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Designing motivational robot: How robots might motivate children to eat fruits and vegetables

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***Abstract*— This study contribute toward the creation of social robots as personal and public assistants. The ability of the robot to persuade and motivate people to follow a given behavior is of particular relevance in several cases, especially those related to people's health recover and maintenance (e.g., personal trainer, diet coach, etc.). In this paper, we evaluated the effect of a humanoid robot's use of verbal and bodily features and behaviors in motivating 80 children (age: 8-9 years old) in following healthier lifestyles (namely eat more fruit and vegetables). The results confirmed the hypothesis that the use of such motivational cues significantly improves the persuasiveness of the robot. Moreover the results highlighted a higher impact of the verbal cues implementations, which is in contrast with previous studies.**

I. INTRODUCTION

Research shows that humanoid robots can be employed as social agents, for their ability to create a bond with human users. The vision which inspires this work is that robots might become important motivator for children to learn and maintain healthy lifestyles. Some experiences in this directions were already proposed in literature in several contexts: education [1], well being [2], health [3], etc. However building motivation to follow healthy lifestyles (especially with healthy children) is not an easy task in general. Several theories and models are available in literature, but the authors selected as a reference the meta-model proposed in [4].

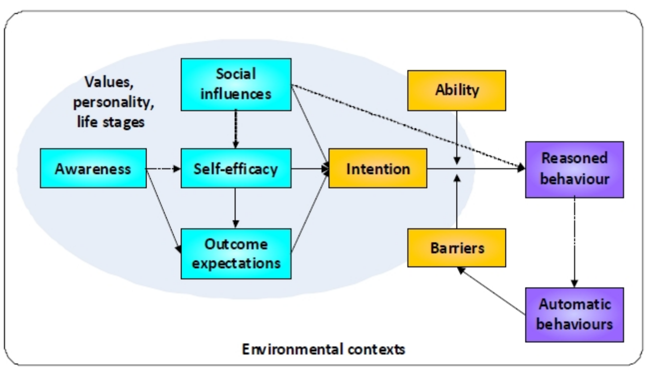

Fig. 1. Meta-model for building motivation.

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The model is summarized in figure 1, and describes how motivational strategies toward healthier lifestyles should be implemented to create behaviors (reasoned behaviors) and maintain them over time (automatic behaviors). The first step is to build awareness, namely make people understand the impact of the daily choices with respect to their health status. Awareness alone is not sufficient to build the actual intention to behave correctly: social influences and support must be addressed and included in a possible motivational intervention, person's self-efficacy must be enforced (i.e., her belief in her potentialities in adopting a specific behavior), and outcome expectations must be managed (i.e., expectations might motivate the person to pursue a goal, but also be demotivating if they are unrealistic or the person doesn't achieve them as fast as she expects). Furthermore all the aspects just mentioned are influenced by personal values, personalities and the life stage in which the person is (e.g., clearly children have different priorities than adult, or elderly, etc.). Once intention to behave is built, there might still be barriers toward its adoption (e.g., poor income, lack of proper infrastructure, like sport facilities, etc.) and the person must have (or be provided with) skills and abilities to actually perform the behavior. Negative automatic behaviors (i.e., bad habits) might be a strong barrier too. The latter elements (barriers and abilities) are influenced by the environmental context in which the person lives (e.g., living in a big city, rather than in the country side, etc.).

The assumption of the current work is that the robotic companion might have a positive persuasive effect by means of creating a bond with the child and acting on the social influences ([5]). This effect can be used to build the intention and motivation.

II. BACKGROUND

This work builds mainly on previous studies on designing persuasive robots [6], in which the ability of the robot to convince people to rank the items in an hypothetical Desert Survival Problem [7]. The limitation of that study was that the persuasion was on a "virtual" decision, without any practical impact on the daily life of the participants. The aim of this study is to repeat as much as possible the experience with a choice which has to happen in the real world. To achieve this goal we designed a set of verbal and non-verbal behaviors for a humanoid robot, and evaluated the effect of these behaviors with an experiment in a primary school in north of Italy with 8-9 years old children.

