Trust, Satisfaction and Frustration Measurements During Human-Robot Interaction

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ABSTRACT

Since the beginning of human race, we have always sought ways to develop bonds and create meaningful relationships with others. In these interactions, there are several parameters that determine how strong the bond is. These parameters include among many others, the trust towards the other person. Humanlike robots have been created with basic human to human interaction rules. Trust is a significant factor for the interaction with the robot, if a human trusts a robot, certainly the outcome from the interaction would be different from the case when a human does not trust a robot. For a human to be able to interact with the robot without any concern, trust must be developed between human and robot. In this paper, we introduce a starting point for quantifying Human-Robot interactions in which we measure the level of trust, satisfaction, and frustration. Due to the different interaction modes during the collaborative task, the human trust towards the robot varied due to interaction and experiences. Results based on feedback from 10 persons, when they interacted with a Baxter robot in a real time collaborative task showed the trust, frustration and satisfaction levels changed depending on the Baxter robot operation modes. The most significant delivery mode is the dropping mode in which the trust, frustration and satisfaction levels are significantly different in comparison with other delivery modes.

The results are based on feedback from 10 persons, when they interact with Baxter robot in a real time.

Keywords

Human-Robot Interaction (HRI), Trust, Satisfaction, Frustration, and Baxter Robot.

1. INTRODUCTION

Trust is an essential aspect of human lives. It defines in some sense who we are and how we interact with each other daily. It can be placed in almost anyone or anything and ranges for the trust in the workspace as well as the trust we put in our friends and family. It is hard to trust something or someone but even harder to regain trust [**1**] [**2**] [**3**]. For instance, when we drive a car, we believe we will reach our destination safely mostly because we trust that our car is not going to break. But what happens when for some reason the car stops working in the middle of the road? The trust we placed on it is suddenly lost. This happens in human-human interaction too, and probably on a larger scale [4] [5] [6].

From a social science perspective, trust is the willingness of a person to become vulnerable to the actions of another person irrespective of the ability to control those actions [7]. However, in the computer science community, trust is defined as a personal expectation that a player has regarding the future behavior of another party, i.e., a personal quantity measured to help the players in their future dyadic encounters [8].

In modern life and future life robot will play an important role, due to many applications of robot ranging from performing simple task like delivering object to disabled people [9], doing complex tasks like doing a surgery [10], doing military task [11] or even doing search and rescue in hazardous locations [12], it is important to study the HRI behavior and make models for different parameters like trust. As the robot developed and become more significant for our lives the demand for such model become essential to make it possible to change the trust mode of a certain human when interacting with robot especially in complex tasks. Many researchers address the trust issue for HRI [13] [14] [15].

According to recent findings by researchers at Chapman University [16], Americans expressed the highest levels of fear about man-made disasters followed by fears about technology such as artificial intelligence and robots. These interesting discoveries highlight the necessity and urgency of conducting research to better understand the notion of trust from human reasoning perspective [17], and consequently, to construct computational models of trust [18] to be incorporated into the controller of the robotic systems that interact with humans.

In this paper, we introduce a starting point for understanding human-robot interaction during a collaborative task in which we measure human trust, satisfaction, and frustration of the robotic assistant. In this study, human trust measurements were periodically measured during a collaborative human-robot object sorting task where a Baxter robot performed different delivery modes and speeds.

Section 2 describes the methodology used to build our experiment. Section 3 is the experimental setup, robotic operation mode and the basic steps. All the results are presented in section 4, also a brief discussion of all the results mentioned in section 4 with conclusions in section 5.

2. METHODOLOGY

In this experiment, a task for robotic home assistance to provide support to people in a daily task were explored. Specifically, the task of passing a bottle of water was examined. We design 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 as explain (table 2). All the participants were of average age ranged from 20 to 40 years old. All participants gave informed consent in accordance with the approved IRB protocol.

In our experiment, we used robot operating system (ROS) to establish a communication, control Baxter robot 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.

3. EXPERIMENT SETUP

The purpose of this experiment is to accomplish some collaborative tasks through interactions with a robotic hand. In this experiment, users will conduct set of rounds of passive interactions with the robotic hand where each round consists of three (3) deliveries of water bottles. At the end of each case (three deliveries), the subject answered a five-choice question with respect to their level of trust/satisfaction/frustration

3.1 Baxter Robot Operation Modes

Baxter Robot (Rethink Robotics, Inc.) [19] was used in this experiment; the robot was pre-programmed to pick objects in our case bottles of water and deliver them to the test subject. The user was asked to give a feedback rating their feeling trust, satisfaction and frustration after each case (three deliveries).

