation of Robots. In *2020 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-7). IEEE
7. [C] Kim, B., Haring, K. S., Schellin, H. J., Oberley, T. N., Patterson, K. M., Phillips, E., ... & Tossell, C. C. (2020, March). How Early Task Success Affects Attitudes Toward

Social Robots. In *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 287-289)

8. [C] Williams, T., Zhu, Q., Wen, R., & de Visser, E. J. (2020, March). The Confucian Matador: Three Defenses Against the Mechanical Bull. In *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 25-33).
9. [C] Joshi, S., de Visser, E. J., Abramoff, B., & Ayaz, H. (2020, March). Medical Interviewing with a Robot Instead of a Doctor: Who do We Trust More with Sensitive Information?. In *Companion of the 2020 ACM/IEEE International Conference on Human-Robot Interaction* (pp. 570-572).
10. [J] de Visser, E. J., Peeters, M. M., Jung, M. F., Kohn, S., Shaw, T. H., Pak, R., & Neerincx, M. A. (2020). Towards a theory of longitudinal trust calibration in human–robot teams. *International journal of social robotics*, *12*(2), 459-478.
11. [J] Pak, R., Crumley-Branyon, J. J., de Visser, E. J., & Rovira, E. (2020). Factors that affect younger and older adults' causal attributions of robot behaviour. *Ergonomics*, *63*(4), 421-439.
12. [J] Tenhundfeld, N. L., de Visser, E. J., Ries, A. J., Finomore, V. S., & Tossell, C. C. (2019). Trust and distrust of automated parking in a Tesla Model X. *Human factors*, 001872081986541.
13. [J] Tenhundfeld, N. L., de Visser, E. J., Haring, K. S., Ries, A. J., Finomore, V. S., & Tossell, C. C. (2019). Calibrating Trust in Automation Through Familiarity With the Autoparking Feature of a Tesla Model X. *Journal of Cognitive Engineering and Decision Making*, 1555343419869083.
14. [J] Hertz, N., Shaw, T., de Visser, E. J., & Wiese, E. (2019). Mixing It Up: How Mixed Groups of Humans and Machines Modulate Conformity. *Journal of Cognitive Engineering and Decision Making*, 1555343419869465.
15. [J] Walliser, J. C., de Visser, E. J., Wiese, E., & Shaw, T. H. (2019). Team Structure and Team Building Improve Human–Machine Teaming With Autonomous Agents. *Journal of Cognitive Engineering and Decision Making*, 1555343419867563.
16. [J] de Visser, E.J., Beatty, P., Estepp, J.R., Kohn, S., Abubshait, A., Fedota, J.R. & McDonald, C.G. (2018). Learning from the slips of others: Neural correlates of trust in automated agents. *Frontiers in Neuroscience,* 12, 309.
17. [J] de Visser, E.J., Pak. R. & Shaw, T.H. (2018). From 'automation' to 'autonomy': the importance of trust repair in human-machine interaction. *Ergonomics*, 1-19.
    a. *2019 Liberty Mutual Award for Best Paper in the Ergonomics Journal.*
18. [J] Baker, A. L., Phillips, E. K., Ullman, D., & Keebler, J. R. (2018). Toward an Understanding of Trust Repair in Human-Robot Interaction: Current Research and Future Directions. ACM Transactions on Interactive Intelligent Systems (TiiS), 8(4), 30
19. [J] Rosen, E., Whitney, D., Phillips, E., Chien, G., Tompkin, J., Konidaris, G., & Tellex, S. (2019). Communicating and controlling robot arm motion intent through mixed-reality

head-mounted displays. The International Journal of Robotics Research, 0278364919842925