The perception of closeness (immediacy) is communicated through a variety of nonverbal behaviors and is positively related to learning and motivation in human-human interactions [8]. Previous studies [6] tried to implement the same immediacy in human-robot interactions by modulating both verbal and non-verbal (bodily) features. In particular gaze, proximity and gestures where used as bodily cues and demonstrated to have an effect on the persuasion of human subjects. The importance of gaze behavior was demonstrated by [9], and the use of eye contact was used also by [10] as a strategy to create engagement with autistic children. Furthermore [11] demonstrated that the combined effect of gestures and gazing on persuasiveness was greater than the effect of either gestures or gazing alone.

As far as the verbal cues are concerned, the speech accommodation theory [12] (SAT) was used to decide modulation in voice parameters which gave more expressiveness to the robot. SAT is a theory which focuses on the cognitive and affective processes underlying individuals' convergence (or divergence) through speech modulations. Furthermore it was demonstrated in previous works that the repeated use of child's name during an interaction lead to higher relatedness, helping to create and maintain the bond between the robot and the child [13][14].

The next chapters will describe the research hypothesis, the methodology to verify them and the results of the experiments.

III. Goals and Hypotheses

The goal of the study is to create a robot which is able to persuade the children to follow healthier lifestyles and be more active in their self-care. Based on the background presented above, we formulated two main hypotheses:

1) The use of motivational cues (both bodily and verbal cues) will improve the success of the robot in persuading the children to achieve a more challenging goal.
2) Compliance with the robot's suggestions will be higher when the robot employs bodily cues only, rather than when the robot uses vocal cues only (based on [6]).

It is important to notice that actual behavioral change in 8-9 years old children is a hard task to achieve, especially because in many lifestyle related aspects they are not the main player (e.g., most of times it's not the children the one who decides on what to eat for the main meals). However at that age it is anyway very important to build awareness of the impact of daily choices on health (see the model presented in section I). Moreover it is hard to reliably collect nutritional diaries for 8-9 years old children, as compliance with filling the diary (they often forget to do it), accuracy of the information reported (e.g., correct assessment of food quantities and portions, problems in remembering what they ate the day before, etc.) and truthfulness (e.g., desire of the children to appear better than they are might influence them in cheating on the diary) are important barriers to have an appropriate measurement tool.

For these reasons, and to provide measurable and objective results, the study did not focus on the actual behavioral change (i.e., on what children eat at home), but rather on the robot's ability to motivate/persuade children in changing behaviors (i.e., what they promised to the robot that they would have done).

IV. Methodology

In order to verify the hypothesis, an experiment was set up in the frame of an educational intervention done in primary schools in Italy. The educational intervention involved children in 3rd and 4th grade (N=80) in the participation to classroom lessons related to nutritional healthy habits (in particular fruit and vegetables intake). The lesson was structured with the concept of "learning by playing", with the whole class participating to a game which helped to discover all the different aspects of appropriate fruit and vegetable diet. Children were then asked to set a personal goal, of course related with the topics of the lesson (e.g., increase daily fruit and vegetables intake from 2 to 3 portions, etc.), to be then verified after some days.

This intervention was improved with the introduction of a humanoid robot, model NAO, from Aldebaran Robotics[1]. The robot participated to the collective lessons, by means of supporting the teachers in executing the educational game. In a second phase, the robot discussed individually in a separate room with each child the goal she set, and it tried to persuade her to improve her personal goal (i.e., make it more challenging) independently from the difficulty of the self-set goal.

Following the experimental design of [6], we designed a two-by-two between-participants study, creating four conditions by manipulating the verbal and nonverbal cues that the robot employed. What verbal and bodily cues are is described by [6], and their implementation for this work is better detailed in subsection IV-A.

