Exploring the Four Social Bonds Evolvement for an Accompanying Minimally Designed Robot

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Abstract. In this paper, we investigate the effect of combining inarticulate utterances (IU) with iconic gestures (IG) in addition to the response mode (proactive or reactive) and its impact on the bonds formation as well as the establishment of a positive relationship between the human and the accompanying robot. Specifically, we employ different scenarios while measuring in each instance the different social bonds that occur and we evaluate the human-robot relationship (HRR) in order to pick the behaviors that yield a positive HRR. Experimental results show that combining proactivity with the full mode (IU+IG) leads to social bonds evolvement and then to a better positive HRR.

Keywords: Inarticulate utterance · Iconic gestures · Social bonds · Reactivity · Proactivity

1 Introduction

An accompanying robot that abides by human social rules is judged to be acceptable to humans. We think that such a robot may trigger positive behaviors in humans' and leads to a more positive HRR. Broadly speaking, in daily life, positive human behavior toward others is driven by the social bonding that evolves during their interactions and which as a result leads to a reciprocation of others' kindness with a noble feeling and/or act. Travis Hirschi's social bonding theory argues that people who believe in societal rules are attached to society and therefore, have a strong commitment in achieving conventional activities and reciprocating the positive gestures of others [1]. These people feel highly involved in their daily lives so they start to invest more time and energy in activities that serve to further bonds with others and this leaves limited time to become involved in deviant activities [2]. Chris et al. [2] highlight that people who have weak bonds are more likely to deviate from normal behavior and have bad relationships with others [2]. On these grounds, we can argue that if we measure robot's users social bonds, we can be capable of detecting the robot's behaviors that have the potential of leading to a better positive HRR. Hirschi defines four following social bonds: belief (B), attachment (A), commitment (C) and involvement (I) [1]. Chris et al. [2] argue that all

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these bonds are incorporated in Talcott Parsons' AGIL schema and, thus, the belief bond serves the function of latent pattern-maintenance (L), attachment to others, serving the function of integration (I), commitment proportional to the energy and time that one puts forward, serving the function of goal-attainment (G), and, involvement, consisting of the extra time and energy that one affords and serves the function of adaptation (A). The AGIL paradigm highlights the societal functions that, every society must meet to be able to maintain a stable, flourishing social life. Therefore, if we assume that we want to establish a stable, positive HRR, we must investigate behaviors that lead to social bonds evolvement during HRI in a way that can guarantee users and accompanying robots integration (attachment), goal attainment (commitment), adaptability to each other (involvement) and support of implicit social norms (belief) [2]. In the current study, we explore behaviors that lead to bonds formation in the context of interactions with an accompanying robot named ROBOMO. We are interested in understanding whether IUs or/and IGs, help to establish the social bonding between the human subjects and ROBOMO. If the social bonding is strong, then we may guarantee a decrease in the possibility of a robot's abundance which is by analogy to Hirschi's theory, the possibility of deviance. We detail the related work in section 2, explain ROBOMO's design in section 3, and explain the robot's architecture in section 4. After that, we describe the hypothesis and the experimental setup respectively in sections 5 and 6 while measurements are described in section 7. Finally, we give the results and insights obtained in sections 8 and 9.

2 Related Work

The concept of the accompanying robot (a robot functioning as a human peer in everyday life) is rapidly emerging. The accompanying robot must facilitate interaction with a human in order to complete a set of tasks. Many studies integrate multi-modal communication in order to satisfy human needs with regards to sociability and task achievement [3][4], etc. Ishiguro et al. [3] investigate the effectiveness of such multi-modal communication in order to explore whether the accompanying robot can help children improve their English ability. Garell et al. [4] utilize a group of robots in order to guide a group of people from a designated starting point to a specific destination. While the ability to perform a set of tasks skillfully is a desirable attribute, this alone does not cause humans to regards robots as partners. Humans do not evaluate their partners based on the success of task achievement alone. Instead, we believe that humans have to feel that a bonding and a stable positive relationship is maintained between themselves and the accompanying robot. As an example, children are likely to learn new concepts and still easily form bonds with a caregiver [5]. In such scenarios, children identify salient objects of a discussion, distinguish the different voices, express themselves using simple gestures, and show interest by picking up tonal differences [5]. Slowed voice tones (which we call in our study, IUs) help the child to bond with the caregiver. Thus, a mutual interest in communication evolves. Both parties can sometimes take the initiative (proactivity), proving their belief in the benefit of the interaction, instead of being only reactive (responsive) [5]. It is then a logical step to think about exploring the bonding between humans and robots that may evolve if we use IUs and IGs. When behaviors are designed adequately, a social bond may then evolve, resulting in people feeling more confident about integrating accompanying robots into their daily lives.

