Evaluation of Emi interaction with non-disabled children in nursery school using wizard of Oz technique

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***Abstract*— Research in the field of emotional interaction is discussed here, for the EmotiRob project, to maintain interaction with children in the 4-to-8 year old age range. The objective of this project is to give comfort to vulnerable children and/or those undergoing long-term hospitalisation through the help of an emotional robot companion. The studies carried out on perception and emotional synthesis have allowed us to develop an experimental stuffed robot Emi, using an emotional model, iGrace, allowing for emotional reaction based on the speech of the user. This paper briefly presents the EmotiRob project and how emotion has been used for Emi. The last experiment done with children to evaluate their interaction with Emi is then described.**

I. INTRODUCTION

A new challenge in Robotics is to create systems capable of behavior enhancement due to their interaction with humans. Research work in psychology has shown that facial expressions play an essential role in the coordination of human conversation [1] and constitute an essential modality in human communication. Among the different experiments in this field, the first work of Shibata [2] and Breazal [3] clearly showed that companion robots could give a certain amount of moral and psychological comfort to those that are most vulnerable. Robots can play a role in both companionship and simulation.

In this context, the objective of the EmotiRob project is to design an autonomous stuffed robot with expressiveness, which may bring some comfort to vulnerable children (eg, children enduring long hospital stays). The design of a companion robot is justified by the fact that robots, which have hitherto been mostly used for industry, are now being used in domestic contexts. Domestic robots help provide services for everyday life. Thus, human acceptance of this type of robot is a very important issue for long-term interaction, as the robot is constantly present in the home. The robot does not only have to be ”perfect” in its tasks to be acceptable, it must also be able to communicate with people in a ”human” way. To make ”natural” communication possible for a robot, it has to be able to use traditional human communication means: gestures, speaking, writing, touch, etc. Furthermore, beyond carrying out the functions for which it was programmed, the robot must also be able to express emotions in return, including: feeling safe, calm, normal, warm, etc.

The first and second sections briefly present the EmotiRob project and how emotion is used in a stuffed robot. The other sections of the article describe the experimentation that has been done here to evaluate EmI-child interaction.

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II. EMOTIROB PROJECT

The EmotiRob project objective is to design an autonomous stuffed robot, which may bring some comfort to vulnerable children (eg, children undergoing long hospital stays). However, a too complex and too voluminous robot is to be avoided. The project aims to equip the robot with perception and understanding capabilities of natural language so that it can react to the emotional state of the speaker. EmotiRob also includes the conception of a model for the emotional states of the robot and its evolution.

Before beginning our project, we did two experimental studies. The first experiment [4] was carried out using the Paro robot to verify if reaction/interaction with robots depended on cultural context. This experiment pointed out that there could be mechanical problems linked to weight and autonomy, as well as interaction problems linked to the robot due to lack of emotions.

The second experiment [5] was to help us reconcile the restriction of a light, autonomous robot with understanding expression capacities. Evaluators had to select the faces that seemed to best express primary emotions of Ekman [6] among a list of 16 faces. It was one of the simplest faces that obtained the best results. With only 6 degrees of freedom [7], it was possible to obtain a very satisfying primary emotion recognition rate.

III. MODELISATION AND EXPRESSION OF EMOTIONS IN A STUFF ROBOT

What is an emotion for a human and how can a computer have this kind of emotion? This extremely complex subject of emotions in humans, and even more so emotions in robots, does not have unanimous conclusions. For example: are you first afraid when you see an animal and see it is a bear after; or do you see that it is a bear first and then become scared because it is a dangerous animal? The Emotirob project has thus proposed an emotion model, GRACE [8], [9], and a calculation method for emotions, iGrace [10], [11], and has implemented them into our robot EmI, which was made specifically to express simple emotions through facial expressions and the posture of its head in response to what it said to it.

