Analyzing Human-Robot Trust in Police Work Using a Teleoperated Communicative Robot

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***Abstract*— Recent advances in robotics have accelerated their widespread use in nontraditional domains such as law enforcement. The inclusion of robotics allows for the introduction of time and space in dangerous situations, and protects law enforcement officers (LEOs) from the many potentially dangerous situations they encounter. In this paper, a teleoperated robot prototype was designed and tested to allow LEOs to remotely and transparently communicate and interact with others. The robot featured near face-to-face interactivity and accuracy across multiple verbal and non-verbal modes using screens, microphones, and speakers. In cooperation with multiple law enforcement agencies, results are presented on this dynamic and integrative teleoperated communicative robot platform in terms of attitudes towards robots, trust in robot operation, and trust in human-robot-human interaction and communication.**

I. INTRODUCTION

Robots are used in vastly different fields including healthcare, manufacturing, education, and law enforcement. In the case of law enforcement, robots are specifically utilized during emergency and disaster responses that may pose lethal dangers to suspects, bystanders, and law enforcement officers (LEOs). In high-risk situations, robots can provide safer alternatives to direct human activities and interactions (e.g., explosive ordinance disposal and surveillance) by distancing LEOs from potential dangers and threats [1], [2]. However, robots focused on facilitating communication between officers during emergencies, or between officers and civilians, have yet to be utilized widely [3].

To protect LEOs, robots have been gaining increased traction as a tool to augment and replace required functions by officers [2], [4]. Recent advances in technology have increased the accessibility to the hardware and software needed to build and program robots, and resulted in increased incorporation of robotics into law enforcement [5]. However, due to the complexity, cost, burden of use, and other limiting factors, many LEOs remain hesitant to adopt robotics into their day-to-day operations. Additionally, LEOs may avoid robots due to the risk of introducing an unknown agent or variable to the scene [6], [7]. Although robots can be extremely beneficial to law enforcement and provide safer alternatives to direct invention, some have argued that there is a lack of transparency and accountability in robotics [2], [8].

To best utilize robots in law enforcement, it is necessary to overcome the pitfalls of adopting robots in police work. One of the barriers of LEOs, particularly police officers, using robots is the lack of trust in their interaction with the robot itself [9]. Though robots in police work can be used as a tactical tool or a communication medium, in both cases, building a trustworthy relationship between the robot and LEO is vitally important. Primarily, factors which influence human-robot trust fall into three categories: human-related, robot-related, and environmental-related factors [10].

The human-related factors include those associated to human abilities (e.g., attention capacity, expertise, previous experience) and characteristics (e.g., attitudes toward robots, personality features). The robot-related factors include features such as physical appearance because it can affect how people perceive robots [2], [11], [12]. In fact, it has been reported that people inherently have preferences about the appearance of communicative robots [11], [13]. Another influential robot-related factor in building trust is the robot's level of automation and control (e.g., autonomous, completely teleoperated, semi-teleoperated) [10], [14]. In terms of robots, there are multiple studies devising various methods to control them on a low level [15]–[17] and high level [18] to grant autonomy to the robot. While some robots are entirely autonomous, others are controlled using an interface, including virtual and augmented reality [19], [20].

Furthermore, the environment in which the robot is placed plays an essential role in building trust. Environmental factors such as team collaboration (e.g., in-group membership, culture, communication, shared mental modes) and tasking (e.g., task type, task complexity, multi-tasking requirement, and physical environment) affect the quality of trust in human-robot interaction (HRI) [10], [21]. Among these factors, the communication method between human and robot is believed to be one of the most important factors in building trust [22]. Therefore, it is necessary to create or choose an effective communication channel in order to establish an appropriate and safe collaboration between humans and

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robots [23]. Many studies have investigated the role of using different communication methods and parameters in building trust in HRI. These different methods include one-way, two-way, audio-visual, synchronous and asynchronous, and verbal and non-verbal communication [23]–[25]. Recently, there has been a vast array of research endeavours to create social robots equipped with various communicative features to engage with people interactively [11], [26] and physically [27]. However, many of these robots are challenged by unexpected problems, have high degrees of uncertainty, or are simply too complicated to be operated or trusted by a human agent [28]. Despite these challenges, social/interactive robots have been relatively successful in making a positive impression on humans through their physical appearance, level of autonomy, and the natural communication modalities that allow humans to interact with robots without receiving training [26].