In the design of our experiment, five different operation mode 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 easy without much effort. In the second mode, the only factor was changed is the speed of delivery, Baxter delivered objects with a very slow speed to the same position from mode 1. Mode 3 was the successful object placement, except with a high delivery speed. Mode 4 is kind of 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 is 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 a human, necessitating that the human must stand up from his or her location and make effort to take the object from the robot. Table 1 shows Baxter robot operation modes.

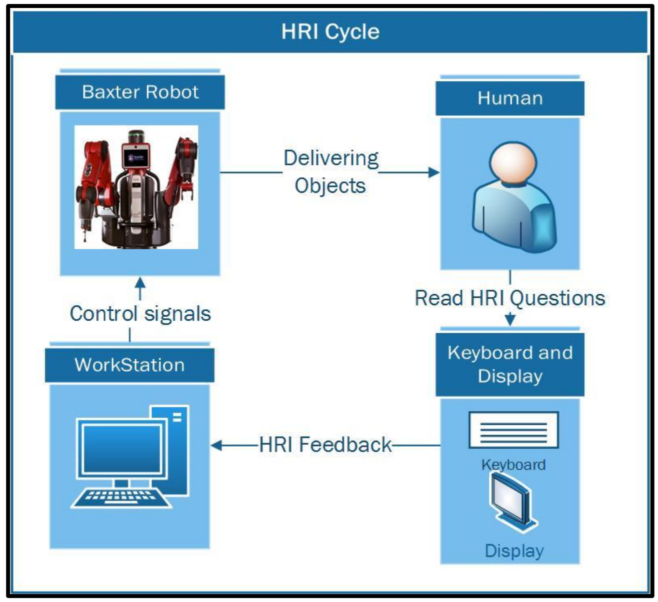

Figure 1. HRI Experiment Setup

Table 1. Baxter Robot Operation Modes

Operational Mode	Robot Operation Mode	Robot Arm Speed
1	Successful placement, medium 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

3.2 Object Delivery Cases

In this research, the sequence of 12 different delivery cases each with three bottle deliveries per case were followed by each of the ten test subjects (Table 2). The cases represent different operation modes (table 1) for delivering object to a human. A human was asked to control Baxter's parallel gripper to take the bottle and place it on a shelf. Photo sequences of HRI is shown in Figure 2, which illustrates the different operation modes and the way the human interacted with Baxter.

