Impacts of Robot Assistant Performance on Human Trust, Satisfaction, and Frustration

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***Abstract*—People look for ways to develop bonds and create meaningful relationships with others. In these interactions, there are several parameters that play an important role when it comes to interacting with any autonomous or semi-autonomous system like robots or prostheses. In this study, the focus was on studying how the performance of a robotic assistant impacted self-reported human metrics related to trust, frustration, and satisfaction with the robot. All these factors could impact the ability for people to successfully interact with autonomous systems; it is likely that the task performance of the human-robot team would be highly variable according to any significant changes in the human trust, frustration, and satisfaction with the robot. In this study, it was found that the performance of the robot during the collaborative task significantly impacted the persons' trust, satisfaction, and frustration with the robot.**

Keywords-Trust; Satisfaction; Frustration; Human Robot Interaction; Robotic Assistant;

I. INTRODUCTION

Generally speaking, trust is the willingness of a person to become vulnerable to the actions of another person regardless of the ability to control those behaviors [1]. In the technical communities such as computer science, trust is determined as an expectation that an entity may have with respect to the future behavior of another party, i.e., a personal quantity measured to help the players in their future dyadic encounters [2]. The formal definition of trust can be defined as follows [3]:

Definition: Let $T_i^j(t)$ be the trust value assigned by P_i to P_j in period t. Let $T_i(t): N \rightarrow R$, i.e., from natural to real numbers, be the trust function that illustrates how trustworthy P_i is:

$$T_i(t) = \frac{1}{n-1} \sum_{j \neq i} T_i^j(t)$$

where $-1 \leq T_i(t) \leq +1$ and $T_i(0)$ is the initial trust value.

As shown, upper and lower bounds should limit a trust value, and an initial value must be determined. For instance, this definition illustrates if we have a technological system that interacts with a group of people, the perceptions that all these people have regarding the trustworthiness of the system will define how reliable it is, i.e., the average of trust perceptions.

According to recent findings by researchers at Chapman University [4], Americans expressed the second highest level of fear about technology such as artificial intelligence and robots. These fascinating discoveries highlight the necessity of conducting research to better understand the notion of trust from human reasoning perspective [5]. Indeed, the ultimate objective is to design computational models of trust [6] for technological systems that interact with humans. These computational models can be then incorporated into the controllers of such systems for reliable interactions between humans and technologies.

Trust is a parameter which usually takes time to develop and is important during interaction with any autonomous system. In general, there are many factors that might affect trust, for example, previous experiences interacting with autonomous systems. A lack of trust may negatively impact the task performance and impact the productivity of a human-robot team task.

The satisfaction level is one of the main factors when it comes to interaction with robotic systems, prosthetic limbs are prime examples of this, where high user abandonment rates are observed to be correlated with low satisfaction with the artificial limb. It is likely that limb absent people must first be satisfied with their prostheses before they are willing to use it long enough to develop a relationship of trust with the device. There is no doubt a correlation between trust and satisfaction, but that is not well understood in human-robotic systems due to the substantial variations from one person to another, from one robot to another, and the myriad combinations of human-robot interactions that are possible. By adding the satisfaction and frustration measurements in this research, possible connections between the trust and satisfaction were explored to evaluate their effects on each other. End-user satisfaction is a crucial metric when evaluating assistive robotic devices such as prosthetic arms [7,8] and surveys have shown that 30%-50% of upper limb-absent people abandon the use of their prostheses because they are not satisfied with the performance of the artificial limb [9, 10, 11]. For users to trust autonomous systems, many factors might affect that trust as mentioned, and the satisfaction and frustration are among these factors.

As shown in [12], different studies demonstrated the importance of satisfaction for the user when it comes to the usage of prosthetic arms. It has been shown that when users are not satisfied with their prosthetic arms, they cease use of the device due to the frustration and dissatisfaction associated with an imperfect replacement of their limb.

In this abstract, we have also evaluated human satisfaction since we are looking not only to help amputees but also to provide assistance to elderly people who cannot perform certain tasks. Moreover, the levels of frustration are also important when it comes to amputees and elderly people. The fact that they are no longer able to perform certain tasks, already raises the frustration level, this is human nature. Without doubt, satisfaction and frustration go hand in hand since the lack of one will most likely negatively affect the other one, making them connected, in same way, with each other.

