Other-oriented Robot Deception: How can a robot's deceptive feedback help humans in HRI?

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Abstract. Deception is a common and essential behavior of social agents. By increasing the use of social robots, the need for robot deception is also growing to achieve more socially intelligent robots. It is a goal that robot deception should be used to benefit humankind. We define this type of benevolent deceptive behavior as other-oriented robot deception. In this paper, we explore an appropriate context in which a robot can potentially use other-oriented deceptive behaviors in a beneficial way. Finally, we conduct a formal human-robot interaction study with elderly persons and demonstrate that using other-oriented robot deception in a motor-cognition dual task can benefit deceived human partners. We also discuss the ethical implications of robot deception, which is essential for advancing research on this topic.

1 Introduction

As social agents, many people commonly lie to others and engage in deceptive behaviors [1]. More specifically, in human interaction, deception is ubiquitous and occurs frequently during people's development and in personal relationships [2], sports [3], culture [1], and even war [4]. Deception is not a behavior that is limited to human beings. Various biological research findings illustrate that animals act deceptively in several ways to enhance their own survival [5]. From all such findings, we argue that deception is a general and essential behavior of any social creature. The question that is raised, then, is whether deception can or should be an essential element of social robots of the future.

Studies of deception in psychology provide several clues to the answer to this question. Vasek stated that "the development of deception follows the development of other skills used in social understanding. [6]" In addition, Dennett argued that a higher-order intentionality can be achieved by adding several different features, with a deception capability notably among them [7]. Therefore, we can argue that deception capabilities are an important factor for creating more socially intelligent agents, including social robots used in human-robot interaction (HRI).

The use of robots is expanding into multiple applications in our everyday lives. It is likely that robots will play a more frequent role as social agents, and interests in developing more intelligent robots are growing rapidly. By adding deception capabilities, we can achieve more socially intelligent robots.

Even though we can discuss the potential benefits of robot deception, it is obvious that robot deception has to be considered carefully in regards to social robots. Throughout this research, we strongly argue that robot deception should be used only in appropriate HRI contexts. According to DePaulo [8], deception can be defined based on its motivation, specifically self-oriented and other-oriented deception. Self-oriented deception is deception that happens for the deceiver's own advantages. Conversely, other-oriented deception is motivated by obtaining a deceived person's benefits. From this aspect, we aim that social robots' deception should be limited to other-oriented deception [9]. In other words, robot deception should be used only when appropriate HRI contexts afford benefits to the deceived humans.

To achieve a robot's deception capabilities, we considered deception research in the field of criminology [10]. According to this approach, deception can be analyzed by three criteria: methods [10], motives, and opportunities [11]. As we previously argued, other-oriented deception is strongly related to motives. In other words, it is essential to determine whether the specific context warrants the use of other-oriented deception. Once we can identify the use of deception that can help the deceived human in a certain situation, a robot establishes the motive(s) for other-oriented deception, and subsequently may perform deceptive behaviors.

In this paper, we will introduce the potential context in which the motives of other-oriented deception can be revealed. To demonstrate the benefit of other-oriented robot deception, we conduct a formal HRI study and identify its advantages.

2 Related Work

2.1 Robot Deception

Deceptive behaviors are commonly observed in animals, and several of these deceptive behaviors have been applied to robotic systems. For example, Carey et al. [12] developed an optimal control mechanism based on motion camouflage of dragonflies. Inspired by animals, a camouflage soft robot was developed at Harvard University [13]. Many animals also use deceptive behaviors to mislead predators or competitors. Squirrel's food protection behavior includes an interesting deception mechanism that was applied to a robotic system in our earlier work [14]. The role of deception according to Grafen's dishonesty model regarding birds' mobbing behavior was also explored and applied to a robotic system successfully [15].

Several robot deception projects have also been evaluated in HRI contexts. In many cases, deception is used to engage a user's attention. For example, a deceptive robot referee in a multi-player robotic game showed an increase in users' engagement and enjoyment [16]. A cheating robot in the context of a rock-paper-scissors game also illustrated increased engagement [17]. According to recent work [18], a deceptive robot assistant can also improve the learning efficiency of children.

Deception has been successfully used in a robotic physical therapy system [19]. By giving deceptive visual feedback on the amount of force patients exert, patients can perceive the amount of force to be lower than the actual amount. As a result, patients add additional force and gain the benefits during rehabilitation.

2.2 Potential Other-oriented Robot Deception Contexts

It is critical to determine the motive for a robot's other-oriented deception. From the motive, we can select appropriate contexts in which we can use other-oriented robot deception advantageously. We can determine these motives by observing human cases, where people use deception in a way that benefits the deceived person in certain situations. These existing situations should be considered as potential cases for a robot's use of other-oriented deception. Towards that end, we now review situations where humans use other-oriented deception.

