Robots That Successfully Elicit Help from Humans

Layla Alarifi
Computer Engineering and Sciences
Florida Institute of Technology
Melbourne, USA
lalarifi2017@my.fit.edu

Marius C. Silaghi
Computer Engineering and Sciences
Florida Institute of Technology
Melbourne, USA
msilaghi@fit.edu

Rajaa Rahil
Computer Engineering and Sciences
Florida Institute of Technology
Melbourne, USA
rrahil2013@my.fit.edu

***Abstract*—Most attention in the development of robots has been focused on the robots' hardware and software to improve functionality. However, the interaction between humans and robots can be key to enhancing robots' performance. Autonomous mobile robots can more often complete their tasks if they are enabled to effectively solicit help from humans when robots face limitations. Hence, in this paper, we examine three different manners of addressing humans: friendly, polite, and indirect. These approaches combine different interaction modalities, like speech and gestures. We conducted experiments where the NAO robot addresses bystanders in one of the aforementioned three manners to get help with opening a public door. The aim of the experiment was to identify the best ways for robots to successfully draw the attention, interact and request help from humans. We investigated if passers-by would respond differently to each manner. Each passer-by was then asked to fill a questionnaire to better understand and classify his actions. In addition, we measure the effects of bystanders' source of control assumptions and the situational awareness desire from the response of the bystanders, with respect to the robot request.**

***Index Terms*—Request, Help, Autonomous mobile robots, Human-robot interaction, Source of control, Situational awareness.**

I. Introduction

Mobile robots (MRs) have become able to perform different types of tasks in our environment. Significant examples are MRs as a tour guide in shopping malls [9] and in museums [4], [23] and as a companion for visitors [15]. However, with the advances in the robotics field, robots still have limitations in their actuation and sensing abilities, which consequently affects their performance. For instance, robots could have difficulties identifying or removing obstacles, recognizing speech in noisy environments, and recognizing gestures. A very common limitation that would require outside help is a robot design. For example, short robots cannot reach high objects needed to complete a task and cannot open a door that blocks their way to a desired destination. Robots with no hands cannot remove objects that block the path. As robots move from structured environments to unstructured, they probably would face situations that they would be incapable to overcome because of their limitations.

The limitations could be overcome by having robots ask humans for help and use humans' abilities to aid them in completing their tasks successfully. Robots could ask humans about their current location during their uncertainty or ask people to remove or identify objects in the path. Asking humans for assistance would not overcome robots' limitations if humans do not respond positively. Therefore, the ability of robots to elicit aid from humans when needed is significant for robots' task completion. Tweenbot is a cardboard robot that navigated across Washington Square Park in New York in 2009 with pedestrians' assistance only [13]. Tweenbot did not have the park's map, sensors, and the ability of localization and navigation, but with people's help, it was able to overcome its limitation. Similarly, the ACE robot was able to navigate to Marienplatz in Munich without GPS sensors or a map model but with bystanders' help [24]. On the other hand, HitchBOT was destroyed in 2015 in Philadelphia when it was trying to proceed to San Fransisco with the assistance of humans [7].

When robots request humans' help, they could be ignored, helped, or even hurt. Therefore, experimenting and finding better ways by which robots could solicit help from humans is significant for robots to perform their tasks successfully. In this work, we conducted an experiment with the NAO robot to examine three different request strategies that could influence the effectiveness of robots' requests and the decision of passers-by whether to assist or not. The request manners that were examined are indirect, friendly, and polite. In addition, the situational awareness desire and the robot source of control assumption effects on bystanders' decision to help or not were examined to measure how the two dimensions could influence the responses of bystanders to the robot's request.

II. Related Work

Research has been done to provide techniques that allow robots to acknowledge their limitations and ask humans for assistance. Human supervisors have been used to control robots and overcome their deficiency. Fong et al. [8] designed a dialog system where the robot would send questions and pictures of its concerns to supervisors who would respond. Other work that has used the supervisor as the helper are [19], [26]. Having humans supervise robots could be expensive regarding the monitoring time. In addition, the performance of robots can be affected by the cognitive skills of the supervisors. Most importantly, supervisors would not be always present directly for help if the robot, for instance, has an obstacle in its way while there are passers-by who could help.