Many HRI studies have investigated if children can form relationships with robots, and if they can view them as friends. As an example, Stevenson et al. [6] show that children are willing to share secrets with robots and interact with them in a similar way as they would with an adult. Similarly, Swerts et al. [7] highlight that children consider playing with a robot like playing with a friend. Although there has been relatively broad research on the child-accompanying robot bonding, it has only dealt with the attachment bond; there is insufficient research that explores the entire evolvement of the four social bonds. Also, we need to investigate the formation of the four bonds between the adult and the robot rather than only between the child and the robot. In fact, Chris et al. [2] point out that the attachment bond is insufficient in predicting the nature of the human-society relationship and insist on the fact that four bonds must be explored for that purpose. Adding to that, little attention was paid to the bonding that may evolve in the context of a minimally-designed accompanying robot. Most of the studies we looked at, focused on the use of speech [3] or autonomous navigation [4] in order to increase a human subject's feeling about the consciousness and agency of the accompanying robot. We believe that bonding can evolve even within a simpler setting. For example, in a traditional adult-child interaction, the caregiver only needs to hold a baby without walking or talking and still the caregiver can interpret the meaning and feel the bonding with the baby [5]. Following the same strategy, we adopt the minimal design concept that it is proposed by Okada et al. [8]. This minimal design concept consists of designing a simple robot in terms of anthropomorphic features as well as the number of communication channels used. In this vein, our goal is to investigate the effect of using proactivity and/or reactivity as an interaction mode as well as the effect of using few communication channels such as IGs and/or IUs on the bonding formation while keeping in mind a strong bonding evolvement is an indicator of a positive HRR.

3 ROBOMO Concept Design

ROBOMO has a long shaped body with no arms. We have intentionally given ROBOMO a pitcher plant (Nepenthe) appearance to encourage people to interact with it much as one might interact with a young child (Fig.1). The IUs were produced according to the generation method for IU described by Okada et al. [9]. Three behaviors were exhibited: (i) the IUs:yes, no, right, left, back, forward, go, stop, slow down (ii) the tone:happy or sad based on the user's previous step correctness and (iii) IGs: turn left, turn right, yes (to implicitly mean "go"), no (to implicitly mean "stop"), bow to the front, bow to the back, face tracking (is used in S3 and S4 when the person has to slow down). A user can ask the robot to give

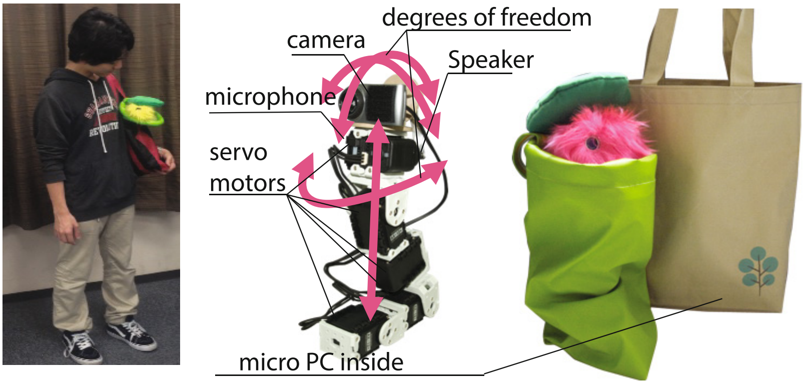

Fig. 1. ROBOMO's design

information about the direction (reactive mode). When the robot automatically helps the user, it is called a proactive robot.