Different object delivery modes were tested from a robotic assistant to a human subject during this research [13], such as changing the Baxter arm speed, the object delivery location, and the objects were occasionally dropped as well. Results based on feedback from 10 people when they interacted with the robotic assistant, showed that the trust, frustration and satisfaction levels changed depending on the Baxter robot operation modes. The most significant impact on the human perception of the robot occurred during the failed delivery attempts, but other modes also produced variations in trust, frustration and satisfaction with the robotic assistant.

II. EXPERIMENTAL METHODS

The purpose of this experiment is to accomplish a collaborative task through interactions with a robotic assistant. In this experiment, users conducted sets of interactions with the robotic assistant where each round consisted of three deliveries of water bottles. At the end of each case (three deliveries), the subject answered three questions regarding their levels of trust, satisfaction, frustration on a scale of -2 to +2.

A. Human Subjects

In this experiment, a task for an in-home robotic assistant to provide support to people in a daily task were explored. Specifically, the task of passing a bottle of water was examined. The human was asked to take the bottle out of Baxter's parallel gripper and place it on a shelf. Figure 1 shows the real time human robot interaction cycle used for the experiment. We designed our experiment based on changing the operation modes of Baxter robot (table 1) in delivering the objects, to examine three different factors trust, satisfaction and frustration. 10 participants were recruited, all the participants' ages ranged from 20 to 40 years old. All participants gave informed consent in accordance with the approved IRB protocol.

B. Baxter Robotic Assistant

Baxter Robot (Rethink Robotics, Inc.) was used in this experiment; the robot was pre-programmed to pick up bottles of water and deliver them to the test subject. In our experiment, we used robot operating system (ROS) to establish a communication line to control Baxter and to record all the necessary information that is essential for our experiment. All the recorded data was synchronized with each other and have the same time stamp.

The user was asked to give a feedback rating their feeling of trust, satisfaction and frustration after each case (three deliveries).

In the design of our experiment, five different operation modes for Baxter robot were programmed. The first mode is the success mode, in this mode, Baxter robot successfully delivered the object to a human with medium speed and in a suitable location for a human to take the object easily without much effort. In the second mode, the only factor that was changed was the speed of delivery; Baxter delivered objects with a very slow speed to the same position as in mode 1. Mode 3 was the successful object placement again, except with a high delivery speed. Mode 4 was the most significant mode as the results will show, which is the dropping mode. The operation speed medium and Baxter robot was programmed to 'accidentally' drop the object before delivering it.

The fifth and final mode was the wrong location mode. Here, the speed of robot was medium, but the Baxter robot delivered the objects to the wrong location, far away from the subject, necessitating that the human must stand up from his or her chair and make effort to take the object from the robot.

C. Object Delivery Case Sequence

In this research, the sequence of 12 different delivery cases each with three bottle deliveries per case were followed by each of the 10 test subjects. The 12 cases of delivery modes were presented to the subjects sequentially in the order of modes: 1, 2, 5, 5, 1, 4, 2, 4, 3, 1, 1, 1.

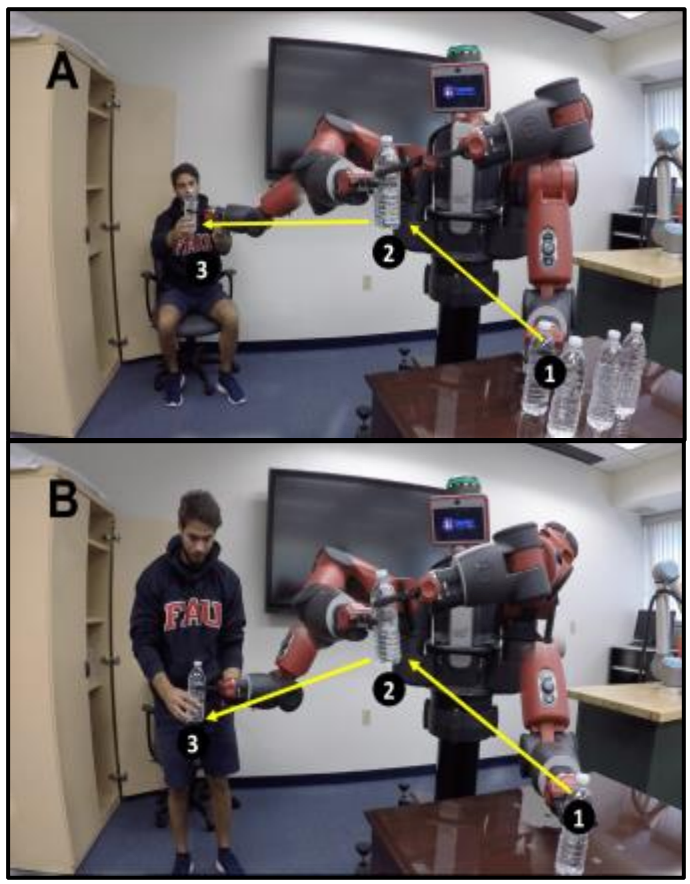

Figure 1: (A). Successful Delivery Case Photo montage sequence, (B). Bottle Delivered to the Wrong Location at a median speed