Occupants or employees of a building where robots operate have been used as the source of help. Rosenthal et al. in [16] conducted an experiment to measure the availability and the willingness of occupants on the floor where a robot resided. The robot would navigate to available willing occupants to ask for help with different tasks. Rosenthal et al. state that occupants were willing to help with the three tasks with which the robot required help regardless of the request size. Weiss et al. [24] conducted a breach study where a robot asked bystanders to direct it to next direction for Marienplatz, Munich. The robot successfully achieved its final destination after two hours even though it did not have GPS sensors or map knowledge.

Having aid of a bystander would reduce the burden of help compared to occupants and supervisors. Bystanders' assistance could be also more time efficient than occupants who need to be navigated to or supervisors who could be busy monitoring other robots or not present in the robots' location. In some cases, if AMRs function in public places, asking bystanders for help could be necessary in order for AMRs to complete their tasks. Therefore, in our research, we chose bystanders to be the target from which the robot would ask for assistance.

Research has been done to improve the interaction between robots and humans, such as in [12]. Kanada et al. present in their work a robot who acts like it understands route directions via eye contact and arm movements. In addition, [1], [5] has focused on developing structural futures for robots to understand humans and interactions with them. Work has been done to help robots understand humans' gestures and speech [2], [10], [21], [22]. and to design robots that can perform speech and gestures [11], [14], [17].

Less research has focused on humans' willingness to assist robots and factors affecting people's decision and robots' request. Yamamoto et al. [25] examined if social authority would affect humans' interaction with a robot. Yamamoto et al. explain that when participants were asked by a human through a remote dialog system, they responded positively to the robot request while the robot command were ignored when it was requested by the robot.

Similar to our work, Srinivasan and Takayama [20] examine how robots could ask for help effectively. Via conducting an online survey, Srinivasan and Takayama investigate how robot familiarity, requests' size, social status, and requests' manner could affect people's decision to help or not. Another experiment was conducted with a physical robot to examine the effects of source orientation on people's willingness to provide help or not. The request manners that were tested in [20] were formulated in the Politeness Theory in [3]. Unlike their work, we tested the three manners, friendly, polite, and indirect that are being used by humans in everyday life. In our work, we aimed to test the three request strategies in real life with passer-by participants and a physical robot to have more realism. Unlike our work, in [20], the experiment was conducted online. In [20], the results indicated that positive politeness was the most effective strategy.

Situational awareness can be described as the knowledge of what is happening around us [6]. In [18], Scholtz et al. analyze different levels of interactions between robots and humans and propose the information needed by both humans and robots. What the robot can do, what the robot would perform next, what caused the robot's present behavior, and what behaviors bystanders can cause, are information mentioned in [18] as appropriate for the bystanders' role. In our work, we attempt to examine whether bystanders desire to be situationally aware. Also, we measure whether their situational awareness desire affects their decision to help the robot or not.

III. The Experiment

We conducted an experiment in the Florida Institute of Technology campus during which passer-by humans were asked by a robot in different manners, such as indirectly, politely, and friendly. The robot asked for help using speech and gestures as this is more similar to how humans ask for help. We chose a scenario where the robot needs a public door to be opened by bystanders, so the robot could complete its task. A NAO robot asked for help, as it is too short to reach the door. In the polite request, the robot addressed people with "Can you open the door, please?", while in indirect requests, the robot asked for help indirectly saying "I cannot reach the door and it is blocking my way". In the friendly manner, the robot asked with less formal tone, saying "You seem taller than me! Would you open the door for me?". With each different request the robot pointed to the door that it needed opened. After the robot requested help from bystanders, they were given a questionnaire to fill regardless whether they helped or not.

The questionnaire is investigating whether the robot's request in each manner was rational, convincing, socially proper, polite, and clear. Also, the questionnaire requires bystanders' assumptions about the robot source of control (autonomous or controlled) and whether they desire to be situationally aware or not. The reasons for passers-by help or not and their comments about the robot's request were required in the questionnaire. The results of our work would be based on participants' response to the robot request in addition to the questionnaire information.