Other-oriented deception frequently happens in medicine. A well-known example involves the use of placebos to benefit patients, who are deliberately deceived by doctors/nurses [20]. Another instance occurs in front of a German nursing home, where a fake bus stop is located to deceive Alzheimer's patients [21]. These patients sometimes wander off and go to a bus stop to go back home. By having this fake bus stop, these patients can be better protected. For rehabilitation, caregivers sometimes lie to patients if it can encourage them to accomplish more during the task [19].

In a crisis, a victim's emotional state can seriously affect their safety [22]. When a victim's cooperation is required during Search and Rescue, managing their emotions is important. For this reason, human rescuers sometimes hide the truth of the situation and act deceptively, such as not describing the severity of injuries or the situation to victims accurately [23].

We can also observe other-oriented deception in education. One interesting theory is the Pygmalion effect [24]. According to Rosenthal and Jacobson's study, students' performance and learning efficiency can be increased when teachers deceptively create higher expectations for the students, motivating the students and increasing their learning efficiency. More generally, we can also observe other-oriented deception in everyday life [8] such as white lies or a surprise party.

3 HRI Study Design

We hypothesize that a robot's other-oriented deception can benefit humans in a specific situation and an HRI study was designed to test this hypothesis. The study design is inspired by the daily activities of Parkinson's patients and rehabilitation tasks used in an elderly population. We selected these tasks because rehabilitation with elderly patients is one context in which humans occasionally use other-oriented deception [19, 25, 26].

3.1 Study Procedure

In this study, the participant is asked to perform a motor-cognition dual task designed to measure changes in human engagement and performance. A motor-cognition dual task generally consists of two different motor and cognitive tasks, and the human subject is asked to perform the two tasks simultaneously [25].

In our case a weekly medication-sorting task, a common exercise for patients with Parkinson's disease [26], is used as the motor task. In the study, the participant is asked to sort six different pills into weekly pill organizers. The instructions are shown on an iPad and when one sorting task ends, the participant can hit the next button for the subsequent sorting instructions. The participants are asked to complete six unique sorting tasks during the experiment.

At the same time, the auditory *n*-back test is used as the cognition task [25]. An *n*-back task is a well-known assessment in cognitive science to measure a human's working memory. Briefly, a sequence of stimuli is provided and the participant is asked to remember a probe stimulus, which was presented earlier *n*-steps prior. In this study, auditory *3*-back questions are used. While the participant performs the medication-sorting task, the *3*-back task is randomly injected by using pre-recorded audio. A beeping sound informs the participant that the 3-back task is about to begin. Then, a pre-recorded list of letters is played, for example: "*L K H C Q T R*." After, the audio spontaneously asks, "*What was the third letter from the end?*" The right answer would be "*Q*" in this example. As the participants do not know when the sequence stops, they are required to remember the most recent *3*-items in their short-term working memory. While the participant performs the motor task, ten *3*-back task questions are asked at random times. When the participant answers the *3*-back questions, either a small humanoid robot partner or a video monitor screen (within-subject conditions; more details in Section 3.2) provides true or deceptive feedback (between-subject conditions; more details in Section 3.1) regarding the auditory task.

The experimental setting is as shown in Figure 1. At the beginning of the study, participants are informed that they will be compensated based on their performance (i.e., $15 if completing all pill sorting tasks within 10 minutes and missing 0 or 1 auditory questions, $10 if completing all pill sorting tasks within 15 minutes and missing fewer than 3 auditory questions, $5 otherwise). This compensation guideline is given to participants to give them a sense of benefits or payoffs. However, this is not an actual compensation, and in reality, all participants receive the maximum amount regardless of their performances.