III. RESULTS AND DISCUSSION

The data was plotted on three bar graphs showing the means and standard deviations to quantify the subjective ratings of trust, satisfaction, and frustration. To assess the statistical differences that occurred between any two cases of robot operation (listed in Table 1), a nonparametric Mann-Whitney U-test was performed on every combination of operational mode.

Table 1. Baxter Robot Operation Modes

Operational Mode	Robot Operation Mode	Robot Arm Speed
1	Successful placement, median speed	0.3 m/s
2	Successful placement, slow speed	0.1 m/s
3	Successful placement, high speed	0.7 m/s
4	Bottle Dropped	0.3 m/s
5	Bottle Delivered to the Wrong Location	0.3 m/s

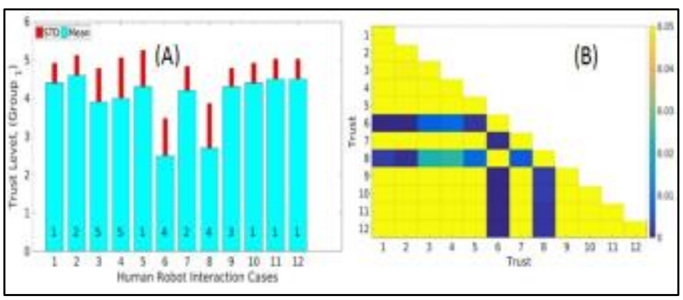

Figure 2. Trust Level, (A). Mean and Standard Deviation, and (B). Mann-Whitney U test

The human trust clearly varied throughout the sequence of the operational modes (Fig. 2.a). Figure (2.b) shows the statistical analysis of the comparison between any two cases of operational modes, which showed several significant findings. The blue blocks indicate which two robot operational mode cases are fundamentally different. The most significant change in trust happened in the dropping mode (mode 4) in cases 6 and 8. The wrong location mode (mode 5) also affected the trust level in comparison to modes 1-3. Also, as shown in Figure 2.b is that Case 7 is significantly different in comparison with case 6 and 8 because the trust level sharply rose from case 6 to case 7 then sharply declined between case 7 and 8 Figure 2.a.

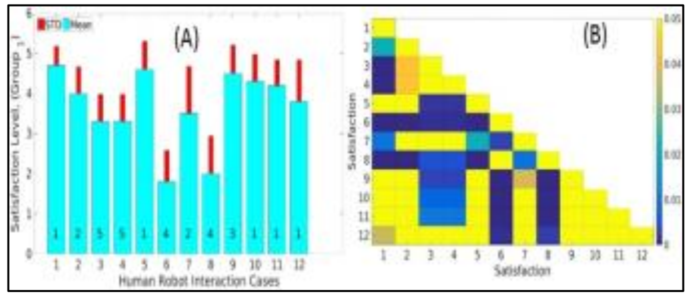

Figure 3. Satisfaction Level, (A). Mean and Standard Deviation, and (B). Mann-Whitney U test

The satisfaction level showed a similar trend as the trust metric because the dropping mode (mode 4) was the lowest across all subjects. The satisfaction levels with the wrong location mode are also low when compared to other robot operation modes, Fig. 3(A). The satisfaction level of cases 3 and 4 are also significantly different than the rest of the cases except for case 7 and 12 (Fig. 3(B)).