The experiments conducted made it possible to validate the hypothesis of the model that was integrated in EmI. To avoid a phenomenon of repetition, a study on behavior dynamics and its evaluation were undertaken. As EmI was under construction during this study, a virtual avatar, Art-e, was created to represent EmI's conscience. Art-e has to display the same facial expressions as the robot, even though they did not have the exact same constraints. Art-e forwarded our work and tests on emotional dynamics, the good results of which were to be used by the robot. Art-e has five expressive components: eyebrows and mouth - which are the same as the robot - and eyes, head and trunk. Each component has a role when an emotive experience is displayed. It is based on the six primary emotions and neutrality.

IV. ROBOTIC CONCEPTION

After an advanced research study on perception and emotional synthesis, we determine the most appropriate way to express emotion and obtain good recognition of expression with our users. The first steps of the project [7] allowed us to determine the degrees of freedom required to express the six primary emotions of P. Ekman [6] and then start robotic conception.

A. Mechanical architecture

EmI, the robotic platform we built, is a stuffed animal with a pleasant texture that can emotionnaly react by using facial expressions and body movements. Research work on emotional synthesis allowed us to determine the different elements that make up the face and number of degrees of freedom necessary for the facial expression of the 6 primary emotions of P. Ekman. The face of the robot is composed of the following elements:

- 1 mouth: 4 degrees of freedom.
- 2 eyebrows: 2 degrees of freedom (1 per eyebrow).

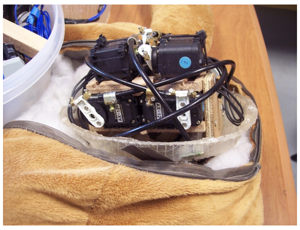
To these elements of the face, we added:

- 2 fixed ears.
- 2 fixed eyes.
- 1 camera at nose level to follow the face and potentially for facial recognition. The camera used is a CMUCam 3.

The material used for the skeleton of the head is made with epoxy resin for better resistance. Movement of the facial elements is done through a cable system (see Fig. 1) and springs to improve the expressiveness of the robot (videos can be downloaded on Website of the project[1]). The system used for the mouth is a spring system surrounded by a very elastic fabric.

To increase the expressiveness of the robot, we associated body movements to facial expressions. The architecture makes the following movements possible:

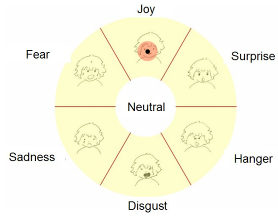
[1] http://www-valoria.univ-ubs.fr/emotirob/, menu Robot –> Video



(a) The cable system with the motors

(b) Emi entire conception

(c) Emi entire design



(d) Interface used to control EmI's expression

Fig. 1. Realization of the third version of Emi

- For the head: 2 degrees of freedom for right–left and up–down movement.
- For the waist, 2 degrees of freedom for right–left and up–down movement.

The skeleton of the torso is made of aluminium and allows the robot to turn its head from left to right, as well as up and down. It also enables the same movements at the waist. There are a total of 4 motors that create these movements.

The motors used for the head are AX-12+ and those for the torso are RX-24 (powerful). These motors allow for numerical communication with the computational architecture created here. The weight of EmI is currently about 2.8 kg.

EmI to play an emotional song, we substitute one of the motors (AX-12+) of the face with an AX–S1. This motor incorporates new features, like temperature and infrared sensors, a buzzer for some music notes, etc.

B. Computer architecture

Currently, communication with the robot is done through a distant computer directly hooked up to the motors. This computer used a process called *iGrace*, like the computational model of emotion we developed. This process was developed with the C++ language and used a FTDI library for communication with motors. This library makes it possible to send (and receive) instruction packets with motor identification, actions to be done, as well as the parameters for this action. The link between the motors and the computer is made with USB cables. The 6 motors for the head use a TTL connection and and those for the torso, RS-485. We need to use a USBDynamixel convertor for USB⇔TTL and USB⇔RS-485.

V. EXPERIMENTATION FOR EMI EVALUATION

This experimentation allowed us to evaluate the quality of interaction between Emi and non-disabled children from 3-

to-5 years of age attending nursery school. It was based on the new paradigm of the Strange Animal Situation test [12]

A. Children participants

Participants were 13 French children with typical development (7 girls and 5 boys) between 3 and 5 years old (mean $\pm$ SD: 4.41 $\pm$ 0.60 years). All of them lived in a rural area. The parents gave their written consent allowing us to film their children.