IV. The Procedure

The nature of the study requires participants to be uninformed about the experiment in advance because we were targeting bystanders to be the source of help. Thus, we chose the location where the robot would ask for help carefully. To ensure that we could get different participants each time, we chose to perform the experiment in a location near professors' offices and near classrooms. Also, to ensure that passers-by would not notice us when controlling the robot remotely while we could see them, the location chosen was in front of a study area with glass walls. This allowed us to monitor the passer-by and the robot without being noticed.

We conducted the experiment on three different days. Two hours in each of these days were allocated for one of the three manners polite, indirect, and friendly to ask with. The total number of passers-by that the robot interacted with during the three-day-experiment was 45 bystanders. For each of the three request strategies, 15 bystanders had been asked by the robot


(a) NAO turning his head towards the door and pointing with his hand.


(b) NAO keeping his head towards the door and pointing with his hand and fingers.


(c) NAO turning back to bystanders.


(d) NAO waiting for the bystanders' response.

Fig. 1: The robot's gestures when asking bystanders for help.

to help. The robot would be standing around the public door it needed passers-by to open. When a passer-by approached, the robot said "Hi" and complete with the request of one of the three strategies. For example, it would address bystanders with the polite manner saying "Hi! Can you open the door for me please?". The robot pointed to the door when asking for help similar to how humans would ask (See Fig. 1). The robot looked at participants, and while speaking, it turned to the door with its head pointing towards the door with its hand and fingers. Then, the robot turned back towards bystanders and waited for participants' response.

If the bystander that the robot interacted with passed by without providing help, we approached her to give her the questionnaire to fill out. However, if the bystander responded to the robot request and provided help by opening the door, the robot said "Thank you for your help" and walked across the door. After that, we handed the questionnaire out to the bystander to fill out.

V. Results

A. Participants

Based on the demographic questions, a total of 45 bystanders completed the questionnaire. Participants included 14 female and 31 male with 51% of participants with an age range of 19-24 years. Of the 45 participants, 28 reported owning pets (62%) and 17 reported having no pets (38%). The participants' familiarity with robots was high as 29 of participants were familiar with robots (64%), while 16 were not (36%).

B. Bystanders' Response to the Robot's Request

In the first day of the experiment from 10:00 a.m to 12:00 p.m, the robot interacted with 15 bystanders using the polite strategy, "Can you open the door for me please?". The results indicated that 8 of 15 bystanders provided help, while 7 did not help. In the indirect manner, where the robot requested help in the second day of the experiment from 12:00 p.m to 2:00 p.m saying "I can not reach the door and it is blocking my way", 4 bystanders out of 15 helped the robot, and 11 did not. In the last day of the experiment from 12:00 p.m to 2:00 p.m, the robot interacted with 15 bystanders with the friendly manner saying "You seem taller than me! would you open the door for me", and 7 bystanders provided help, while 8 passer-by did not. The results indicate that the robot request with the polite manner resulted in more positive responses than the indirect and friendly manners. After performing a chi-square test considering the three manners and the bystanders' response to the robot request, the chi-square statistic is 2.3684, and the p-value is 0.305988. The result is not significant at $p > 0.05$.

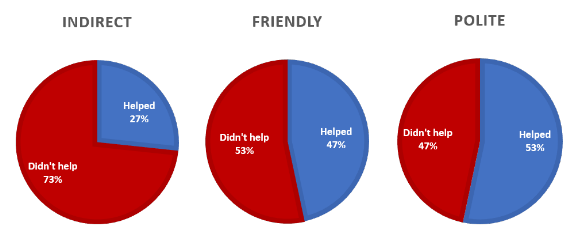


Fig. 2: Pie Chart of Bystanders' Response

C. The Robot Request Evaluation

Five evaluation questions in the questionnaire are investigating whether the robot's request was rational, convincing, socially proper, polite, and clear in each manner. We included words, rather than numbers, for scaling choices to help participants decide effectively. Each of these questions has five scaling choices. For example, regarding the request rationality, the scales are (Not rational in extreme way, Not rational, Neutral, Rational, and Extremely rational). We used (1,2,3,4,5) as equivalent numbers for analyses where 1 and 2 refer to the first two scales indicating the dissatisfaction, 3 refers to the middle scale point indicating the neutrality, while 4 and 5 refer to the last two scales expressing the satisfaction.