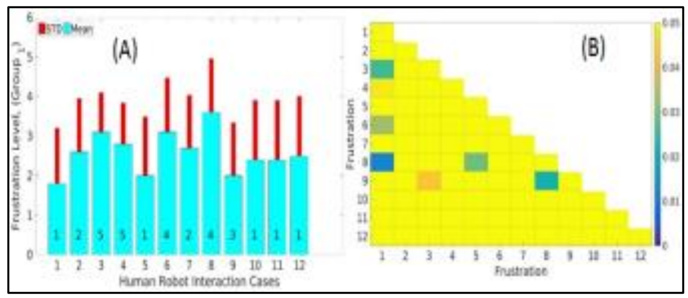

Figure 4. Frustration Level, (A). Mean and Standard Deviation, and (B). Mann-Whitney U test

The self-reported frustration levels also changed with respect to the robot operational mode. The frustration level was high in operation mode 4 (dropping mode), Fig. 4(A). The wrong location modes are also had slightly higher frustration levels. The statistical analysis for frustration level showed a significant difference between cases 1, 3, 6 and 8. is completely different from case 8, 6, 3, and 4. Also, case 8 (the dropping mode) and case 3 (the wrong location mode) are different from case 9 (the fast delivery mode).

IV. CONCLUSION

This work focuses on the interaction with a robot in daily life tasks like passing objects to disabled or elderly persons to help them with the daily routine. Self-reported feedback was collected for trust, satisfaction and frustration levels after interaction with Baxter robot during the collaborative task. It was observed that the human trust, satisfaction and frustration levels changed depending on the interaction mode with Baxter robot. If the robot did the delivery task without any mistake the subjects had higher levels of trust and satisfaction with less frustration.

V. REFERENCES

[1] Roger C Mayer, James H Davis, and F David Schoorman. An Integrative Model of Organizational Trust. Academy of Management Review, 20(3): pp. 709-734, 1995.

[2] Lik Mui, Mojdeh Mohtashemi, and Ari Halberstadt. Notions of Reputation in Multi-Agents Systems: A Review. In 1st ACM International Joint Conference on Autonomous Agents and Multiagent Systems (AAMAS), pp. 280-287, 2002.

[3] Mehrdad Nojoumian and Douglas R. Stinson. Social Secret Sharing in Cloud Computing Using a New Trust Function. In 10th IEEE Annual Conference on Privacy, Security and Trust (PST), pp. 161-167, Paris, France, 2012.

[4] http://www.chapman.edu/wilkinson/research-centers/babbie-center/survey-american-fears.aspx

[5] Mehrdad Nojoumian. Trust, Influence and Reputation Management Based on Human Reasoning. In 4th AAAI Workshop on Incentives and Trust in E-Communities (WIT-EC), pp. 21–24, 2015.

[6] Mehrdad Nojoumian and Timothy C. Lethbridge. A New Approach For the Trust Calculation in Social Networks. In E-business and Telecommunication Networks: 3rd International Conference on E-Business, Best Papers, volume 9 of CCIS, pp. 64–77. Springer, 2008.

[7] J. Belter, J. Segil, A. Dollar, and R. Weir, Mechanical design and performance specifications of anthropomorphic prosthetic hands: a review," Journal of Rehabilitation, Research, and Development, vol. 50, pp. 599-618, 2013

[8] K. Ziegler-Graham, E. MacKenzie, P. Ephraim, T. Travison, and R. Brookmeyer, "Estimating the prevalence of limb loss in the us: 2005-2050," Arch Phys Med Rehabil, vol. 89, pp. 422-429, 2008.

[9] J. Davidson, "A survey of the satisfaction of upper limb amputees with their prostheses, their lifestlyes, and their abilities," Journal of Hand Therapy, vol. 15, pp. 62-70, 2002.

[10] E. Biddiss and T. Chau, "Upper limb prosthesis use and abandonment: a survey of the last 25 years," Prosthetics and Orthotics International, vol. 31, pp. 236-257, 2007.

[11] P. Kyberd, C. Wartenberg, L. Sandsjo, S. Jonsson, D. Gow, J. Frid, et al., "Survey of upper-extremity prosthesis users in sweden and the United Kingdom," Journal of Prosthetics and Orthotics, vol. 19, pp. 55-62, April 2007.

[12] F. Cordella, A. L. Ciancio, R. Sacchetti, A. Davalli, A. G. Cutti, E. Guglielmelli, and L. Zollo, “Literature Review on Needs of Upper Limb Prosthesis Users,” Frontiers in Neuroscience, vol. 10, Dec. 2016.

[13] Moaed M. Abd, Iker Gonzalez, Mehrdad Nojoumian and Erik D. Engeberg. “Trust, Satisfaction and Frustration Measurements for Real-Time Human-Robot Interaction”. 30th Florida Conference on Recent Advances in Robotics (FCRAR), pp. 89-93, Boca Raton, USA, 2017.