4 ROBOMO Architecture

To communicate with ROBOMO, the user has to communicate slowly so that the robot, using its internal microphone and Julius (a Japanese word recognition software)[1], can interpret and satisfy the user's request. ROBOMO tracks the user's face using a web camera (Fig.2). ROBOMO integrates a micro PC to adapt to the user's request and affords an answer through its speaker. Moreover, it uses five servo-motors (AX-12+) to exhibit the gestures described in section 3 ([10]).

5 Hypothesis

We believe that being reactive proves that there is at least a minimal interest in the interaction with the robot and we expect that being proactive shows that one is goal-directed and actively taking charge of the situation. Thus we summarize our first hypothesis as follows:

- H1: ROBOMO should behave proactively when suggesting help. (Proactivity versus Reactivity)

The current study also focuses on another design choice, one the concerns the usage of iconic gestures and/or IU that can possibly be integrated in the character of an accompanying robot. This is why we want to investigate:

- H2: To guarantee a more positive HRR, the robot has to use only IUs, gestures or a full mode (gestures+IUs).

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[1] Julius is a continuous real-time speech recognition decoder for speech-related studies that does not need training.

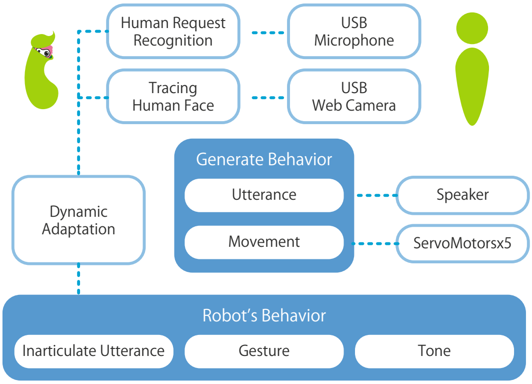

Fig. 2. The system architecture of ROBOMO.

6 Experimental Protocol

We setup an indoor ground for navigation tasks that contained intersections (Fig. 3). To pick the right behavior, the participant is instructed by the robot. We asked the participants to talk to ROBOMO slowly whenever they believed that they needed the robot's help. There was no training period in which the participants were familiarized with the task and/or the robot. Users could ask about directions or the traffic light[2] color in order to complete the task and reach the reward (music CD) location. Users were to ignore the reward location and only rely on robot's directions in order to reach it. 20 participants with ages varying from $[22 - 30]$ years old, took part in four scenarios. We have chosen several different configurations[3] during the four non contiguous scenarios to guarantee the diversity of the participants' responses. This also helped to ensure that any successful guess in the meaning of ROBOMO's behaviors was not related to the fact that participants were accustomed to the same configuration. In our scenarios, if the human did not understand the robot's response, he/she would repeat his/her question within a short time for direction confirmation. In each scenario, the participant interacted with ROBOMO for at least two minutes and then answered the questionnaires indicated in the section 7. After two days, the human subject came again for the second session. As a result, the experiment took twelve days to be completed (four scenarios in total). We designed four different scenarios of interaction: for scenario 1 (S1), the robot adopted a reactive mode using IUs; during scenario 2 (S2), the robot adopted a proactive mode using IUs; during the scenario 3 (S3), the robot adopted a proactive mode using IGs; during scenario 4 (S4), the robot adopted a proactive,

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[2] We increase the number of traffic lights by 2 in each new scenario and we change it positions. So in S4, we have 8 traffic lights.

[3] In each new configuration, we increase the target path's complexity and we change the starting location.

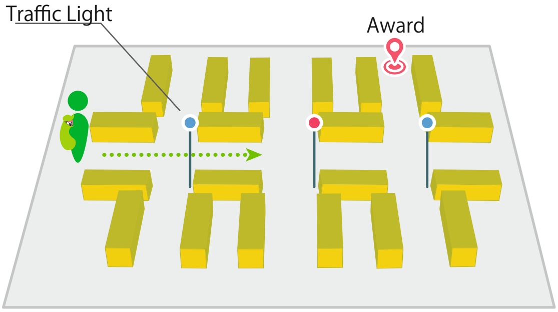

Fig. 3. The experimental setup.

full mode (IUs+IGs). The whole experiment was video recorded so that the users' facial expressions[4] could be detected.