a) Rationality: The rationality level of the robot polite request has been evaluated by 100% of participants with satisfaction level (4, 5). The mean is 4.3 with 0.488 SD. Regarding the rationality of the request with the friendly manner, 74% of the participants evaluated it in the satisfaction level with 4.2 mean and 0.862 SD. In the indirect request, 53%

of participants indicated their satisfaction of the rationality of the indirect request, (M=3.6, SD=0.828). We performed a chi-square test between the three manners and participants' perceptions regarding the request rationality. The chi-square statistic is $\chi^2(6, N = 45) = 13.11429, p = 0.041257$. The result is significant at p<0.05. We also performed a chi square test to calculate the significance between participants' responses to the robot request (helped or ignored the request) and participants' perceptions regarding the robot's request rationality. The result is significant at p<0.05. The chi square statistic is 7.843768, and the p value is 0.049353 with DF=3.

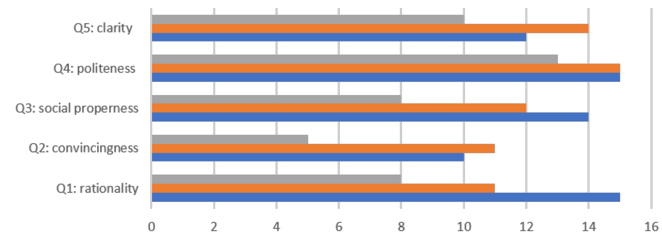
b) Convincingness: Regarding the convincingness of the robot request with the polite manner, 67% of participants indicated that the robot polite request was convincing (4, 5) with 0.915 SD and 3.867 mean. With the friendly manner, 74% of participants agreed that the robot request was convincing (M=3.933, SD=0.884). While only 34% of participants indicated their satisfaction of the convincingness of the robot indirect request with M=3.133, SD=0.990.

c) Social properness: Of all participants, 93% evaluated the polite request to be socially proper (4,5) with 4.467 mean and 0.639 SD. With the friendly request, 80% of participants indicated their satisfaction regarding the request social properness (M=4.133, SD=0.915). In the indirect manner, the robot's request was evaluated by 54% of participants to be socially proper with 3.4 mean and 0.910 SD. The chi square test for the significance between participants' responses to the robot's request and their opinion regarding the request social properness is $\chi^2(3, N = 45) = 11.339, p = 0.010027$. The result is significant at $p < 0.05$.

d) Politeness: The polite request was evaluated by participants (100%) to be polite. The mean is 4.733 with 0.458 SD. The request friendly manner was also evaluated by 100% of participants to be polite with 4.533 mean and 0.516 SD. Of all participants, 87% agreed on the politeness of the indirect request with 4.066 mean and 0.594 SD. The chi square test for the three manners and participants' perception regarding the politeness of the request is 11.026, the p value is 0.026273. The result is significant at $p < 0.05$.

e) Clarity: Of participants, 80% have evaluated the polite request to be clear (M=4.2, SD=0.561). With the "friendly manner", 94% of participants agreed on the request clarity with mean 4.2 and SD 0.561. With the indirect request, 66% of participants indicated their satisfaction regarding the request clarity (M=3.8, SD= 1.146). After performing a chi square test for participants' responses to the robot's request and their perceptions about the clarity of the robot's request, the χ^2 is 9.4648 and p= 0.023709. The result is significant at $p < 0.05$.

The Figure 3 summarizes the satisfaction results of the five aspects (rationality, convincingness, social properness, politeness, clarity) with the three manners. The figure describes the ratio of participants in each manner who evaluated aspects with scores 4 and 5 referring to satisfaction level, noting that each manner has been evaluated by 15 different participants. It is clear that the indirect manner has less satisfaction in all the five aspects comparing with the polite and friendly strategies. We can say that between the three manners, the indirect request was evaluated by participants with less satisfaction. While the polite request seems to yield the best participant satisfaction level.



