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Analyzing children's expectations from robotic companions in educational settings

Maria Blancas[1], Vasiliki Vouloutsi[1], Samuel Fernando[2], Martí Sánchez-Fibla[1], Riccardo Zucca[1], Tony J. Prescott[2], Anna Mura[1] and Paul F.M.J. Verschure[1,3,5]

Abstract— **The use of robots as educational partners has been extensively explored, but less is known about the required characteristics these robots should have to meet children's expectations. Thus the purpose of this study is to analyze children's assumptions regarding morphology, functionality, and body features, among others, that robots should have to interact with them. To do so, we analyzed 142 drawings from 9 to 10 years old children and their answers to a survey provided after interacting with different robotic platforms. The main results convey on a gender-less robot with anthropomorphic (but machine-like) characteristics.**

I. INTRODUCTION

In the last years, the use of robots in educational settings has increased, as there is a belief that they offer a valuable benefit in terms of individualization, adaptability and monitoring of educational interventions [28]. Nevertheless, so far the attitudes of the main users in this context, i.e. children, are not systematically mapped. However, it is of great importance to understand children's expectations about robots and consider these when designing robots for educational purposes. Here, we aim at gaining a better understanding of children's needs and expectations from educational robot companions in terms of their appearance, characteristics, and functionality.

A. Human-Robot Interaction

Nowadays, the development of robots goes beyond utilitarian purposes: a change of paradigm is observed as robots with a more social character start to gain ground. As machines become more present in everyday life, they start to assume roles with a more predominantly social dimension: they interact on a frequent basis with humans. Indeed, the International Federation of Robotics (IFR) [20] predicts that approximately 40 million personal service robots are expected to be sold between 2016 and 2019 and most of these units are developed for household, entertainment and leisure tasks. It is therefore plausible to assume that one target user group will be children.

To socially interact with humans, robots need to recognize human social cues and respond accordingly [32]. The term "socially interactive robots" defines robots with social characteristics including the ability to perceive or express emotions, use natural cues, such as gaze or facial expressions, and establish social relationships. These features assist robots in peer-to-peer human interactions [16].

An anthropomorphized body ensures a better interaction between humans and robots, as sharing the same physical space and gestures helps establish common ground [23], [31], [10], [16]. Anthropomorphism also allows the robot to show facial expressions, whose importance as a communicative channel has been extensively defended [17], [24]. Other perceptual cues that facilitate Human-Robot Interaction (HRI) are related to non-verbal communication channels such as gaze, eye contact, gestures, imitation and synchronization [29], [25]. Eye contact is seen as a highly communicative indicator of attention and as a sign of presence of someone else [6]. In general one can speak of a social salience effect that depends on morphology, social cues and task capabilities [22].

Age and previous experience with robots have been found to influence the kind of features children expect from a robot [33]. For instance, human-like appearance is preferred by children younger than nine years old, whereas robot skills and functions are more appealing to older children and adults. Moreover, after interacting with a robot, children pay more attention to their motor abilities than to only their shape.

B. Robots in Educational Scenarios

In terms of expressivity in a learning task we can distinguish two types of robots.First, robots that mainly focus on knowledge transfer, and socially supportive robots that engage in active dialogue and supportive behavior towards the learner. The latter has been shown to positively affect the learning performances of children [31]. One of the main

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[1]Maria Blancas, Synthetic Perceptive Emotive Cognitive Systems (SPECS) group, N-RAS, Universitat Pompeu Fabra, Barcelona, Spain maria.blancas@upf.edu

[1]Vasiliki Vouloutsi, Synthetic Perceptive Emotive Cognitive Systems (SPECS) group, N-RAS, Universitat Pompeu Fabra, Barcelona, Spain vicky.vouloutsi@upf.edu

[2]Samuel Fernando, Sheffield Robotics, University of Sheffield, Sheffield, UK s.fernando@sheffield.ac.uk

[1]Martí Sánchez-Fibla Synthetic Perceptive Emotive Cognitive Systems (SPECS) group, N-RAS, and Engineering Information and Communication Technologies (ETIC), Universitat Pompeu Fabra, Barcelona, Spain University Pompeu Fabra marti.sanchez@upf.edu