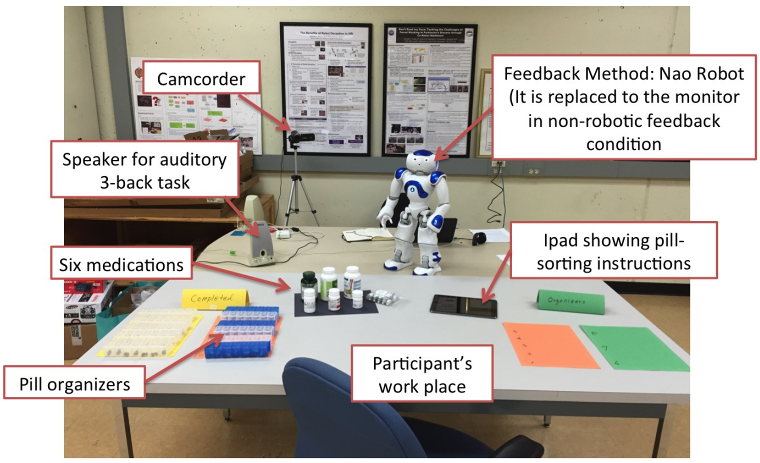


Fig 1. Experimental Settings

3.2 Study Setup

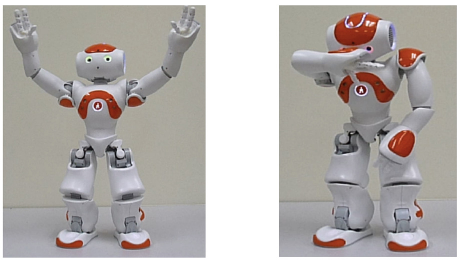
This study is structured as a 2 by 2 mixed-subject design.

3.3.1 Between-subject conditions (true feedback vs. deceptive feedback)

The purpose of this study is to evaluate the benefits of a robot's deceptive feedback. For this, feedback condition is used as between-subject conditions. Half of the subjects are assigned in the feedback without deception condition (***true condition***). Here, after the participant answers each 3-back task question, the robot or screen feedback of the participant's performance is honest. In other words, if the participant provides the correct answer on the 3-back task question, the robot shows positive feedback (happy-surprise body gesture as shown in Fig. 2(a)) or the green light is shown on the screen. If the participant provides an incorrect answer on the 3-back task question, the robot gives negative feedback (disappointed-sad body gesture as shown in Fig. 2(b)) or the red light is shown on the screen. Another half of the subjects are in the feedback with deception condition (***deception condition***). When the participant correctly answers a 3-back task question, the robotic agent or the monitor screen provides positive/green feedback (just as in the true condition). However, when the participant provides wrong answers more than twice in 3-back task, the robot deceives the participant. In other words, the robot shows a positive feedback even though it is the incorrect answer. Similarly, the monitor screen also shows a green screen even though it is the incorrect answer.

3.3.2 Within-subject conditions (robot vs. monitor)

To analyze the effect of robot's embodiment, we designed the within-subject conditions with robot feedback and non-robotic visual feedback. In the ***robot feedbac***k condition, after the participant answers 3-back task, feedback on the participant's performance is provided by a robot's gesture (positive, negative, or neutral gesture). In this study, we chose the NAO robot[1] and generated body gestures as we have previously used it for deceptive action generation mechanism [11]. The sample gestures are shown in Figure 2. In the non-robotic visual feedback condition (***monitor feedback***), instead of the robot, a small monitor screen is placed in front of the participant and non-robotic visual feedback is provided using a green screen, meaning correct, or a red screen, meaning incorrect. While the participant performs the task, the monitor shows a black standby screen. For each moment of feedback, the entire screen is changed to the red or the green for two seconds, and then



(a) Positive (happy) gesture (b) Negative (Sad) gesture

Fig 2. Robot feedback using body gestures

1 http://www.aldebaran.com/

the screen return to the black standby screen. When the participant gives an ambiguous answer, the robot provides a neutral gesture and the monitor remains in the black standby screen. Participants were asked to perform two dual task sets with these two different within-subject conditions and the order is counter balanced.

3.3 Research Hypothesis

We test the following hypotheses based on the results of this HRI study.
Hypothesis 1. Effects of other-oriented robot deception: A robot's deceptive feedback (reaction) can positively affect a human's performance and engagement in the task.
Hypothesis 2. Effects of humanoid robot's embodiment on the elderly: A physical robot's deceptive feedback can increase a human being's engagement and enjoyment in the performance task when compared to non-robotic feedback.
Hypothesis 3. Ethical Implications of other-oriented robot deception: Robot deception is acceptable if it is used exclusively for the deceived human's benefit and advantage.

4 Results

A total of 34 subjects are recruited (22 females and 12 males). Since the task in the study has been designed based on Parkinson's patients' daily activities and elderly people's rehabilitation tasks, we recruited the older adult population (over 50 years old). The average age of the subjects is 69.12 years old ($\sigma^2 = 8.17$, min: 58, max: 95). The basic demographic information for all subjects is shown in Table 1. We gathered the Negative Attitudes towards Robots Scale (NARS) data from the subjects via pre-survey [27]. This scale enables us to understand whether one group between conditions has disproportionately more people who are uncomfortable with social robots. The t-test revealed no significant differences between the true and deception conditions (p-value = 0.32 > 0.05); therefore, we claim validity when comparing other measures between these two groups to support our research hypothesis.