	Q1: rationality	Q2: convincingness	Q3: social properness	Q4: politeness	Q5: clarity
Indirect	8	5	8	13	10
Friendly	11	11	12	15	14
Polite	15	10	14	15	12

Fig. 3: Satisfaction results of the five aspects with the three manners

D. Bystanders' Reasons For Helping The Robot

We have analyzed the answers of the participants concerning their reasons for decision on providing help, in addition to their comments about the robot way of asking, to investigate the influence of the request manners on bystanders' response to the robot's request. In Table I, we show the classification of answers provided by bystanders who helped the robot with the polite manner. It is clear that the polite request has affected 100% of participants who helped (8 in total), and that they did not help only because they were curious, or because the robot was adorable. It is also remarkable that 2 participants have been influenced by the gestures of the robot when pointing to the door.

Polite Request	
Classification	**N**
The robot pointed to the door	2
The robot looked nice	1
The request was polite, convincing, friendly, simple, proper, or clear	8
I was curious if the robot will walk in	1

TABLE I: Classification of bystanders' answers with the polite manner

We can see in Table II that the friendly request has influenced 6 participants (86%) who helped, as they described the request positively.

Friendly Request	
Classification	**N**
The request was good, polite, rational, clear, proper, friendly, understandable	6
The robot looked nice	3
I was curious what the robot will	1
The robot asked for help	1

TABLE II: Classification of bystanders' answers with the friendly manner

In the Table III, it is shown that only two of participants who helped when the robot was using the indirect manner mode pointed out that the request was polite or/and proper. In fact, one participant mentioned that the request was not polite even though she provided help. Thus, the participants who helped were not affected positively by the indirect request pattern.

Indirect Request	
Classification	**N**
The request was polite, proper	2
The situation was not clear (e.g: prank, debug, demo)	1
The request was not polite	1
The robot wanted help	2

TABLE III: Classification of bystanders' answers with the indirect manner

The polite request induced more participants to help, and 100% of participants who helped claim to have been influenced by how the robot requested help.

E. Situational Awareness Results

We asked participants if they desire that the robot had provided more information during the request about its abilities or its next actions. The purpose of this question is to measure if participants desire to be aware of the situation. Another purpose is to investigate if participants' situational awareness desire could have changed the outcome. The results indicated that 25 of the 45 participants (56%) responded with yes to the situational awareness desire question, 18 (40%) answered with no, and 2 (4%) did not answer the question. This shows that participants who wanted more information from the robot are more than those who did not want additional information. (See Fig.4).

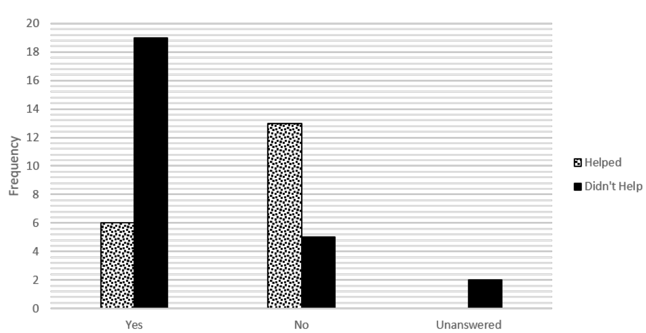


Fig. 4: Bystanders' situational awareness desire

The Table IV illustrates participants' responses to the situational awareness desire question and their responses to the robot request in percentages. We did not split the data based on the request manners because in all three strategies the robot provided the same level of information (just asking for the door to be opened with the three manners). Considering the participants' response to the robot request, 13 (68%) of participants who helped the robot (19 in total) stated that they did not want additional information to be provided. However, 19 (73%) of participants who did not provide help (26 in total) indicated their desire to have more information about the robot abilities and actions. Therefore, providing more information might result in more positive responses to the robot request, but further research in this is needed for more exact evaluations.

Response	Helped	Didn't Help
Yes	32%	73%
No	68%	19%
No answer	0%	8%
Total	100%	100%

TABLE IV: Participants' responses to situational awareness desire and robot' request

We performed a chi-squared test to verify our hypothesis considering the participants response to the situational awareness questions and their response to the robot request. We hypothesized that participants decision to help or not can be influenced by their desire to be situational aware. We found that the chi-square is 9.8676, and the p-value is 0.001682. The result is significant at p less than 0.05.