[1]Riccardo Zucca Synthetic Perceptive Emotive Cognitive Systems (SPECS) group, N-RAS, Universitat Pompeu Fabra, Barcelona, Spain riccardo.zucca@upf.edu

[2]Tony J. Prescott, Sheffield Robotics, University of Sheffield, Sheffield, UK T.J.Prescott@sheffield.ac.uk

[1]Anna Mura, Synthetic Perceptive Emotive Cognitive Systems (SPECS) group, N-RAS, Universitat Pompeu Fabra, Barcelona, Spain T.J.Prescott@sheffield.ac.uk

[1,3,5]Paul F.M.J. Verschure, Synthetic Perceptive Emotive Cognitive Systems (SPECS) group, N-RAS, Universitat Pompeu Fabra, Barcelona, Spain, Catalan Institute of Advanced Studies (ICREA), Institute for Bioengineering of Catalonia (IBEC), The Barcelona Institute of Science and Technology. paul.verschure@upf.edu

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differences between the kind of behavior a robot should show in a school environment and other educational contexts such as a museum is duration and the nature of the interaction. The use of robots in schools requires ongoing participation, as the children the robot interacts with are always the same; contrarily, while when utilizing robots in other scenarios the interaction with the users is usually short lasting and transient [23].

C. Co-designing with children: Drawings' analysis

With the aim of developing an educational robot that both considers the findings in the field and meets children's expectations, we implemented an exploratory co-design method to understand which would be the required characteristics for such a robot. Co-designing technology with its potential users increases the probability that results will meet expectations. Thus, in case of education, children should be involved as co-designers of new educational technologies [11]. This is particularly significant when considering the age-related differences between the mindsets of the adults who typically design the technology and that of children who use it [27]. Indeed, a systematic age dependent anthropomorphic bias has been reported with the users of complex robot exhibition technology [13]. Thus, seeing children as robot co-designers allows us to better understand their point of view and gain insights into their specific needs.

In addition to age dependent effects also gender differences have been observed in the way children represent people and objects. Boys' drawings usually show the omission of arms, trunks, and clothing (however, these omissions decrease with age) together with an asymmetry in facial features as compared to girls [34]. However, they begin to draw movement before girls, for example, they draw limbs in positions other than straight-out.

Drawing can be used as a method of representing individuals' preferences and is in the co-design context a way for children to make sense of their experiences [1], [12]. It is also a useful method to evaluate children's perception, experience and understanding, as drawing is shown to be considered more enjoyable than answering questions [26]. Moreover, drawing is a task that allows to overcome linguistic barriers [8]. We thus asked children to design the robot they would like to have; this way, we can have a more effective intuition of their needs and expectations.

II. METHODS

This study was conducted in the form of school workshops at the Cosmo Caixa Science Museum of Barcelona (Spain). A total of 142 children (64 females) from Year 4 of Elementary school (9-10 yo) were divided into groups of 8-9 kids. At the beginning of the session, all the children were introduced to three different robots (Zeno -Robokind-, Nao -SoftBank robotics- and CodiBot -SPECS-) and freely interacted (in groups of three) with each robot for approximately four minutes. Subsequently, two kids per group were selected to individually interact with the Zeno robot to do an extra activity (explained in section *The healthy living task*). Additionally, we provided all children with colored pencils and sheets and asked them to draw the robot they would like to have. The drawing session occurred while each of the selected children interacted with the robot. An image of the robots and their location is provided in Figure 1.

Before the end of each session, all the participants were requested to fill in a questionnaire that contained the following information: gender, if they liked the activity, if they would do the activity again and if they would recommend it to their friends. Additionally, we asked them to order the three robots they interacted with by preference.

A. The Tools

1) Robotic Systems: All children interacted with the following robots:

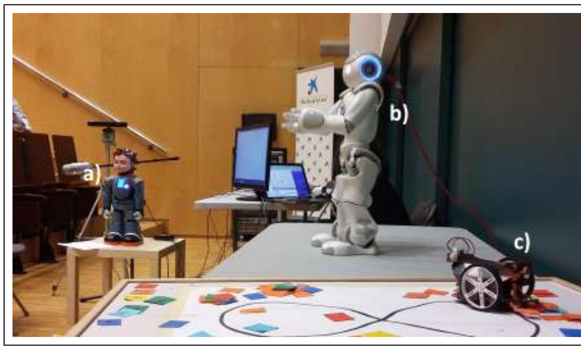

Fig. 1. Image of the room with the setup and the position of each of the robots. a) Zeno, b) Nao and c) CodiBot.