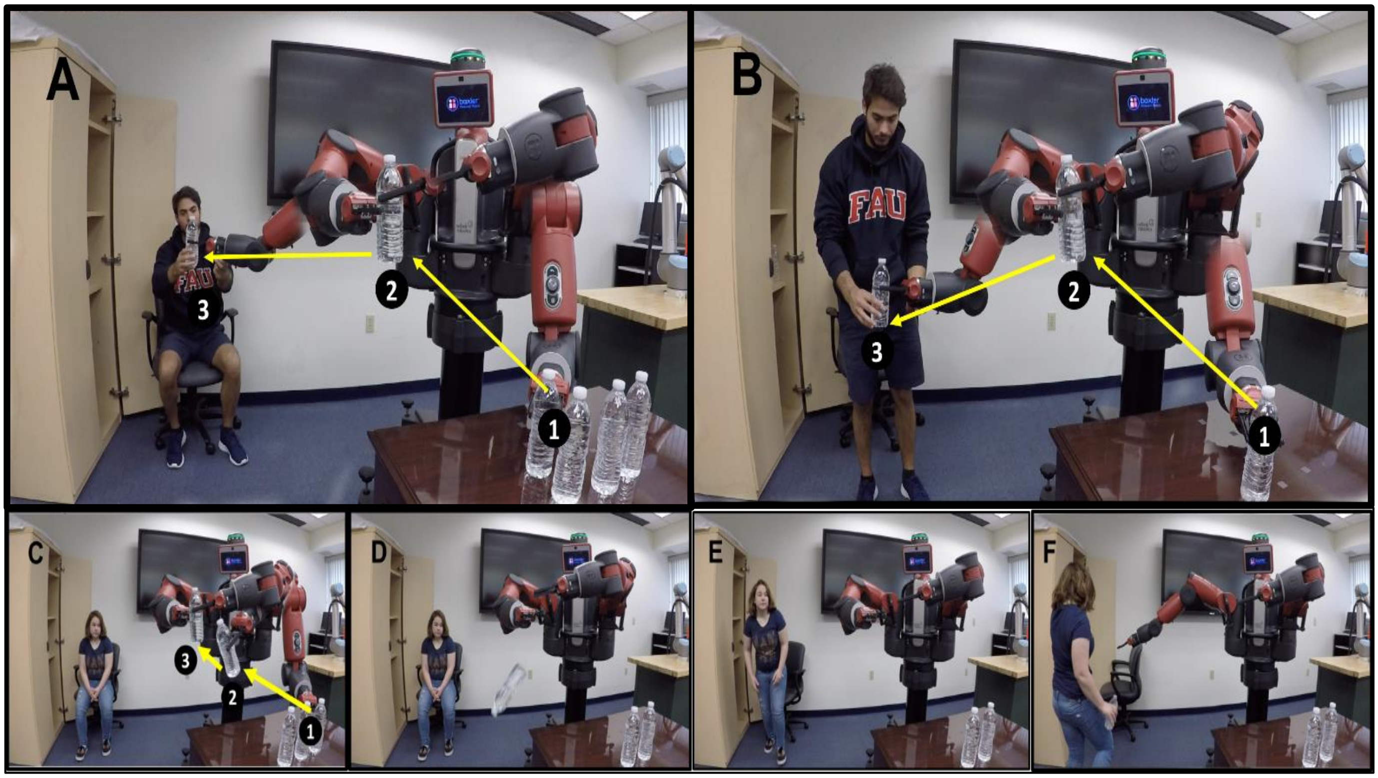

Figure 2. Photo sequence of the Baxter Robot operation modes, (A). Successful placement, (B). Bottle Delivered to Wrong Location, (C, D, E, and F). Bottle Dropped

The nonparametric Mann-Whitney U test (Wilcoxon Rank Sum Test) was used to statistically analyze the data. It is a null hypothesis that data in x-axis and y-axis are samples from a continuous distribution with equal medians, against the alternative that they are not. Both tests are a non-parametric test for equality of population median of two independent samples.

Table 2. Cases Sequences

Interaction Case	Number of deliveries	Baxter Robot Delivery Mode
1	3	1
2	3	2
3	3	5
4	3	5
5	3	1
6	3	4
7	3	2
8	3	4
9	3	3
10	3	1
11	3	1
12	3	1

4. RESULTS AND DISCUSSION

During the experiment, Baxter performed the tasks in all the different modes that were carefully selected to accomplish and receive an honest feedback from the subjects and allow us to analyze the data in an efficient manner. This set of tasks helped measure the levels of trust, satisfaction, and frustration from the subject towards the robot. Once all the data was collected, the data was plotted with a series of bar graphs showing the mean and standard deviation to understand the significance of the values acquired. Also, a set of comparisons were made by statistically testing the frustration, satisfaction, and trust levels to see the relation that these parameters may play in the experiment.

The mean and standard deviation show a clear comparison for Trust from the subjects towards Baxter Figure (3.a). Also, by using The Mann-Whitney U test, Trust-Trust allows us to understand how each case differs from each other. Figure (3.b) shows the statistical analysis of trust data. Depending on the robot operation mode human trust changed. The most significant change in trust level happened in the dropping mode (mode 4). The trust level declined in case 6 and case 8 which are the cases when robot operation mode was mode 4 dropping mode. The wrong location mode (mode 5) also affected the trust level in comparison with mode 1,2 and 3. Also as shown in Figure 3.b 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 3.a.

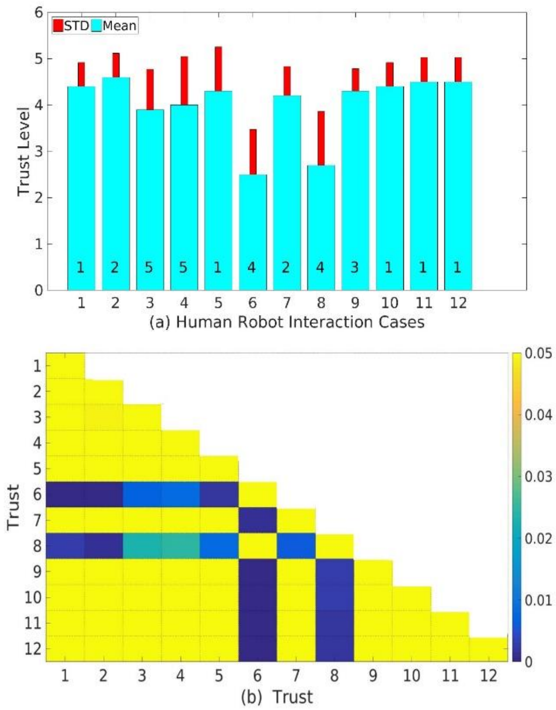

Figure 3. Trust Level, (a). Mean and Standard Deviation, and (b). Mann-Whitney U test

Also, depending on the Baxter robot operation modes, the satisfaction level changed. The speed of the robot affected the satisfaction level as in case 2 (Figure 4.a). The wrong location mode (mode 5) had satisfaction levels lower than in mode 1 the successful mode. Case 6 and 8 which represents the dropping mode have the lowest satisfaction level. The statistical analysis is shown in Figure 4.b demonstrating the statistical differences between any two cases. The blue blocks indicate that the intersection cases are statistically different, such as case 6 or case 8 with the rest of the cases. The satisfaction level of cases 3 and 4 is also significantly different than the rest of the cases except for case 7 and 12.