Some reasons that participants stated for their desire to have additional information from the robot are:

- To know the robot's abilities.
- To understand the intention of the robot and the situation.
- To be informed of the next action and whether the robot will really enter if I open the door or not.
- It is interesting to know more about the robot.
- Having more information will be helpful because with robots its not like the case with humans where we would infer what they can do or will do.

The following are some reasons stated by participants for having no desire for additional information besides the robot request:

- It will take too long.
- The request this way is more natural.
- Additional information is not needed.
- What the robot said was enough.

F. Source of Control assumption effects

We asked participants to state their assumptions about the robot source of control (autonomous or controlled) when they provided help. The purpose of this question is to measure whether participants' assumptions about the source of control affected their decision of helping the robot or not. Did participants help when they supposed the robot was autonomous and needed help more than if they supposed the robot was controlled? or the opposite. We did not split the data based on the request three manners in this analysis because they were not associated with the source of control assumption.

Of the 45 participants 30 (67%) thought that the robot was autonomous, 7 (16%) supposed it was controlled, and 8 (18%) did not answer the question (See Fig.5).

Given the responses from participants to the robot request (see Table V), 15 (79%) of participants who helped the robot (19 in total) supposed that the robot was autonomous. Of the participants who provided help, 3 (16%) thought the robot was controlled, and one (5%) did not answer the question.

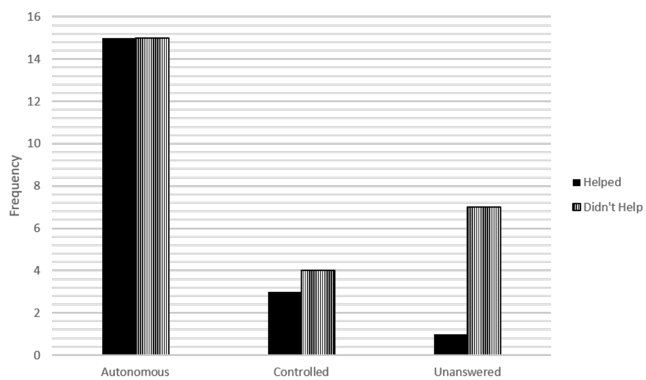


Fig. 5: Bystanders' responses to source of control

On the other hand, 15 (58%) of the participants who did not help (26 in total) supposed the robot was autonomous, 4 (15%) thought it was controlled, and 7 (27%) did not answer. It seems that the source of control assumption would not influence the decision to help or not as the results did not indicate significant correlation between the source of control assumption and the request response.

Response	Helped	Didn't Help
Autonomous	79%	58%
Controlled	16%	15%
No answer	5%	27%
Total	100%	100%

TABLE V: Source of control and request responses

We performed a chi squared test to verify the significance between the source of control assumption and the response to the robot request. The chi-square statistic is 0.1159. The p-value is 0.733508. The result is not significant at p bigger than 0.05.

The following are some reasons stated by participants for their assumption about the source of control:

The robot was autonomous because

- No one was around
- The robot was watching me with its eyes
- It asked me only when I approached
- It registered what was happening around
- It immediately reacted

The robot was controlled because

- I have not seen many autonomous robots
- It was not speaking randomly
- I assumed a student was controlling it
- The robot actions were limited

VI. Conclusion and Outlook

Our experiment aims to enhance the interaction between humans and robots helping to design robots effectively. The NAO robot requested bystanders to open a door. The question was shaped in three different manners (friendly, polite, and indirect) and different modalities (speech and gestures). During the experiment, 45 bystanders interacted with the robot, and subsequently they were given a questionnaire to answer.

We found that: (1) the polite request resulted in more bystanders' help, and they were effected positively by the request manner. (2) Bystanders evaluated the polite manner with a high satisfaction level, while the indirect manner was evaluated with less satisfaction, which could had affected bystanders' response to the robot request. (3) More than half (56%) of passers-by expressed their desire to be situationally aware, and the results indicated that bystanders' response to whether they desire to be aware or not has affected their response to the robot request. (4) Whether the robot was autonomous or controlled had not affected how bystanders reacted to the robot request contradicting our hypothesis that the source of control assumption will affect passers-by response to the robot. These findings can aid in designing methods by which robots more successfully elicit help from human to conduct their tasks.

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