7 Measurements

To measure the social bonding we established, based on each of the bond's definition a set of subjective and objective metrics. As we assumed that the belief bond corresponds to the latent social laws, we associated the belief bond[5] to the human's belief in the robot's social presence and it conscious agency. We then calculated the instances of eye contact, the rate of respect[6], the number of averted gazes, and, finally, cooperation metric (a 7 point Likert-scale questionnaire inspired from [11]).

As the attachment bond[7], is the emotional link that may evolve during the HRI, we used a different 7 point Likert-scale metrics, one that included : the pleasure [12], caring [13], perceived closeness [11], stress-free [11] and likeability[14].

The commitment bond[8] involves time, energy and effort expressed in conventional lines of action to achieve the task goals. To measure this commitment, we measured cognitive effort using a 7-point Likert-scale with the following metrics: arousal [12], mutual attention, users evaluation of the robot's "cognitive" effort through perceived competence [13] and perceived intelligence [14]. We also measured the user's: successful cognitive effort[9], expanded energy (physical effort

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[4] Features used to determine the facial expressions are the lips, eyebrows, eyes.

[5] Survey for the belief bond:http://goo.gl/forms/GkJzXrMmUt

[6] Rate of respect= number of times the human asked the robot/number of total times the human should have asked the robot (a specific number for each configuration). It gives indirectly an idea about the overall system's performance and the participants' ability to understand the feedback (intelligibility).

[7] Survey for the attachment bond:http://goo.gl/forms/eoikVunVjG

[8] Survey for the commitment bond:http://goo.gl/forms/ItqTMqKVpU

[9] Successful cognitive effort= successful interactions/ total number of interactions. It gives indirectly an idea about the overall system's performance and the participants' ability to understand the feedback (intelligibility).

rate[10]) and time (interaction time). Achievement was also measured (achievement [11]) just like Tanioka and Glaser [15] used achievement scores to measure commitment bond in schools. Finally, we asked users to describe their experience with the robot (situational empathy) just like Lasley et al. [16] used self-report descriptions of high school students to assess their evaluation of the attainment of good grades. In our case, the human subject was required to talk about the most prominent achievement that he believed the HRI succeeded in attaining.

The involvement bond[11], is closely tied to the commitment bond in that it entails the actual amount of extra expanded time a human takes to pursue the HRI. It is also an indicator of the human's adaptation according to Chris et at [2]. It focuses on the idle time available when one is not engaged and the effort expended during that extra time. We used different 7-point Likert scale questionnaires to assess the involvement bond through different metrics: positive and negative human faces support [17]. Positive and negative human face support consists of supporting a user's social needs in terms of involvement during the HRI [18] (indicators of human's adaptation to the HRI). To ensure that the subjects were not getting accustomed to their surroundings, we asked the users whether they felt used to the task (adaptability [11]) so that we can discard any user who confirms that he get used to the environment of the experiment. We also calculated the number of times eyes were wide open (surprised), corners of the mouth were turned upwards (disgust), one eye brow raised (wondering) and mouth corners raised (happy) since these are optional behaviors that the human is not obligated to express and which indicates that he/she is emerged by (involved in) the HRI.

Finally, deviance[12] (not a bond) may be translated in the context of HRI as one's refusal of interacting with the robot. Based on this definition, we devised a measurement for persuasiveness. We instructed subjects to arrange a list of words according to their own priorities and then we calculated the level of persuasiveness using Kendall-tau distance metric [19]. We measure also trust [13]and the long-term use [11]. In fact, by measuring the different social bonds, we may be able to conclude whether there is a positive or a negative HRR. To confirm so, we tried to establish a correlation between the evolvement trend (positive or negative) with the deviance values. If, for example there were no positive evolvement in the bonding, we may draw a preliminary conclusion and say that there is a negative HRR. By combining this conclusion with deviance results, we may be able to confirm this insight (a negative HRR evolved).

8 Proactivity versus Reactivity

Results comparing the four bonds values of the first two scenarios (S1 and S2) are represented in Table 1 . We used two gray scales to color the cells, corresponding

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[10] Physical effort rate= number of steps/ total number of due steps (a specific number for each configuration). It gives indirectly an idea about the overall system's performance itself and the participants' ability to understand the feedback (intelligibility).