The novelty with respect to the experiment made by [6] is twofold: 1) the experiment was made with children and 2) the robot was trying to persuade the children to do something in the real world. The latter indeed is of particular importance, as the main limitation of the previous study, as identified by the authors, was that the decision was purely hypothetical, so the persuasive effect on real-world situations was unknown.

The study was designed to have the same number of children in the four groups (the two-by-two conditions), thus all the groups using the robot had N=20 children each. All children were randomly assigned to each group depending on the gender (meaning that boys and girls had separate random assignment) by means of throwing a dice, in order to have the same number of males and females in the different groups. The randomization has been done in each school class participating to the experiment.

The groups have been named for an easier understanding with a short name which summarizes the condition (V = verbal cues; NV = no verbal cues; B = bodily cues; NB = no bodily cues).

Summarizing children were divided as reported in table I.

[1]http://www.aldebaran-robotics.com/en/

TABLE I
GROUPS AND EXPERIMENTAL CONDITIONS

Group	Name	Robot	Verbal cues	Bodily cues
1	NV+NB	Yes	No	No
2	V+NB	Yes	Yes	No
3	NV+B	Yes	No	Yes
4	V+B	Yes	Yes	Yes

A. *Robot's behaviors*

The set of actions was coded using Choregraphe[2], through which it was possible to create every single movement of the robot and generate simple blocks of behaviors, linking them in a flow style; specifically using Choregraphe it was possible to set the values of the joints and links and the parameters for the correct working (e.g. the pitch of the voice).

According to [6], the main actions were related to verbal and bodily cues:

- Verbal cues: two type of modulations were used, in the para-verbal parameters and in the contents of the dialog. For the para-verbal parameters, the speed and the pitch of the voice was modified in happier (faster and louder voice) or more sadly (slower and lower voice) sentences. As far as the contents were concerned, the verbal cues used in this experiment were given by more encouraging expressions used to convince the child to change the nutritional goal and the use by the robot of the name in the conversation [13][14]. Through Choregraphe, a set of specific sentences (e.g. "I believe that you can improve your life style, you can add more fruit every day! At least one more fruit!" vs "Why don't you add one more fruit?") was inserted.
- Bodily cues: in this category we manipulated gaze, the proximity and the gestures, as proposed by [6]. Gaze variable was manipulated by directing the eyes of the robot toward the face of the child when she was speaking as opposite to looking explicitly in another direction. This was obtained by a specific function in the interface, which allowed to manually change the position of the robotic head during the interaction. Proximity was modulated by changing the distance between the child and the robot: in the bodily cases (groups NV+B and V+B), the robot was in the personal space, between two and four feet from the person; in the non bodily cases (groups NV+NB and V+NB), it was in the social space, between four and twelve feet from the person (see Figure 2). The two different proximity conditions were obtained putting a desk between the position of NAO and the one of the child. Finally, the gestures were related to explanatory actions, which supported the sentences said by the robot; some specific behaviors were created in order to emphasize the persuasiveness of NAO during the discussion of the goal; in the non bodily cases (groups NV+NB and V+NB), the robot was in the sitting position almost without moving.

[2]http://www.aldebaran-robotics.com/en/Discover-NAO/Software/choregraphe.html

Fig. 2. Different proximity in the two conditions. On the left the robot is in the personal space, on the right the robot is in the social space.

All the variables are summarized in table II.

B. *Experimental task*

The experiment was carried out in a one to one interaction with each child, which lasted in average twenty minutes.The encounter was divided into the following parts: presentation, quiz, discussion, persuasion and final greetings. The initial presentation was led in different ways depending on the verbal cues variable: when instructed to use verbal cues, the robot looked at the child since she entered in the room, it presented itself and it used the name of the child during the interaction; in the other case, the robot was looking in another direction and after having asked the name to the child, it never used it again.