- **CodiBot:** developed by the Synthetic Perceptive Emotive Cognitive Systems (SPECS) group, at Pompeu Fabra University[1]. The main purpose of this robot is to help children learn how to code by using music and colors. CodiBot allows children to create melodies in an interactive way by mapping the seven notes of the C major scale to seven colors: a melody is created in the form of a score/program by placing the colored patches to the robot's trajectory.
- **Nao:** developed by SoftBank Robotics, France, Nao is an autonomous humanoid robot with a height of 58cm. It has 21 degrees of freedom, four microphones (for speech recognition and sound localization), two speakers and two HD cameras. Although it cannot display facial expressions as it lacks mouth and eyebrows, it can exhibit emotional states through a circle of colored LEDs surrounding its eyes. At the beginning of each session, the Nao welcomed the students and provided a brief introduction of the activity. During the interactive session, students could interact with the robot and trigger several behaviors by activating its sensors (e.g., the feet or its head).
- **Zeno:** developed by Robokind, Zeno looks like a male cartoon character. It can display rich facial expressions through a face with seven degrees of freedom composed of eyebrows, mouth opening and smile. Additionally,

[1] `http://www.codibot.com/`

it has five degrees of freedom in its arms and four degrees of freedom in its legs and waist. During the group interaction, children could freely trigger a variety of behaviors by choosing the desired response from the touchscreen embedded on the robot's chest. During the dyadic task, the robot verbally interacted with the participant using a speech synthesizer based on the Acapela software [2]. Movement was tracked using the Kinect sensor and the Scene Analyzer software [37].

The aim to have the children interacting with the three robots was to explore the differences between the educational robots used by the two universities conducting the study. Our objective was to assess if the the differences between the three robots affected how children perceived them and their resulting preferences. Thus, the robots could be divided in non-anthropomorphic (CodiBot) and anthropomorphic (Zeno and Nao); and the last group, distinguished by cartoon-like (Zeno) and non-cartoon-like (Nao).

In terms of language, the provided questionnaires were in Catalan, the Nao robot spoke in Spanish and the Zeno robot spoke in English, both during the first interaction with all the children and during the aforementioned dyadic task.

2) Automatic Speech Recognition (ASR): We used two corpora for training the ASR acoustic models. The first was the British English version of the Wall Street Journal corpus created at the University of Cambridge [30]. The second was the PF-star corpus of British English child speech [2]. Both corpora were used to create a single acoustic model that can be used for both adult and child speech.

To improve robustness to noise, we applied background noise audio to augment the training data. For this purpose, we used the CHiME corpus [9] which contains various kinds of background noise recorded in real-life environments. Since our main relevant use-case for the ASR is a public museum setting, we decided that the "cafe" background noise would be the best matching type of noise to use for our model. For each utterance in the training set, a section of the noisy corpus of the same length was randomly selected and added to the utterance audio. The addition was done using the SoX[3] sound processing tool, using the mix option. We added the noise at three different signal-to-noise levels, 5 dB, 10 dB and 20 dB.

We used the Kaldi toolkit to train the acoustic models for the ASR system. The toolkit has relatively standardized scripts (collectively known as recipes) designed to work with different sets of training data. We followed the Wall Street Journal (WSJ) recipe and trained a DNN model using the `train_multisplice_accel2.sh` script provided in Kaldi, which at the time of writing was the recommended script to use for DNN training[4]. We used four hidden layers and trained over one epoch, which came to 62 iterations. The initial effective learning rate was 5×10^{-3} and the final rate was 5×10^{-4}.

We used Beep[5] as the pronunciation dictionary, since it is designed for British English pronunciations. For words that are not in the dictionary (e.g. robot names, such as Zeno) we use the Sequitur tool [4] to estimate the phone sequences given the letters of the word.

To provide online (i.e. live) ASR we refactored and extended the online examples provided in Kaldi. A fuller description of the ASR development is given in [14]. Moreover, despite not being English speakers, the system had no problem to recognize the children's speech, and they could understand what the robot was saying during the interaction.