[11] A survey of the involvement bond:http://goo.gl/forms/YUCtIVuNz0

[12] A survey of the deviance:http://goo.gl/forms/M7DWeM1mqO

to an increase in the metric values. For example, if the percentage of participants whose metric values in S1 exceeded the values in S2, we used the light gray color; we used the darker gray in the reverse situation. The t-test results comparing the reactive and proactive conditions (S1 and S2) show that there was an increase in most of the bond values when the robot was in proactive mode (S2). Consequently, we may give a preliminary conclusion by saying that a proactive robot leads to a more positive HRR. The averted gaze metric had higher results during S1 which shows that users were avoiding the robot more during S1 in comparison to S2. We also noticed that there were no significant differences in terms of the number of times the mouth corners raised (disgust) and the eye brows were raised (wondering) which indicates that users most of the time were showing the same level of negative feelings. As we had better results in S2, we can confirm these by comparing the bonds evolvement increase in S2 with the three metrics: trust, persuasiveness and long-term use that we have better positive HRR when the robot is proactive. This suggests that using a proactive accompanying robot is more adequate to trigger more bonding between the human and the robot and this leads to a more positive HRR (H1 investigated).

9 Comparison of Proactive Full Mode with IU-Based and Gesture-Based Communication

One-Way ANOVA and Tukey HSD results comparing the four bonds values of the last three scenarios (S2, S3 and S4) are represented in the Table 1 (IUs vs IGs vs full mode(IUs+IGs)). We colored the cells gradually with gray to indicate the increase in the metric values for S2 (S2 the lightest, S4 the darkest). For example, if the cell is colored with lightest gray and we were comparing S2 and S4, then that means the percentage of participants had results in S2 that exceeded the results in S4, and vice versa. Table 1 shows that there was an increase in most of the bonds metrics in S4 (the dark gray color prevailed in Table 1; significant Tukey HSD results also given). There were no differences in terms of successful cognitive effort when comparing S2 and S4 (F-test=5.681; p-value=0.006) HSD [S2 vs S4]=0.218, which shows that the added gestures in S4 were not responsible for IUs understanding (users could understand the IUs since S2). IGs, too, were considered to be expressive enough, as there were no differences in successful cognitive effort, when comparing S2 and S3 (HSD[S3 vs S2]=0.220). We can also point out that there were no differences in terms of persuasiveness between S2 and S3, which highlights that using the IUs or IGs is already enough to make the robot convincing for the user. By comparing S2 to S4 or S3 to S4, we see that users find the robot more persuasive when it combines the IUs and IGs instead of using the IGs and the IUs separately. This highlights that the full mode (IUs+IGs) guarantees better persuasiveness. By comparing S2 to S3, we see that most of the S2 bonding-metric results were higher than or the same as the results in S3 except for averted gazes (F-test=3.543; p-value<0.001;p-value<0.001) which were higher in S3. This means that a silent robot was not as appealing to the users.

Table 1. The comparison results of S1 and S2 (2 tailed paired t-test, df=19, alpha=0.05: proactivity vs reactivity) as well as comparison results of S2, S3 and S4 (One way ANOVA and Tukey-HSD tests: IUs only vs IGs only vs full mode (IUs+IGs)) with "p." stands for "perceived.", "E" "evolution" (the % of participants whose metric results increase in S1 or S2), "N/A" refers to cases when further statistical tests were not warranted (F-test was not significant) and 3 gray scales to color the cells corresponding to an increase in the metrics values with light gray corresponds to S1 and the darkest gray color to S4.