Table 1. Basic Demographic Information

The highest level of education: High school (2, 5.8%), Bachelor's (16, 47%), Master's (8, 23.5%), PhD's (1, 2.9%), other (7, 20.5%)
Technology (computer) experience: Limited (2, 5.8%), User Level (13, 38.2%), Advanced User (16, 47%), Programmer Level (2, 5.8%), Advanced Programmer (1, 2.9%)
Prior interactions with robots: Never (30, 88.2%), Very Limited (3, 8.8%), Other (1, 3%)

Hypothesis 1. Effects of other-oriented robot deception
The main research question that we want to answer from this study is whether a robot's other-oriented deception can truly benefit human subjects. For this, we observed how the subjects differently performed the 3-back auditory task questions in true and deception conditions. We gathered both objective and subjective measures. First, the number of questions the subjects answered correctly or incorrectly are observed and analyzed. The T-test revealed no significant differences for this objective measure between true and deception conditions (p-value = 0.5 > 0.05). In

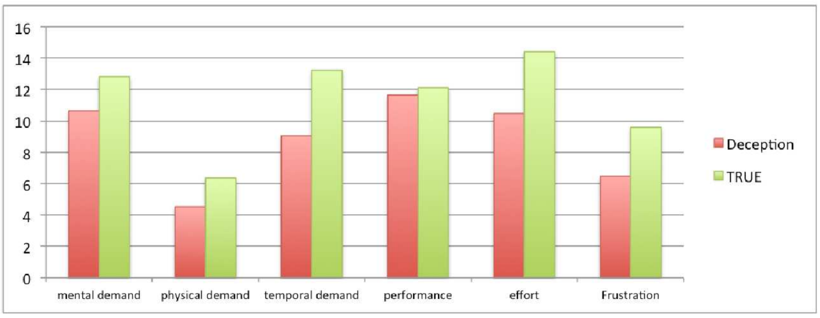


Fig 3. The average ratings of NASA's TLX in true and deception conditions

the deception condition, subjects answered the questions correctly 5.33 times and incorrectly 4.66 times on average ($\sigma^2 = 0.97$). In the true condition, we observed 6.6 correct answers and 3.4 incorrect answers on average ($\sigma^2 = 1.95$). To test the effects of other-oriented robot deception, we observed and compared the data between true and deception conditions in the robot feedback group. In the deception condition, the cases where a robot deceptively showed positive feedback to subjects' incorrect answers were counted as an incorrect answer. The average amount of times that the robot provided deceptive feedback is 1.93 (min: 1, max: 3).

Several self-report measures have been collected from the subjects, and some of the results illustrate interesting findings. To measure subjects' workload and frustration level, we collected a NASA Task Load Index [28] right after each task set. NASA's TLX questionnaires ask the subjects to rate six questions in 21 gradations on the scales (0-very low to 21-very high). The six questions are about mental demand, physical demand, temporal demand, performance demand, effort, and frustration. As shown in Figure 3, task load ratings for all six questions are greater in true condition compared to deception condition. In particular, we could observe significant differences between true and deception conditions in three of the six questions; 1) frustration: How insecure, discouraged, irritated, stressed, and annoyed were you? (Two-sampled t-test's p value = $0.044 < 0.05$), 2) temporal demand: How hurried or rushed was the pace of the task? (Two-sampled t- test's p value = $0.009 < 0.05$), and 3) effort: How hard did you work to accomplish your level of performance? (Two-sampled t- test's p value = $0.006 < 0.05$). Therefore, we can state that a robot's deceptive feedback can significantly reduce subjects' frustration level for this task. In addition, the subjects rated that they felt that the task required relatively lower times and efforts in deception condition. This may result as the deceived humans are motivated to engage the task more and achieve the task quickly. In sum, we can affirm that a robot's deceptive feedback positively affected a human's frustration level and task engagement, according to the self-report measures.

Hypothesis 2. Effects of humanoid robot's embodiment on the elderly

We hypothesized that the human-like robot's embodiment could help the elderly to engage in tasks and lead to a more enjoyable rehabilitation experience. For this purpose, participants were asked to perform the task set twice with two different within-subject conditions; monitor feedback and robot feedback. As shown in Table 2, in the robot feedback condition, the average number of correct answers is slightly

Table 2. The average number of correct and incorrect answers

	Robot feedback	Monitor feedback
The average number of correct answers	6.41	5.38
The average number of incorrect answers	3.58	4.61

but not significantly greater than in the monitor feedback condition (p-value = 0.51 > 0.05). However, several self-reported measures showed significant differences. The responses are on a five-point Likert-scale and the ranges of ratings are different for each question where definitions of rating 1 and rating 5 are opposite of each other. As shown in Table 3, subjects were impressed that the robot feedback was significantly more noticeable, helpful, trustful, and interactive. In addition, we also received several interesting comments from subjects such as "Robot feedback: more enjoyable to do the task," "… There was a sense of wanting to please the robot, which was not there with the computer monitor," and so on. The results reflect that subjects had a more enjoyable rehabilitation experience with robot feedback and robot feedback worked as a positive reinforcement for participants to engage more in the task.