In the present study, we strive to address these problems, particularly those related to law enforcement. We do this by using a telerobotic communication platform (robot mediated communication) to establish trust between LEOs and the robot. The teleoperated robot platform was mounted on a mobile base and equipped with a two-way audio/video communication channels. To investigate trust in the interaction between LEOs and the robot, a set of pretest surveys were administered to LEOs, designed to capture preconceptions and gauge previous experience with robots. Subsequently, the participants attended a series of training sessions in communication and robotics. In the communication sessions, participants were trained on topics including non-verbal, intercultural, and mediated communication by a team of communication researchers and scholars. In the robotics sessions, LEOs were trained in the use of the robot platform and then tasked with piloting the prototype robot while utilizing the audio-video communication capabilities. After both training sessions, LEOs completed a set of post-test surveys designed to capture their feedback and perspectives regarding communication and robotic sessions. The pre/post-test results were then analyzed to investigate the quality and trustworthiness of the interaction between the LEOS and the robot.

The study's research questions are presented in Section II; the study's methodology is described in Section III; and the results and conclusion are presented in Sections IV and V, respectively.

II. Research Questions

The overarching aim of this study is to investigate the use of high fidelity communication using robots in law enforcement. Accordingly, it is important to examine the LEO's trust in the utility of these robots. The willingness of LEOs to adopt robots in their work will increase when they are able to build a trustworthy relationship with them. To address this aim, we pose the following questions:

1) Do LEOs perceive a teleoperated communicative robot as a trustworthy medium of communication?

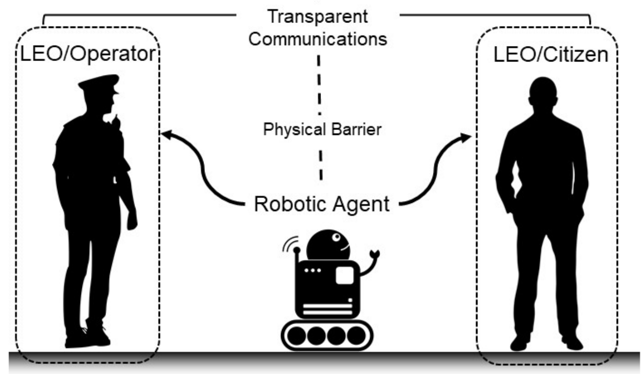

Fig. 1: Transparent Human-Robot-Human (HRH) Communication Proposition.

2) How does the communication and robotic training affect LEOs' attitudes towards robots?
3) What robot design factors (e.g., physical appearance, level of autonomy, interactive capabilities) should the communicative robot possess to establish trustworthy and transparent human-robot-human (HRH) communication?

To answer the study questions, we developed a novel teleoperated communicative robot platform and received feedback from LEOs regarding their level of trust in its functionality as a communication medium. Figure 1 shows the HRH communication paradigm using the proposed teleoperated communicative robotic platform.

III. Methodology

In this study, a teleoperated communicative robotic platform was used to examine HRH communication and trust. Results are quantified using a pre/post-test experimental design. As part of the study design, LEOs were trained in the topics of robotics and communication between pre- and post-test surveys. The training sessions included multiple audible and visual modes using non-verbal communication strategies. All study procedures were approved by the IRB at The University of Alabama (Protocol ID: 20-07-3711). The participants' consent was obtained prior to the pretest surveys.

A. Study Design, Procedure, and Activities

1) General Procedure: After obtaining consent, participants were asked to complete a series of online pretest surveys via the Qualtrics platform. These surveys were designed to capture participants' perceptions and feedback regarding utility and trust in communication with robots in police work. After finishing the survey, participants went through a communication training session. In this session, researchers presented LEOs with a curriculum related to the topics of nonverbal, inter-cultural, and mediated communication. After the communication training session, subjects participated in a robotic training session and interactive demonstration. This training session and demonstration included a description of all features of the robot, its different functions, how to pilot it, and finally how to communicate through the robot with another individual. After completing the communication and robotics training sessions, LEOs were asked to complete post-test surveys in order to obtain their feedback regarding robotic teleoperation and communication. Additionally, the post-test surveys measured any changes in the level of participant's trust in interacting and communicating with robots.