B. Experimental design

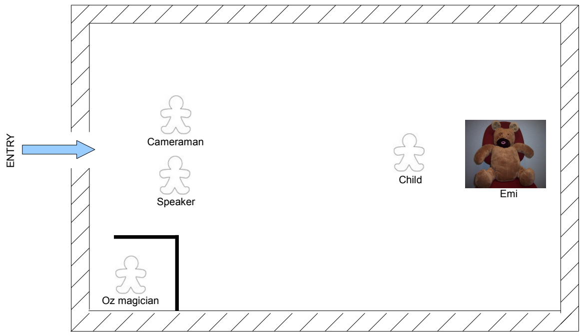


Fig. 2. Plan of the room we equip for evaluation

1) Equipment: The experimentation took place in an isolated room in the nursery school. The room was equipped before the child's arrival (Fig 2) with Emi on a chair, two cameras (one on a tripod facing Emi and one carried by a neutral cameraman) and the wizard of Oz device (i.e. a computer engineer with his laptop using the interface used to control Emi's expressions, Fig 1).

2) Experimental setting and data recording: First, all of the children together, in the classroom, were told Emi's story: "Emi is a little stuffed bear...he can understand what you say, move his head (by yes or no) and express emotions...he is coming today to see you". We informed the children that Emi was waiting for each of them in another room. Further information was given individually to ensure the child's understanding.

Before the experiment, each adult was instructed by the Speaker as follows:

- The Cameraman: her role was to record the child's behaviors. If the child spoke to him, he was to answer "I don't know. Ask "first name of the Familiar Adult" or "first name of the Speaker". He moved only if data loss was significant (e.g. child with his/her back to him).
- The Magician of Oz: his role was to manipulate the robot with his laptop's interface. If the child spoke to him, he would answer the same sentence as the Cameraman.
- The Speaker: her role was double. First, she ensured the good progress of the experiment. Second, she could comfort the child if he/she asked for it. She should not initiate interaction but she could answer the child's questions (i.e. in the simplest and quickest possible way without initiating discussion; e.g. ask a question in return).

All the adults remained neutral and silent in an unobtrusive place in the room (preferably behind the child and Emi). They should not interact between them (e.g. gaze, smile, speech). The same adults participated in all the experiments.

Before the experiment, the Speaker fetched each child in the classroom and gave him/her the following instructions before going into the experimental room. During the 5-minute experimental session, he/she was free to interact (or not) with Emi. He/she could behave as he/she desired (e.g. touch, kiss, speak, hold, stroke), included leaving the experimental room. We made it clear that no behavior was considered either right or wrong. During the experimentation, if he/she had any questions, he could ask them to the speaker (see above for explanations on their roles). The children were aware of the adults' presence, their roles, and that the experiment was video-recorded.

After giving the instructions to the child, the Speaker and the child entered the room. As soon as they entered, the Cameraman switched on both cameras and the session started. During the experiment, Emi was seated on a chair and manipulated at a distance by the Magician of Oz. The Speaker stopped the experiment after 5 minutes and left the room with the child. Before returning to the classroom, the child answered a short questionnaire.

C. Data collection and analyses

1) Questionnaire: Nine simple questions were asked (present tense was used to simplify the understanding of the questions; Table I).

TABLE I
ASKED QUESTIONS AND THE ASSOCIATED NUMBER

Number	Question statements
1	Are you happy to see Emi?
2	Do you want to see Emi again?
3	Do you want to take Emi home with you?
4	Is Emi alive?
5	Is Emi intelligent?
6	Is Emi kind?
7	Is Emi your friend?
8	Do you like stuffed animals?
9	Do you like robots?

To answer, the child used a graduated scale with a smiley (Fig 3). A negative answer was coded as -1, a neutral answer was coded as 0 and a positive answer was coded as +1. The maximum score is 9. Higher the score was, higher was Emi recognized as a companion. Thus, we had a general score as well as detailed results. We recorded his/her answers with a sound recorder to have spontaneous comments and explanations in context.