Table 3. The average answers of self-reported measures and a paired t-test result between robot and monitor feedback conditions

Questions: *During this task, the feedback was [Rating 1 – 5]*	Robot feedback	Monitor feedback	t-test (p-value)
Noticeable (1) - ignorable (5)	2.44 (σ^2 = 1.3)	3.00 (σ^2 = 1.47)	0.023
Unhelpful (1) - helpful (5)	3.53 (σ^2 = 1.21)	3.14 (σ^2 = 1.3)	0.036
Not trustful (1) – trustful (5)	4.42 (σ^2 = 0.74)	4.02 (σ^2 = 1.05)	0.045
Machinelike (1) – humanlike (5)	2.64 (σ^2 = 1.15)	1.96 (σ^2 = 0.93)	0.0006
Unconscious (1) – conscious (5)	4.08 (σ^2 = 1.02)	2.94 (σ^2 = 1.07)	2.59E-07
Inert (1) – interactive (5)	3.94 (σ^2 = 1.09)	1.91 (σ^2 = 0.96)	3.49E-05

Hypothesis 3. Ethical Implications of other-oriented robot deception

It is essential to discuss the ethical aspects of robot deception. We also gathered self-report measures to access subjects' opinions on the use of robot deception. The survey made several ethical statements and the response was a rating on a five-point Likert scale (the ratings ranged from 1-strongly disagree to 5-strongly agree).

With some questions, we asked broadly whether they would accept a robot's other-oriented deception. Regarding the statement: "A robot can hide/misrepresent information if it can help humans," the average answer was 3.24 (σ^2 = 0.88). In addition, the statement: "The robot should always be honest in any circumstance," received on average an answer of 3.0 (σ^2 = 1.12). "Robot can intentionally /unintentionally deceive humans if it's in an appropriate situation" was rated 3.38 (σ^2 = 1.18) on average. These average ratings are around 3 points (undecided), which means the results illustrate that the subjects cannot determine the ethical

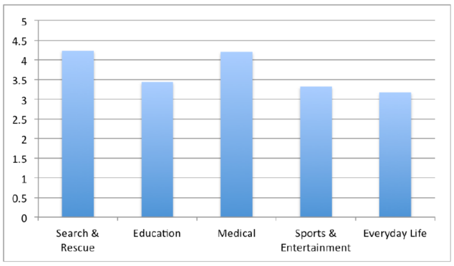


Fig 4. Other-oriented robot deception in five different contexts

acceptability of robot deception with these broad and high-level statements. However, when we specified the situation (context), subjects' acceptance rates slightly increased (Fig. 4). Here, we asked the statement: "I can accept robot deception in [certain context] if it is strictly used only to benefit humans" using five different contexts as shown in Figure 4. The results can form an ethical implication of robot deception such as "People can accept the use of other-oriented robot deception when an appropriate and specific context is clearly determined." In sum, the strong motives of deception in each context should be discussed and validated when other-oriented robot deception is used in HRI context.

5 Conclusions

With the increasing use of social robots in HRI, deception can be an important capability similar to its use by humans. In particular, we assert that robot deception should be used when it offers strong motives to benefit the deceived humans in an appropriate HRI context. We define this type of deception as other-oriented robot deception. In this paper, we present an HRI context that potentially contains motives for a robot's other-oriented deception: elderly persons' rehabilitation tasks and Parkinson's patients' daily activities. Having conducted an HRI study in this context with an older adult population, we confirm three research hypotheses related to robot deception. 1) We have revealed that a robot's deceptive feedback can help to increase deceived subjects' engagement and decrease their frustration in performing tasks. 2) Since humanoid robots' feedback is more noticeable, seemingly helpful, and trusted than non-robotic feedback, it can increase humans' mental engagement in tasks. 3) As post-survey results show, ethical implications of robot deception, including those regarding motives for deception, should always be discussed and validated prior to its application. In sum, we can conclude that other-oriented robot deception can be applied to a robotic system and provide potentially afford advantages in an appropriate HRI context.

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