2) Robot Design: The robot used in this study was developed by modifying a Turtlebot2i platform (Trossen Robotics). By default, the platform included a 3D Camera (Intel RealSense SR305), a stereo camera (Orbbec Astra), a mobile base (Kobuki by Yujin Robot), and a five degree of freedom robot manipulator (Pincher MK3 by Trossen Robotics), along with several other components. Modifications included the addition of an external microphone and speaker, a touchscreen mounted to the top of the robot (Sun Head Raspberry Pi Capacitive Touchscreen), an additional camera mounted to the top of the robot (Logitech C270), and a pan/tilt servo mechanism (PhantomX by Trossen Robotics) to mount the camera. The robot was controlled using an Intel Nuc (OS: Ubuntu 16.04) and wirelessly communicated (802.11AC WiFi) with a Dell workstation desktop (OS: Ubuntu 16.04) using a secured local area network hosted on a router (ASUS AC2900). The workstation was also equipped with a camera (Logitech C270), microphone, speakers, and headset. Both the Turtlebot and the workstation utilized Robot Operating System (ROS Kinetic) for communication and control. To run commands on the Turtlebot, the workstation would SSH into the Turtlebot. The primary ROS packages used to control the robot included usb_ cam, image_view, turtlebot_teleop, audio_capture, and audio_play. To avoid conflicting topics (e.g., audio and video streams), custom launch files were created.

From the workstation, an LEO is able to operate the robot manipulator to retrieve objects, use the pan-tilt camera mechanism to look around, toggle two-way audio/video streams for communication, and drive and steer the robot base. To drive the robot, LEOs were provided an Xbox controller. Cumulatively, the multitude of cameras, microphones, and speakers allowed LEOs to remotely communicate and interact with others with near face-to-face communication. The robot is shown in Figure 2.

B. Study Participants

A total number of 54 sworn LEOs with various years of experience participated in communication workshops and training with the robot prototype. After the data cleaning process, 37 officers' data was usable for the purpose of data analysis[1]. LEOs of various ranks were recruited from four law enforcement agencies in the State of Alabama. All subjects were 19 years of age or older at the time of study.

[1]Some participants failed to provide the identifying number assigned to them in order to link their pretest and post-test data.

C. Study Measures

It is likely that the introduction of a new technology in police work will require the assessment of various elements to ensure safety, efficacy, and success. Therefore, it is crucial to develop or use instruments to assess multimodal communication strategies and trust-relations in remote communication and HRI. To this end, a thorough review of literature in the above-mentioned areas was conducted and the following three measures were selected for the purpose of this study: Negative Attitudes Towards Robots Scale (NARS) [29], Affective Learning Scale (ALS) [30], and Human-Robot Interaction Trust Scale (HRITS) [31].

1) Negative Attitude Towards Robots Scale: NARS was used for the purpose of both pretest and post-test assessment. It was used to evaluate LEOs' attitudes, opinions, and experiences communicating and interacting with the robot prototype. This scale consists of three subscales of S1: Negative Attitudes towards Simulations and Interactions with Robots, S2: Negative Attitudes towards Social Influence of Robots, S3: Negative Attitudes towards Emotions in Interaction with Robots. NARS is a 7-point Likert scale that ranges from 1= strongly disagree, to 7= strongly agree.

2) Affective Learning Scale: ALS was only administered in the post-test assessment. ALS measures cognitive and affective learning of LEOs in robotics and communication training. It comprised of three subscales of affect towards content, course behaviors, and instructor behaviors. The affect toward content subscale was utilized in this study to measure LEOs' affective feelings towards training content and interactions with the robot. Affect toward content is a 7-point Likert scale ranging from 1= strongly disagree, to 7= strongly agree.

3) Human-Robot Interaction Trust Scale: The HRITS scale was used in the post-robotics training assessment to capture the officers' overall level of trust in the robot prototype, as well as trust in human-robot team configurations. It accounts for individual differences for varying trust levels and allows for a comprehensive measure of trust. Participants used this 7-point Likert scale and selected their level of agreement, with each statement ranging from 1= strongly disagree to 7= strongly agree. The calculated score of this scale allows for the analysis of overall human trust in robots and human-robot team configuration.

Sample questions for the measures are displayed in Table I.