3) Scene Analyzer (SA): The Scene Analyzer is a framework that provides a human-like understanding of the information coming from the surrounding environment. It uses a Microsoft Kinect 1 sensor and a variety of libraries (Kinect SDK, SHORE etc.) that provide a wide range of multimodal data: high-level verbal/non-verbal cues of the people present in the environment, such as facial expressions, gestures, position and speaker identification. This information is later processed to extract significant social features, which are structured in a "metascene" data packet to be transmitted to rest of the modules. More information about the framework can be found at [37].

B. The healthy living task

The purpose of the interaction was to assist learners in an inquiry-based learning task to discover the benefits of physical exercise. The task consisted of two parts. In the first part, the robot encouraged the participant to perform exercises at various speeds and for various duration and provided information about the amount of energy spent by the kid. To detect participant's movements, we used the Kinect sensor and the Scene Analyzer. A sound, whose pitch was paired to the intensity of the movement (i.e., higher pitch, faster movement), was played while the participant performed the exercise. In the second part of the interaction, the robot asked questions about the consumption of energy during various kinds of exercises. The questions were also displayed on a TV screen and participants would verbally provide their answer. At the end of the session, children could request the robot to perform various actions (like "make a happy face" or "do the monkey dance"). The purpose of this task was to train the Automatic Speech Recognition System with non-native English speakers.

III. Results

A. Results from the questionnaires

We first explored for any gender differences in Likeability (whether they liked the task, whether they would do it again and whether they would recommend it to their friends). A Mann-Whitney Test showed significant differences between males (4.97 ± 0.18) and females (4.90 ± 0.35) (p = 0.015)

[2]http://www.acapela-group.com

[3]http://sox.sourceforge.net/

[4]At the time of writing the DNN scripts are under continuous development by the Kaldi team as DNN approaches for speech recognition are a highly active area of research. See the Kaldi website http://kaldi-asr.org for the latest information about the DNN setup.

[5]ftp://svr-ftp.eng.cam.ac.uk/pub/comp.speech/dictionaries/beep.tar.gz

in Likeability (whether they liked the task), (Figure 2). There were no significant differences among genders for the questions “Would you do it again?” and “Would you recommend it to a friend?”.

As stated in the introduction, we wanted to assess if there were differences in preference order among the robots. As a result, 75.8% of the children placed the Nao as their first preference, 64.1% placed the Zeno as their second choice and 77.3% placed the CodiBot as their third choice of preference.

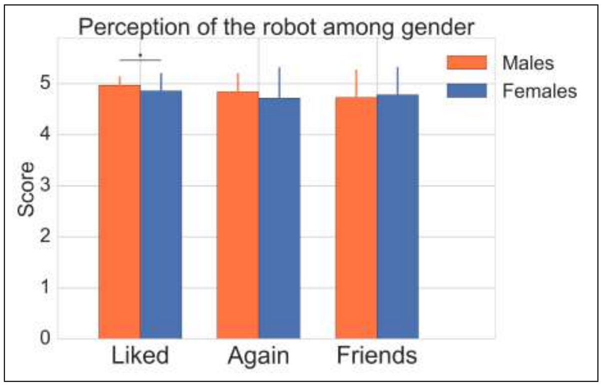

Fig. 2. Gender differences in perception of the task. “Liked” refers to the question “Did you like the task?”; “Again”, to “Would you do it again?”; and “Friends”, to “Would recommend it to your friends?”.

B. The Drawings

We classified each drawing based on several parameters: morphology, functionality, relative size of the robot to the child, body features, facial expression, and others. Morphology was further divided into: anthropomorphic (appearance resembles that of humans, which also contained the level of anthropomorphism), caricatured (appearance is not necessarily realistic or believable and usually have exaggerated features to provide a comic effect), functional (the embodiment reflects the task the robot performs), and zoomorphic (appearance resembles that of animals, adding also the kind of animal they resemble) [16].

The group related to functionality comprised of pet, defense, learning, health, chores, and playing. The facial features we looked for were hands, eyes, mouth, nose, ears, and hair. The identified facial expressions were happiness, sadness, anger, and neutral. Additionally, we analyzed the size of the drawings (the space they occupied in the paper), the robot’s gender and whether kids drew themselves with the robot or not.