20. [J] Bradford, J. C., Lukos, J. R., Passaro, A., Ries, A., & Ferris, D. P. (2019). Effect of locomotor demands on cognitive processing. *Scientific reports*, *9*(1), 9234
21. [J] Solon, A. J., Lawhern, V. J., Touryan, J., McDaniel, J. R., Ries, A. J., & Gordon, S. M. (2019). Decoding P300 Variability using Convolutional Neural Networks. *BioRxiv*, 569616
22. [J] Ries, A. J., Slayback, D., & Touryan, J. (2018). The fixation-related lambda response: Effects of saccade magnitude, spatial frequency, and ocular artifact removal. *International Journal of Psychophysiology*, *134*, 1-8.
23. [J] Haring, K. S., Watanabe, K., Velonaki, M., Tossell, C. C., & Finomore, V. (2018). FFAB—The Form Function Attribution Bias in Human–Robot Interaction. *IEEE Transactions on Cognitive and Developmental Systems*, *10*(4), 843-851
24. [C] Haring, K. S., Nye, k., Darby, R., Phillips, E., de Visser, E.J., & Tossell, C. C. (in press). I'm not playing anymore! A study comparing perceptions of robot and human cheating behavior. In proceedings of *the International Conference on Social Robotics*. Madrid, Spain.
25. [C] Haring, K. S., Mosley, A., Pruznick, S., Fleming, J., Satterfield, K., de Visser, E. J., ... & Funke, G. (2019, July). Robot Authority in Human-Machine Teams: Effects of Human-Like Appearance on Compliance. In *International Conference on Human-Computer Interaction* (pp. 63-78). Springer, Cham
26. [C] Alexander, S. A., Rozo, J. S., Donadio, B. T., Tenhundfeld, N. L., de Visser, E. J., & Tossell, C. C. (2019, April). Transforming the Air Force Mission Planning Process with Virtual and Augmented Reality. In *2019 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-4). IEEE
27. [C] Lorenz, G. T., Ehrenstrom, J. S., Ullmann, T. B., Palmer, R. C., Tenhundfeld, N. L., de Visser, E. J., ... & Tossell, C. C. (2019, April). Assessing Control Devices for the Supervisory Control of Autonomous Wingmen. In *2019 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE
28. [C] Tomzcak, K., Pelter, A., Gutierrez, C., Stretch, T., Hilf, D., Donadio, B., de Visser, E. J. & Tossell, C. C. (2019, April). Let Tesla Park Your Tesla: Driver Trust in a Semi-Automated Car. In *2019 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE
29. [C] Pennington, E., Hafer, R., Nistler, E., Seech, T., & Tossell, C. (2019, April). Integration of Advanced Technology in Initial Flight Training. In *2019 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-5). IEEE.
30. [C] Culver, D. J., Colon, A. B., Washington, D. R., Appleton, M. G., Strang, A., Alizadeh, A., ... & Tossell, C. C. (2019, April). Field Test of Wearable Sensors for Hydration Monitoring. In *2019 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-4). IEEE

31. [C] Peterson, J., Cohen, C., Harrison, P., Novak, J., Tossell, C., & Phillips, E. (2019, April). Ideal Warrior and Robot Relations: Stress and Empathy's Role in Human-Robot Teaming. In *2019 Systems and Information Engineering Design Symposium (SIEDS)* (pp. 1-6). IEEE
32. [C] Yitzhak, S., Rosen, E., Chien, G., Phillips, E., Tellex, S., & Konidaris, G. (2019) End-user programming using mixed reality. *International Conference on Robotics and Automation (ICRA)*, Montreal, Canada.
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35. [C] Zhao, X., Phillips E., & Malle B.F. (*2019).* Rethinking anthropomorphism: The antecedents, unexpected consequences, and potential remedy for perceiving machines as human-like. Submitted to *Proceedings of the American Psychological Association's Technology, Mind, and Society Conference (TMS APA),* Washington, DC.
36. [C] Zhao, X., Phillips E., & Malle B.F. (*2019*). Rethinking anthropomorphism: The antecedents, unexpected consequences, and potential remedy for perceiving machines as human-like. Symposium submitted to *Proceedings of the Association for Consumer Research.*
37. [C] Haring, K.., Phillips E., Lazzara, E., Keebler, J., & Ullman, D. (*under review*). Swift trust in humans vs. robots: Drawing parallels and understanding divergence. In J. Lyons (Ed). *Trust in Human-Robot Interaction: Research and Applications.* Elsevier.
38. [C] Wen, J., Stewart, A., Billinghurst, M., & Tossell, C. (2018, October). Band of Brothers and Bolts: Caring About Your Robot Teammate. In *2018 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS)* (pp. 1853-1858). IEEE
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43. [C] Chad Tossell, Bianca Donadio, Amanda Stewart, Nathan Tenhundfeld, Elizabeth Phillips, Jade Driggs, Kerstin Haring, Ewart de Visser. Human Factors Capstone Research at the United States Air Force Academy.
44. [C] Malle B.F., Zhao, X. & Phillips, E. (*2019*). Inferring robot mind from robot appearance. *Annual Meeting for the Society for Experimental Social Psychology.* Toronto, Canada.
45. [C] Malle, B.F., Zhao, X., & Phillips, E., (*2019*). Systematic and multidimensional perception of robot minds. In *Proceedings of the American Psychological Association's Technology, Mind, and Society Conference (TMS APA),* Washington, DC.
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