		proactivity vs reactivity			IU vs Gestures vs full mode				
	Metrics	t-test	p-value	E	F-test	P-value	S2 vs S4	S2 vs S3	S3 vs S4
B	eye contact	3.3441	0.0034	85%	185.023	< 0.001	< 0.001	0.055	< 0.001
	averted gaze	6.2056	0.0001	65%	63.714	< 0.001	< 0.001	< 0.001	< 0.001
	cooperation	5.977	0.002	95%	55.541	< 0.001	< 0.001	0.006	< 0.001
	respect rate	8.3533	0.0001	5%	117.163	< 0.001	< 0.001	0.033	< 0.001
A	pleasure	5.2248	< 0.001	85%	94.709	< 0.001	0.001	< 0.001	< 0.001
	likeability	2.4982	0.0218	100%	129.041	< 0.001	< 0.001	0.003	< 0.001
	stress-free	4.1944	0.0005	100%	111.309	< 0.001	< 0.001	< 0.001	< 0.001
	caring	10.2172	< 0.001	95%	148.371	< 0.001	< 0.001	< 0.001	< 0.001
	p.closeness	3.5962	0.0019	75%	92.224	< 0.001	< 0.001	< 0.001	< 0.001
C	mutual attention	18.4042	0.0001	90%	30.852	< 0.001	0.006	< 0.001	< 0.001
	interaction time	13.4509	0.0001	95%	187.142	< 0.001	< 0.001	0.005	< 0.001
	achievement	10.8076	0.0001	65%	12.418	< 0.001	< 0.001	0.538	0.001
	p.competence	7.5597	0.0001	95%	49.323	< 0.001	< 0.001	0.965	< 0.001
	p.intelligence	2.5696	0.0188	95%	41.216	< 0.001	0.001	< 0.001	< 0.001
	physical effort	11.2489	0.0001	90%	85.763	< 0.001	< 0.001	< 0.001	< 0.001
	cognitive effort	4.8221	0.0001	95%	5.681	0.006	0.218	0.22	0.004
	arousal	2.8961	0.0093	100%	13.11	< 0.001	0.009	0.114	< 0.001
I	Wondering	1.73	0.092	N/A	0.221	0.803	N/A	N/A	N/A
	Surprise	2.9043	0.0091	25%	0.662	0.52	N/A	N/A	N/A
	Disgust	0.5125	0.6142	N/A	1.834	0.169	N/A	N/A	N/A
	Happy	2.4047	0.0265	N/A	32.309	< 0.001	< 0.001	< 0.001	0.009
	adaptability	4.7618	0.0001	100%	37.487	< 0.001	< 0.001	0.931	< 0.001
	HPFS	6.7219	0.0001	100%	211.405	< 0.001	< 0.001	0.313	< 0.001
	HNFS	12.4617	0.0001	55%	246.403	< 0.001	< 0.001	0.983	< 0.001
D	persuasiveness	2.8536	0.0102	55%	5.343	0.007	0.697	0.059059	0.008
	trust	3.0	0.0074	80%	20.643	< 0.001	< 0.001	0.999	< 0.001
	long-term use	23.8471	0.0011	50%	29.807	< 0.001	< 0.001	0.446	< 0.001

By combining the three Tukey-HSD comparisons, we can deduce that, for most of the bonds, we have higher bonding results in S2 compared to S3, and in S4 compared to S2. In summary, IUs were sufficient to make the robot persuasive and the communication meaningful, but it appears to be that adding synchronized IGs to the IUs makes the robot aesthetically more appealing in terms of behavioral design. These insights are in line with the participants open-responses (situational empathy), with one of the participant indicating: "In this last day, I felt that the robot was more human-like and smarter in comparison to the previous times, since it can synchronize what it says with added body movements." As the bonding had high results in S4, and by comparing these results with deviance results we can conclude that, from a behavioral design perspective, it is better to integrate a full mode (IUs+IGs) for accompanying minimally designed robots as it may guarantee strong social bonding evolvement and a more positive HRR (H2 investigated).

10 Conclusion and Future Research

Our study explored the human bonding with a robot as a reciprocation to the accompanying robot's different exhibited behaviors and functioning modes. We tested two functioning modes: proactive and reactive. Results suggest that humans overwhelmingly prefer the proactive mode to the reactive one. Moreover, when interacting with an accompanying robot, users seem to prefer a combination of the robot's gestures within the context of the conversation (full mode); this was pointed out to be more aesthetically appealing. In the future, we intend to investigate the proactive full mode under two conditions of robot's operation: advice mode (the robot can give advice to humans) and prosocial mode (the robot needs help from humans).

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