After the presentation part, the robot played a short quiz game with the child in order to be more acquainted with her. The game consisted in four questions made by the robot to the child. Each question had four alternative answers and the child had to guess the correct one. For each of them, a feedback and eventually an explanation was given after the answer. A similar game was already implemented and described in [13]. When the game was completed, no matter which was the final score, the robot pretended to notice that the child was carrying a piece of paper, with the nutritional goals set by the child.

Depending on the original child's goal, NAO suggested different ways to improve the goal: adding more fruit or vegetable, adding the goal to check fruit or vegetable's seasonality, adding one color to those she chose, or to try at least once during the week one fruit or vegetable that she didn't like. This discussion was the same for all the children in the different groups, while the robot's behavior changed depending on the four conditions. Furthermore the robot tried to improve the challenge of the child's goal independently from the original difficulty (e.g., to a child who decided to eat 10 portions of fruit and vegetable during the week, the robot proposed to go for 11, even if 10 would have been already an hard task).

Before the final greetings, NAO said to the child that it was happy if she maintained the new goal and it tried to encourage the child.

C. *Measurement*

The persuasiveness of the robot is measured by observing the children's goals sheets, which was compiled before meeting the robot (see figure 3).

TABLE II

MOTIVATIONAL BEHAVIORS AND CHARACTERISTICS

Cues	Implementation	Cue type
Familiarity	The robot use the child's name when referring to her	Verbal
Familiarity (Reversed)	The robot never use the child's name	Verbal
Encouragement	The robot uses encouragements when discussing the child's personal goal	Verbal
Encouragement (Reversed)	The robot doesn't use encouragements when discussing the child's personal goal	Verbal
Voice modulation	The robot modulates voice speed and pitch to express feelings	Verbal
Voice modulation (Reversed)	The robot uses a flat voice speed and pitch	Verbal
Proximity	The robot is in the child's personal space	Bodily
Proximity (Reversed)	The robot is in the child's social space	Bodily
Gaze	The robot always looks toward the child's face	Bodily
Gaze (Reversed)	The robot never looks toward the child's face	Bodily
Gestures	The robot uses gestures coupled with speech	Bodily
Gestures (Reversed)	The robot doesn't use any gesture	Bodily

Fig. 3. The paper sheet where each child wrote her own goal.

The goals sheet is an explicit child's promise to the robot (a sort of a contract) about a change in their fruits and vegetables intake during the next weeks. The goals' sheet presents some pre-compiled targets that can be selected and personalized by the child:

- I promise to eat fruits and vegetables every day
- I promise to eat N colors of fruit or vegetables every day
- I promise to eat N portions of fruits every day
- I promise to eat N portions of vegetables every day

The child was asked to select one or more target in the list, and to insert the numbers inside the sentences. Finally there was an empty space to propose another personal goal. After discussing with the robot the goal sheets were analyzed again. The scoring of the target are based on the difference of the target before and after discussing with the robot (i.e., if the robot managed to convince the child to pursue a more challenging goal).

Looking only at the interaction itself, it seemed that most of the children were convinced by the robot to improve their target. However only a subset of them actually modified their target on the goals sheet. For this reason the score was built with the items reported in table III.

TABLE III

SCORES ASSIGNED BASED ON THE OUTCOMES OF THE DISCUSSION ABOUT PERSONAL GOALS

Points	Items
0	If a child doesn't want to modify her target
1	The child accepts to modify the target, but she doesn't actually change it in the goals sheet
2	The child accepts to modify the target and updates the goals sheet

D. Software

All the robot's behaviors and Wizard of Oz software were developed with Aldebaran and Gostai development kits. The robot was controlled by a human operator in a Wizard of Oz mode, through interfaces developed with Gostai Lab[3]. The Wizard had four different interfaces for the four conditions. Figure 4, which represents the interface used in group 1, shows the main structure of the system: the screen was divided according to the main parts of the interaction: the setup of the variables of the robot on the top area of the screen; the introduction functionalities on the left side; the behaviors for the main interaction (quiz game, discussion and final greetings) in the center of the screen, divided in two groups for when the robot was in the standing (upper part) and sitting (lower part) positions.

