was present which may be due to the participant having an indication of task difficulty implicit in the robot's assessment. For reference the figure includes random self-assessment reports, however we did not include it in our analysis for this specific question.

Figure 3: Stacked column plot of task outcome when self-assessments were absent, random, or informed showing a significant decrease in task failure between the informed and absent condition.

*RQ3: Does trust increase when the team is assigned a robot of **high performance**?* Fig. 4 shows a bar plot of self-reported MDMT Reliability and Capability trust ratings for high and random robot performance while in Automatic Control mode. We conducted a one-tailed independent t-test to test whether the agent performance level affected participants self-reported MDMT capability and reliability trust scores and found that participants had significantly higher reliability trust when working with a high performing agent, $t(1149.7) = 17.5$, $p < .0001$, with a large effect size according to Cohen's d (d=1.0). We also found significantly higher capability trust when working with a high performing agent, $t(1093.34) = 19.73$, $p < .0001$, with a large effect size according to Cohen's d (d=1.13). This indicates that the presence of a higher performing robot could lead to substantial increases in trust.

*RQ4: Does trust increase when the robot presents an **informed report**?* Fig. 5 shows a bar plot of self-reported MDMT Reliability and Capability trust ratings for absent, random, and informed self-assessments reported to the participant. We conducted a one-tailed independent t-test to test whether the informed reporting affected participants self-reported MDMT capability and reliability trust scores and found that in both cases trust increased but not significantly for capability, $t(598.98) = 1.55, p = 0.0605$, and reliability, $t(598.98) = 0.66$, $p = .2539$. For reference the figure includes random self-assessment reports, however we did not include it in our analysis for this specific question.

We believe that the small differences in trust were partly due to the trust scale used. The MDMT Performance dimension, which is composed of Reliability and Capability scales, measures trust related specifically to robot performance. We made the assumption that the participants would

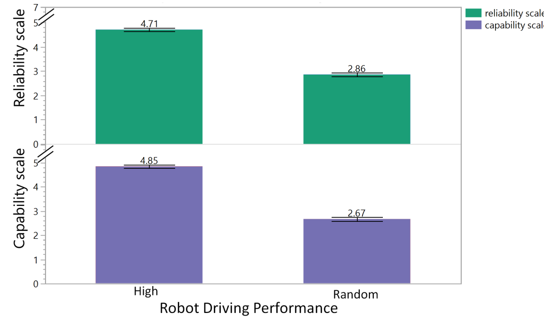

Figure 4: Bar plot of self-reported MDMT Reliability and Capability trust ratings for high and random robot performance showing a statistically significant increase in participant trust when the participant was paired with a high performing robot.

consider performance to include both the robots physical performance (navigating the grid world) and the robots reasoning performance (self-assessment reporting). This however may not be the case, and a future research direction for us is to investigate trust metrics and scales aimed specifically at an agents cognitive reasoning ability.

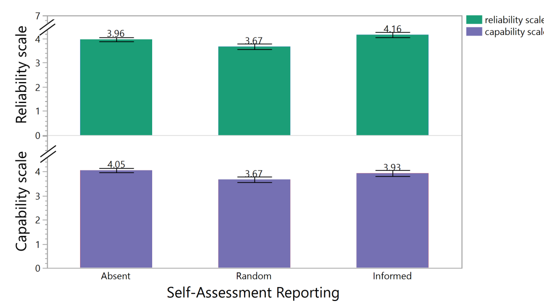

Figure 5: Bar plot of self-reported MDMT Reliability and Capability trust ratings for absent, random, and informed self-assessment reports showing a small improvement in reliability and capability trust between the informed and absent condition.