IV. Study Results

A. Survey results regarding LEOs' attitudes and emotions towards robots

LEOs' pre/post-test responses on the NARS scale were analyzed in Statistical Package for the Social Sciences (SPSS) software to measure LEOs' attitudes, opinions, and emotions towards the influence of robots in police work. The result of the paired t-test analysis revealed that LEOs' negative attitudes towards social influence of the robots (S2 sub-scale) were reduced almost significantly after the

TABLE I: Sample questions for NARS, ALS, and HRITS measures

Measure	Question
NARS	I would feel comfortable talking/interacting with robots (S3). I would feel uneasy if I was given a job where I had to use robots (S1). I would hate the idea that robots or artificial intelligences were making judgements about things (S1). I feel that if I depend on robots too much, something bad might happen (S2).
ALS	I believe that the Robotics and Communication Training (RCT) is useful. I always participate in continuing education trainings or workshops. I value the content of the RCT. I always pay attention during continuing education trainings or workshops.
HRITS	The robot (teleoperated communicative robotic platform) was dependable. The user interface for operating the robot was reliable. The robot remote communication and interactive capabilities were dependable. The robot's navigation and piloting capabilities were consistent.

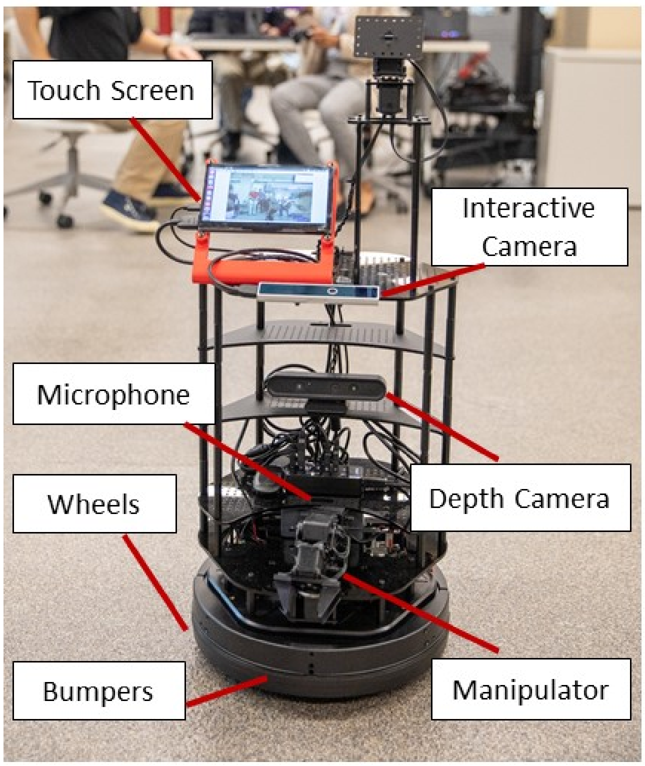

Fig. 2: Teleoperated Communicative Robot.

robotic and communication training sessions. The post-test mean was lower than the pretest mean of 4.11, approaching significance level (7-point scale, N=37, M=3.78, p=0.06). This result shows that LEOs had a positive interaction with the proposed communicative robotic platform in terms of attitudes, emotion, and trust.

As noted in Section III, ALS was utilized in this study to measure LEOs' affective feelings towards the robot and the quality of training sessions. The results of the paired samples t-test analysis in SPSS showed that the mean of the *affect towards content* sub-scale was significantly higher than the scale's mid-point of 4.00 (7-point scale, N=37, M=5.8, $p<0.05$). It is worth noting that in the fields of social and psychological sciences, the mid-point of a scale is considered the base neutral point where the line of significant and non-significant is drawn. Therefore, the fact that the calculated mean of the above subscale is significantly higher than the mid-point of the scale indicates the positive impact of the experiment on the sample subjects.

B. Survey results regarding trust in HRI

HRTIS was used in this study to asses LEOs' level of trust in the proposed platform. The results of t-test analysis in SPSS revealed that the mean of the HRITS was significantly higher than the scale's mid-point of 4.00 (7-point scale, N=37, M=5.43, $p<0.05$). This finding indicates that LEOs' had a high level of trust in the teleoperated communicative robot that they engaged with during the training sessions.