The mean and standard deviation is shown for frustration as shown in Figure 5.a. The frustration level for all cases is close to each other but still is the highest for case 6 and 8 which represent the dropping mode. The statistical analysis for frustration level is shown in Figure 5.b, which shows that the frustration level for case 1 is completely different from case 8, 6, 3, and 4.

Also, case 8 (dropping) and case 3 (the wrong location) modes are different from case 9, the fast delivery mode.

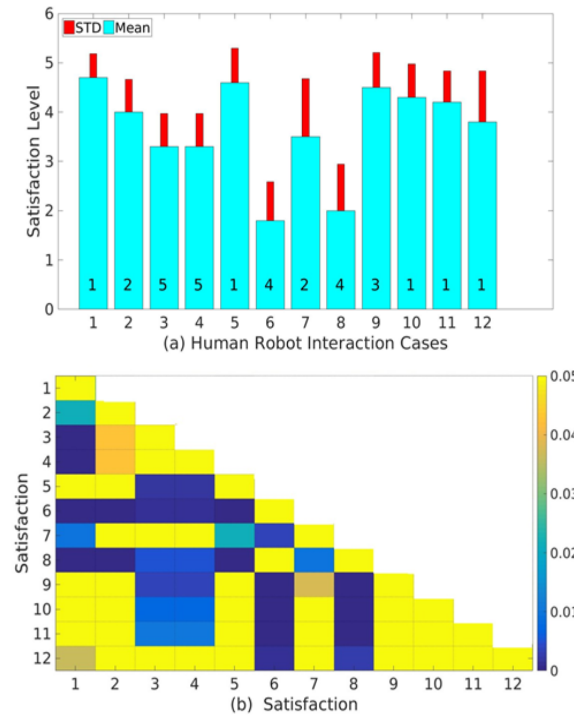

Figure 4. Satisfaction Level, (a). Mean and Standard Deviation, and (b). Mann-Whitney U test

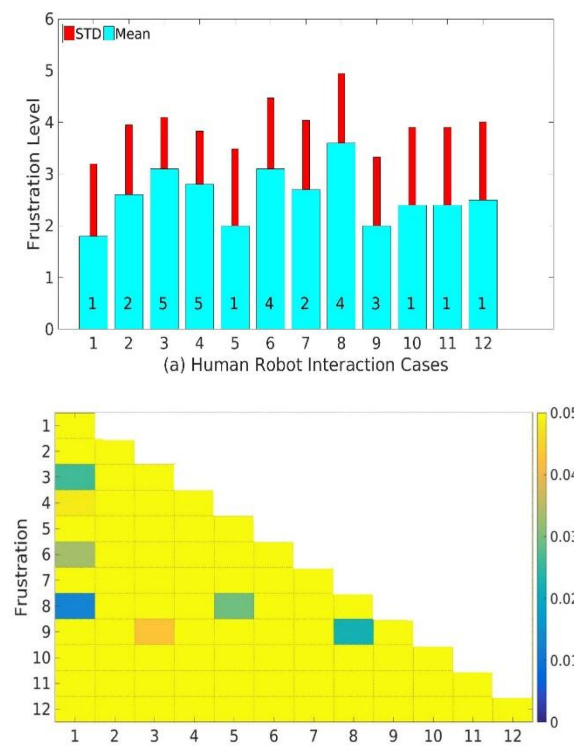

Figure 5. Frustration Level, (a). Mean and Standard Deviation, (b). Mann-Whitney U test

5. CONCLUSION

As the robot become more and more involved in our environment, the demand for human trust of robots is more important than ever. Humans must trust autonomous systems to improve interaction. This work focused on the interaction with a robot in daily life tasks like passing a common objects to people. This task is representative of how a robot assistant could help disabled or elderly persons with their daily routines. Different Baxter robot operation modes were tested throughout this research. HRI feedback was measured for trust, satisfaction and frustration levels after interaction with Baxter robot. The feedback was altered based on the operation mode of the robot in delivering the objects to a human. It turns out that the human trust, satisfaction and frustration levels depends on the interaction mode with Baxter robot, whether Baxter moving slowly, quickly, or delivering the objects successfully.

6. ACKNOWLEDGMENTS

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