RQ5: Does the presence of robot self-assessment reports cue the participant to change autonomy to the appropriate level? We broke this question into two parts:

All self-assessment reports: We conducted a one-way analysis of variance (ANOVA) to test whether the presence of a robot self-assessment report affected the control proportion and found significant effect of report presence on control proportion, $F(4, 52.57)$, $p < .0001$. Post-hoc comparisons using Tukeys HSD test revealed difference of control proportion between tasks reported as very bad and [fair, good, very good] $(p < .0001)$ and tasks reported as bad and [fair, good, very good] $(p < .0001)$. This indicated that the team was more likely to change to a level of autonomy appropriate for the displayed robot self-assessment report. However here we also saw a tendency for the participant to follow the report regardless of its accuracy, which under-

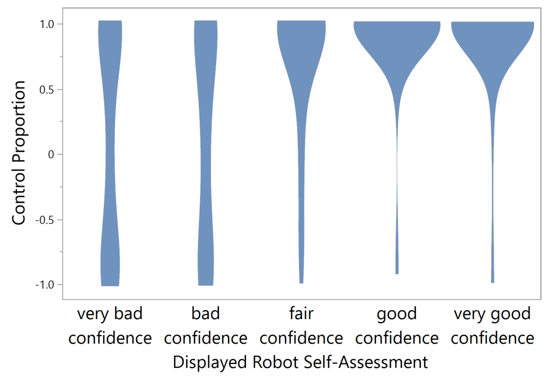

Figure 6: Box plot of control proportion for all robot self-assessment reports showing alignment between robot reports and control proportion. Positive control proportion indicated more robot control while negative control proportion indicated more participant control.

scores the importance of a robot being able to accurately self-assess. This data is shown in Fig. 6.

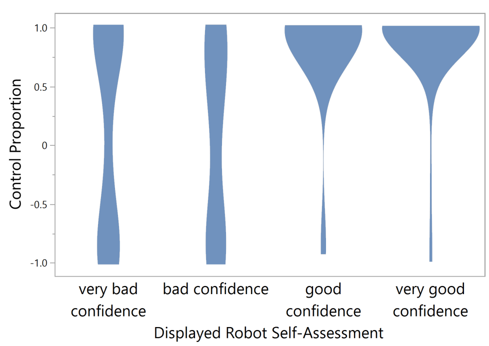

Figure 7: Box plot of control proportion for all informed robot self-assessment reports showing alignment between the robots reported confidence and control proportion. Positive control proportion indicated more robot control while negative control proportion indicated more participant control.

Informed self-assessment reports: We conducted a one-way analysis of variance (ANOVA) to test whether the presence of informed robot self-assessment reports affected the control proportion and found significant effect of informed reports on control proportion, $F(3, 29.04)$, $p < .0001$. Post-hoc comparisons using Tukeys HSD test revealed difference of control proportion between tasks reported as very bad and [good, very good] ($p < .0001$) and tasks reported as bad and [good, very good] ($p < .0001$). This data is shown in Fig. 7. Similar to the previous case, this indicated that participant were more likely to change to a level of autonomy appropriate for the displayed robot self-assessment report. However control proportion also shows us that Automatic Control mode was still used (though much less frequently) for tasks with poor self-assessments (very bad, bad). Further exploration should investigate possible biases towards using the automation in the presence of robot self-assessments.

FUTURE WORK

We have shown the value of robot proficiency self-assessments to human-robot teams given simple short duration tasks. However, during more complex tasks or longer interactions an *a priori* self-assessment can quickly become stale, leading to the human inadvertently push a system beyond its competency bounds. Additionally, control proportion as described here assumed a fixed proficiency, and as such may be inappropriate for interactions in which the robots proficiency changes over time. In order capture the dynamic nature of realistic team interactions, our future work will focus on methods for real-time robot self-assessments and the development of performance metrics suited for online and longer term interactions.

CONCLUSIONS

Reporting of a robot's *a priori* proficiency self-assessment can provide valuable information to improve a human teammate's decision making process. In this study we found that the reporting of robot self-assessment, in the form of rewards based FaMSeC Outcome Assessment, resulted in a decrease in task failures and small improvements to the participants self-reported trust. An *a priori* robot self-assessment essentially aligns the participants task expectations with the robots belief in its abilities. Our objective trust metric, control proportion, gave us insight into the participants choice of autonomy allocation: tasks in which the robot reports lower self-confidence in meeting user expectations showed an increase in participant control, while tasks in which the robot reported higher self-confidence in meeting user expectations showed an increase in autonomous control. This work is an incremental step in improving trust and performance within a human-robot team.

Acknowledgments

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