2) Video analyses: Video analyses were based on the 5-minute video-recordings. Only the child's behavior is considered here. We focused on latency of first touch (time in seconds between the entrance into the room and the first

TABLE II

BEHAVIORAL TERMS USED AND THEIR DEFINITIONS

Behavior	Definition
a. Vocal and verbal behaviors directed to Emi	
Talking to	Addressing to the *item* (i.e. adults or Emi), for instance, using the pronoun "you" (e.g. "you are so cute").
Talking about Emi	Talking about Emi to describe it (e.g. "it is so cute")
Exclaiming	Emitting shouts that expressed, for instance, excitement (e.g. "ooh, wow") when discovering Emi
Pointing	Using his/her forefinger to obtain a desired object or to share attention/interest about an event with others
b. Visual / facial behaviors	
Looking at	Directing gaze towards the *item* concerned (i.e. adults, Emi or nothing)
Smiling	Facial expression when the brows are not drawn together, but the corners of the mouth are retracted and raised [13]
c. Tactile behaviors	
Touching adult	Establishing physical contact with a present adult
Touching Emi	Physical contact between the child and Emi
Hesitation	Stopping or withdrawing hand before touching Emi
Self-centered gestures	All behaviors centered on self (e.g. "touching own hair")
d. Moving behaviors	
Moving	Change one's place in the room (e.g. walking, running)
Staying motionless	Being standing without motion and without gaze
Going out	Leaving the room

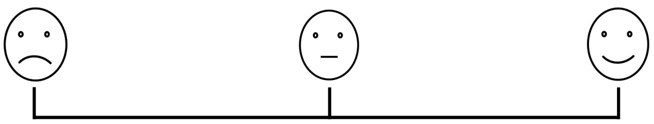


Fig. 3. Graduated scale for questionnaire

tactile contact with Emi) and on latency of leaving the room. Then, using instantaneous sampling [14], the rater recorded the distance between the child and Emi with 5-sec-intervals (i.e. 60 scans per child) in child's arm length (i.e. contact, 0 to $1/2$, $1/2$ to 1, 1 to $1\,1/2$, $> 1\,1/2$, out of the room). This method provides an estimation of child attractivity to the robot. Same analyze was done for the distance between the child and the Speaker. Then, we evaluated the nearest neighbor of the child (Emi or Speaker). With the same technique of instantaneous sampling, we recorded child's behaviors. The behavioral terms used and their definitions are in Table II (target was specified when useful).

The rater had experience in coding human-robot interactions. To calculate reliability, an additional rater coded 25% of the video recordings that were randomly chosen and evaluated according to the coding standards developed for this study. The degree of correlation between the two raters was established by calculating Cohen's Kappa. Our reliability was excellent (0.93 [15]).

Statistical analyses.
Data analyses used Minitab 15© software. The accepted P level was 0.05. Data collected were frequencies and time (latencies in seconds). As our data were not normally distributed, we used nonparametric statistical tests [16]: Fisher exact tests, Mann-Whitney U tests and Wilcoxon tests, for example, to study whether gender differences existed in the displayed behaviors.

VI. RESULTS

One boy and one girl turned down before the beginning of the experiment (both were afraid).

A. Questionnaire

The mean total score was 5.89 ± 2.20 (1-9). Figure 4 summed up the children's answers. All children were happy to see Emi that they considered as their friend (Q1, Q7) and they are agree about the fact that Emi was kind (Q6). Whereas all children said that they liked stuffed animals, only 7 of them like robots (Q8, Q9). Most of them said that Emi was intelligent (Q5) and would to take Emi home with them (Q3). At last, children's answers were much more mixed about seeing Emi again and the fact that Emi was living (Q3, Q4). Notice that one boy refused to answer the questions after seeing Emi.