Every button was programmed to load the behaviors created with Choregraphe, or to set some run-time parameters (e.g., the volume, the motors stiffness, the color of the eyes, etc.).

V. RESULTS

All 80 children participated in the experiments, divided omogeneously in the four groups, and well balanced between males and females. Children were randomly assigned to the four groups, randomizing males and females separately to

[3]http://www.gostai.com/products/studio/gostai_lab/

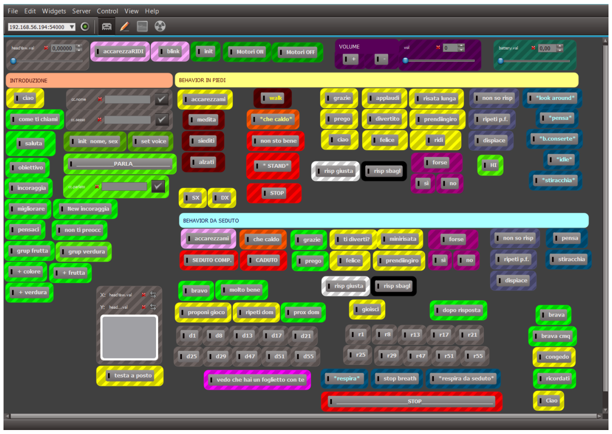

Fig. 4. Graphical interface for the Wizard of Oz to control the Robot.

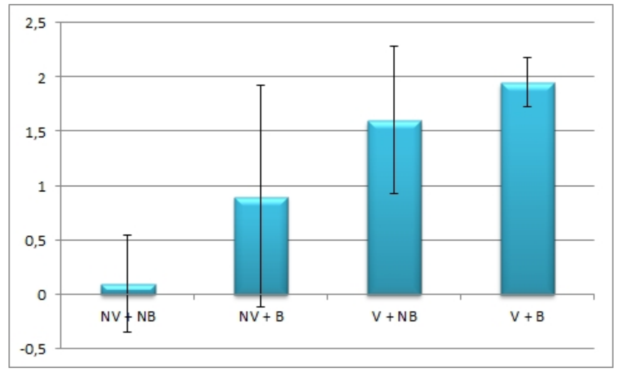

Fig. 5. The mean and SD of the motivational scores in the four groups. On the x axis the groups are reported, as defined in table I. The score is calculated based on table III. (V = verbal cues; NV = no verbal cues; B = bodily cues; NB = no bodily cues)

ensure a correct gender balance. The group were formed as reported in table IV.

TABLE IV
PARTICIPANTS TO THE STUDY, DIVIDED BY GENDER AND GROUPS

Groups	Males	Females
NV+NB	11	9
V+NB	11	9
NV+B	11	9
V+B	11	9

The simple scoring system created to measure motivation resulted to have high internal consistency (Cronbach alpha > 0.9). To analyze the data we performed two-way ANOVA to see how this score was influenced by the 2x2 conditions, and we noticed a significant effect both of verbal ($F(1,79)=74.091$, $p=0.000$) and body cues ($F(1,79)=15.069$, $p=0.0002$).

A further one-way ANOVA was performed to understand the difference between the use or not use of any kind of cues. For this analysis results of groups V+NB, NV+B and V+B were combined (i.e., any kind of modulation), and compared against group NV+NB (i.e., no modulation). Also in that case there was a significant difference ($F(1,79)=49.99$, $p=0.000016$) in the means of group NV+NB ($M=0.1$, $SD=0.447$, $N=20$ subjects) and the other three groups combined ($M=1.48$, $SD=0.83$, $N=60$ subjects).

Table V reports the means and standard deviations for the scores in the four groups.