Based on the HRITS result, we hypothesize that several factors, including physical appearance and communicative abilities of the robot are contributing to this high level of trust. To test this hypothesis, a pre/post-test survey was conducted, titled "Inquiry into Robot Design" to analyze what design factors and communicative features contribute to establishing this trust. The questions of this survey helped to determine the traits police officers desire in a police robot. These multiple choice questions directly corresponded to traits on the robot designed by the research team. The questions on this survey asks LEOs to evaluate each of the robot's attributes in terms of their importance displayed in Table II among very important (VI), important (I), slightly important (SI), and not important (NI).

The result of this analysis (Table II) shows that almost half of the participants (43%) considered humanoid appearance as an unimportant factor in establishing their trust in the robot. Although in social robotic studies, humanoid appearance has been found to be an effective factor in developing social robots, the current study result implies that this factor is unimportant in the context of police work due to police

TABLE II: Survey results in robot design (physical appearance, camera mechanical, camera viewing, battery)

Category	Attribute	VI (%)	I (%)	SI (%)	NI (%)
Physical Appearance	Humanoid appearance	5	0	24	**43**
	Voice and volume level	27	**38**	5	3
	Size of robot	**24**	19	22	8
	Expression of emotion in robot	16	16	**22**	19
Camera I	A camera which can peer around corners	8	**40**	18	5
	A camera which can be controlled to look around	8	5	19	**40**
	A camera which can be moved up and down	5	16	**30**	21
	A camera with 3rd person viewing	16	16	**22**	19
Camera II	A camera with the ability to zoom in and out	3	24	**38**	11
	A camera which has a 360 view	**32**	16	8	19
	Multiple cameras, multiple views simultaneously	**32**	11	11	22
Battery	Battery life	**67**	11	0	0
	Battery type	0	5	11	**62**
	Removable/ Replaceable battery	3	11	**54**	11
	Rechargeable battery	8	**51**	13	5

* There were missing data in each category due to participants not entering data at the time of taking the survey.

officers' different needs regarding the application of robot. In other words, using a live interactive video feed feature installed in the robotic platform appears to compensate, to some extent, for the same anthropomorphic advantages of humanoid appearance in robot. Additionally, 24% of LEOs selected size of the robot as a very important factor, and 38% of LEOs ranked voice and volume level of the robot as an important feature. Almost 22% of LEOs considered the capability of expressing emotion by the robot as a slightly important feature. Interestingly enough, this result is in line with the low rating of humanoid appearance in the sense that human features such as appearance or emotion expression were not considered to be important by LEOs in their police work. As for the voice and volume levels of the robot, LEOs rated these features as important (38%) most likely due their essential role in facilitating communication and interaction with other individuals. Additionally, our results show that battery life was another important factor for LEOs affecting their perception of trust in robot. Furthermore, 67% of LEOs rated battery life as a very important feature for a robot in order to be considered reliable. While battery type was considered as not important at all, LEOs regarded the feature of rechargeable battery as important (51%). Finally, nearly one-third of LEOs (32%) believed that it is very important for a robot to have multiple cameras with multiple views (e.g., a camera which has a 360 degree view).

V. CONCLUSION

This study developed and tested a new teleoperated communicative robotic platform to explore LEOs' attitudes towards the application of robots in police work. The proposed platform consisted of a mobile robot equipped with two-way audio/video communication channels. It was piloted and used by LEOs as a communication medium to interact with other individuals. Pretest and post-test surveys allowed for examinations of LEO attitudes, emotions, and trust in police robot platforms. Three measures of NARS, ALS, and HRITS were used to investigate these concepts. The results reveal that in general, LEOs had a positive experience operating the robot, interacting with other individuals via the robot, and displayed a high level of trust in the communicative robot platform. This was shown by the reduction of their negative attitude towards the social influence of the robot, positive affect toward the content of training sessions, and a high general level of trust in their interaction with the robot. These findings were also validated and verified by further analysis via the inquiry into robot design scale which tapped into important features and characteristics of the robot from the perspective of LEOs regarding their trust in the proposed communicative platform. It is worth nothing that because the current study did not include a non-LEO control group, the results may not necessarily be generalizable to the public domain. Therefore, as a future direction for current study, the researchers plan to conduct more studies with a non-LEO control group.

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