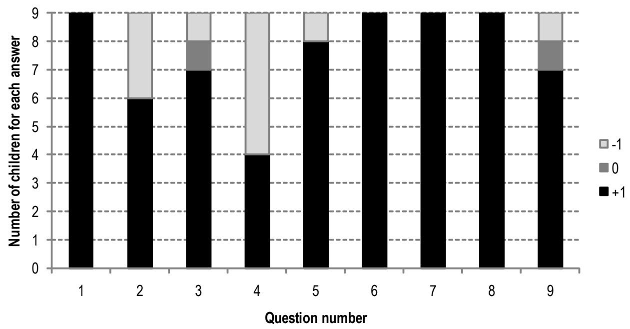


Fig. 4. Children's answers to our nine questions about Emi (the question's statements were gathered in Table I)

B. The encounter between children and Emi

Among the 11 children who were agreeing to encounter Emi, three experimental sessions were stopped by child's request (in mean, after 81.6 sec).

Most of the children stayed away from Emi (i.e. 88.05% at more than $1\,1/2$ child's arm). Only one girl stayed very close to Emi during all the experiment (less than one child's arm). The children's favorite position is faced to Emi (60.16%). Notice that 10% of the time experiment, children were with their back to Emi (9.76%). At last, the Speaker was mostly the nearest neighbor of the child (74.3%), especially for the girls (4/5 for the girls, 2/4 for the boys). No significant gender difference was found (Fisher exact tests and Mann-Whitney U tests, p>0.05).

In our experiment, children displayed six categories of behaviors: staying motionless, looking at, talking, touching, moving and displaying self-centered gestures (Fig 5). Mainly, the children were observers (looking at; 37.7%) with numerous self-centered gestures (38.1%). Then, they stayed motionless, without gazing (18.1%). At last, some behaviors remained marginal: moving (to enter and to leave the experimental room; 4.3%), talking (1.5%) and touching Emi (0.4%). Clearly, differences existed here between genders. Girls displayed more self-centered gestures than boys (Fisher test p<0.001). Boys moved more frequently than girls (Fisher test p=0.013), in parallel with the fact that girls stayed more motionless (Fisher test p=0.014). Interestingly, boys talked more than girls (Fisher test p<0.001).

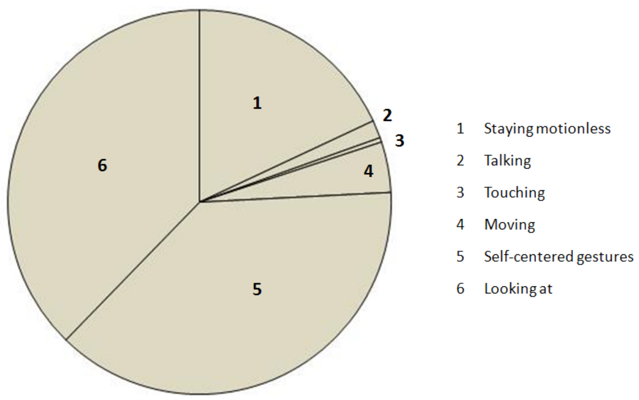


Fig. 5. distribution of the observed behaviors frequencies

The children had different target for their gazes: Emi, Speaker, Magician of Oz, Cameraman as well as no target (e.g. with downcast eyes; Fig 6). Interestingly, most children gazed significantly nothing during the experiment (40.0%, Wilcoxon's tests p<0.05; Fig 6). Emi was then the favorite target of their gazes (32.9%, Wilcoxon's tests p<0.05; Fig 6). No significant gender difference was found (Mann-Whitney U tests, p>0.05).

VII. DISCUSSION

A. *Children's reports and observations: two different points of view*

On the one hand, answers to our questionnaire illustrated that children were somewhat attracted to Emi and had a positive perception about him (e.g. happy to see Emi, considered as a friend). On the other hand, the observations showed a very different situation. Children did not seem ready to interact with Emi (e.g. long distance, no tactile interaction and no smile for the majority of children). This opposition is probably not inherent in our experiment. Indeed, research conducted with students showed that their