TABLE V
MEAN AND STANDARD DEVIATIONS FOR THE SCORES IN THE DIFFERENT GROUPS

Groups	Mean	S.D.
NV+NB	0.1	0.447
V+NB	1.6	0.681
NV+B	0.9	1.021
V+B	1.95	0.224

The same data is also reported graphically in figure 5

Gender did not seem to influence significantly the results in any way. The score was meant to be a measure on how persuasive the robot was, not on how it actually changed the behavior of the child. The analysis of the results related to self-reported behavioral change with follow-up encounters (including a control group) is still ongoing, but that's out of scope for this particular study.

VI. DISCUSSION

The results obtained showed a clear difference between group NV+NB, not exposed to any motivational cues, and group V+B, exposed to motivational cues, goes from 0.1 to 1.95. Thus there is a clear indication that the motivational cues implemented by the robot played a strong role in persuading the children to pursue a more challenging goal, leading us to accept hypothesis 1. This was already demonstrated by [6] with adults on hypothetical tasks, and it is interesting to notice that this is confirmed also with children taking a personal commitment to change their nutritional habits at least in a given time frame.

As shown in Figure 5 also the difference between group V+NB (using bodily cues only) and group NV+NB is significant, despite the high standard deviations. This led to think that it is the verbal part which played a stronger role than the bodily part, contradicting hypothesis 2. This goes also against the findings in [6]. A possible explanation lies in the different implementation of the bodily cues, in particular related to touching, posture and facial expression, because of the specific physical characteristics of the robotic platform selected. Furthermore the verbal (and paraverbal) cues used in this study were probably more effective than in the previous ones. In particular: 1) the use of the name already demonstrated in previous studies [13][14] to be very effective to engage the child, and 2) the modulation of the voice used in response to positive or negative events (e.g., the robot expressing happiness when the child answers correctly to the quiz game) might have provided the feeling of being in front of an empathetic response, which have reinforced the bonding effect. The study of the latter verbal cue is a possible subject for a separate study.

Standard deviations are very high, and this is not a surprise as the scale is very simple and can comprise only three values (0, 1, 2). This is more evident in those groups where higher variability was found (i.e., groups V+NB and NV+B).

The fact that no significant difference was noticed between participants' genders (as opposite to what was demonstrated by [6]), might be due to the specificities of the selected ages (8-9 years old), where secondary sexual characteristics are not fully developed yet and social skills are almost the same for males and females.

The study has of course some limitations. The main one is that even if children are taking a commitment on an actual behavioral change, to be actuated in the "real world", this is anyway a child's promise with all the implications that carries (children may not be fully aware of the burden of the commitment, children might be promising things they do not intend to keep, etc.). Moreover the applicability of this persuasion is not automatically mapped into an actual behavioral change, because often children are not decision makers on their own diet, which is instead provided by parents, schools, etc. Finally the fact that the robot was able to persuade many children to improve their goals might be even more interesting if we include in the study the difficulty of the original goals. However this was not analyzed because of the complexity to objectively assess the difficulty of a goal for a child (e.g., ten portions of fruit and vegetables might be trivial for a vegetarian child, but very difficult for another one).

VII. CONCLUSIONS

The aim of the research presented in this paper is to create a robot which is able to build and maintain motivation to follow healthier lifestyles. The first step to work in this direction is the design of strategies to persuade human users to undertake behavioral change. We developed verbal (speak, speed and volume modulation, use of the name, encouragements) and bodily (gaze, proximity and gestures) behaviors and characteristics to make the robot more effective in this task, and we tested them with 80 children.

The results confirmed that the strategies to design persuasive robots are suitable not only with hypothetical choices but also with actual choices in the real world. With respect the previous studies on persuasiveness it was found that the verbal cues implemented were more effective than the bodily cues. This could be due to the different target of the previous studies, but also to the specific strategies implemented in these experiments. In particular the use of the name already demonstrated in the past to be effective in the creation of the bond with the child [14], but this study found that it can be used to increase the persuasive effect. Moreover the robotic "empathic" reaction seemed to play a role to which could be further investigated in feature studies.

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