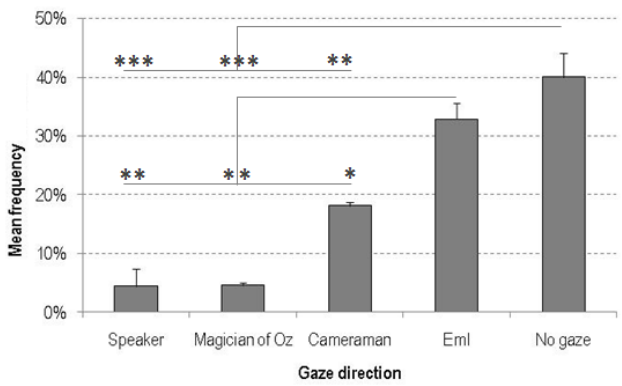


Fig. 6. mean frequency (%) spent by the children to gaze different targets. Level of significance: * p<0.05, ** p<0.01, *** p<0.001 (Wilcoxon's test)

expectations - measured with a self-administered questionnaire – were different from the observed behavior (Barbu, personal observations). Thus, it appears essential to link both the questionnaire and the observation methods, especially in the case of people with low cognitive abilities (e.g. very young children, elderly with Alzheimer's disease). Moreover, it is possible to complete these two methods by questioning a third person.

B. *Encounter Emi: a stressful situation?*

The observed parameters suggest that this encounter with Emi may be perceived as stressful by children. Indeed, they mostly remained aloof from Emi, being closer to the Speaker (possible source of reinsurance). They frequently displayed self-centered gestures, another indicator of stress [12], [16]. In extreme cases, they stayed motionless without gazing, sometimes even turning their back to Emi and asking to leave the experimental room before the end of experiment.

We can also explore the possible parameters of this stress: the camera presence (e.g. frequent glances toward the Cameraman), Emi (e.g. physical aspect, movements, absence of verbal behavior) or the protocol itself (e.g. child was alone, presence of three adults, Emi presentation). Some considerations must be undertaken to improve interaction between the child and Emi – and robots in general – especially if we want them to reach their status of companion robot.

But interactions with a robot for young children are not always stressful. For example, Melson et al. [13] found no apprehension when children encounter Aibo [17]. Nevertheless, we have no details about experimental conditions (e.g. are children familiar or not with the robot?).

C. *Children and robots, specific interactions*

In our study, children were mostly aware that Emi was not alive, showing that they distinguish the categories of "alive" and "not alive" [9], with a bias for the alive and animated (including animals [18], [19]. Melson et al. [13] compared attitudes expressed by children in kindergarten with both Aibo and stuffed dog. If the affective behavior does not differ in prevalence, behaviors of interaction initiation (e.g. talking to, throwing a ball) are 4 times more frequent with Aibo. Thus, we hypothesized that the movement capacities - Emi cannot move in space - and the robot appearance may participate in a stronger attraction of the child. Similarly, although infants acquire basic knowledge about emotions from the first month of life (Brun [20], 2001), we may raise the question of the skills development to process emotions produced by the robot (e.g. children aged between 6 to 8 years are able to discriminate Emi facial emotions [10]). Interactions underlie the emotion recognition (Boccia & Campos [21], 1989) and alterations in emotional processing are related to social interaction problems [22]. Thus, we assume that absence of close interaction may be correlated to the fact that children were unable to decode Emi facial emotions. Finally, robot technology should allow quite effective responses – in both quantity and quality - to maintain interactions with the human partner [23].

Few differences between girls and boys were observed, consistent with previous experiments (e.g. [13], [19]). However, we don't exclude that differences may have been erased by stress, leading to common behavioral responses displayed by both girls and boys.

VIII. CONCLUSION AND FUTURE WORKS

In conclusion, in this experimental situation, Emi doesn't seem achieve its goal of robot companion. If some parameters appear to inhibit the child interactive initiation, notice that companion status could only be achieved over the long term, when a relationship is established [24]. Therefore, repeated encounters and interactions with the robot must be considered. We rose here some ways of research. On the one hand, we want to improve the robot Emi and their interactional skills at the first encounter. For example, Emi may have verbal skills - even limited - that make easier the interactions (e.g. "hello", "how are you", "Come play with me").

On the other hand, we proposed to conduct change in the protocol to improve the well-being of the children in such situation. Therefore, our goal may be the encounter between Emi and children, for example, in group - and not alone.

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