1) Differences in morphology: In terms of functionality, we classified the drawings based on the four main categories defined by Fong: anthropomorphic, caricatured, functional, and zoomorphic. In figure 3, we report the frequency of robot appearance based on those categories. Results show that children tend to mainly image robots with an anthropomorphic appearance, with the 58% of those human-like robots looking like the Nao.

2) Differences in functionality: Regarding functionality, we identified six main categories: robots as pets, as partners for play activities, robots as educators (that teach them and help them with their homework) and doctors, robots used for defence and robots that do chores (as cooking or cleaning). Figure 5 shows the frequency of robots based on their functionality. Results indicate that children preferred robots as pets or doctors (with a 22% of them corresponding to robots as pets and another 22% to robots as doctors).

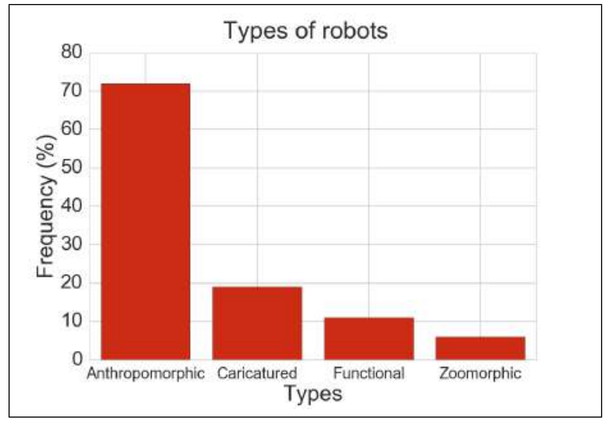

Fig. 3. Frequency of the four types of robots occurring in the drawings based on [16]. The blue part of the “Anthropomorphic” bar represents the drawings containing robots classified as “machine-like”.

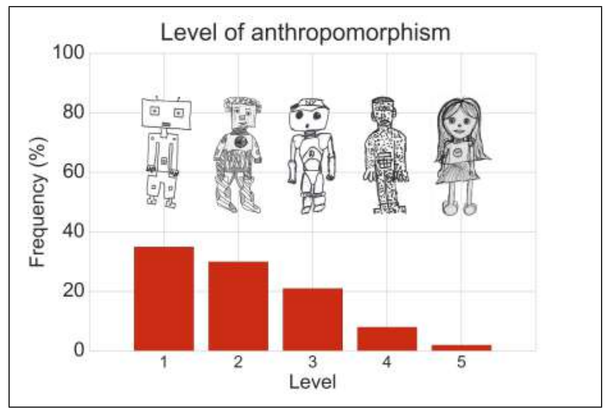

Fig. 4. Frequency of anthropomorphism shown in the drawings (only for the robots inside of the “anthropomorphic” type). An example of each level is shown above each bar.

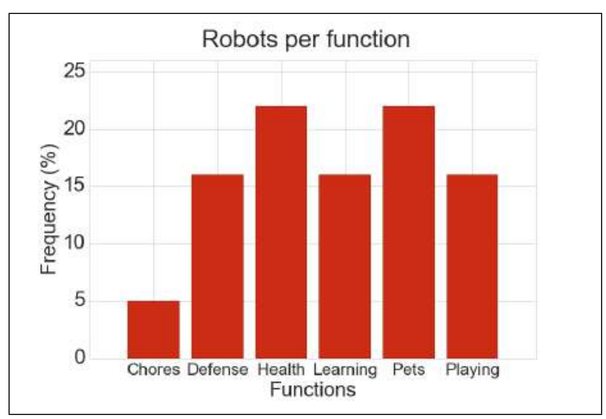

Fig. 5. Frequency of envisioned robot functionality as extracted by children’s design.

3) Gender differences: We did not observe differences between genders in use of movement, contrarily to [34]. In our case, from the 35% of drawings depicting movement (e.g. using lines to represent speed or drawing arms in positions other than straight), the distribution of these drawings per gender was equitable (a 50% of them were drawn by boys and the other 50% of them by girls). Children tended to draw genderless robots compared to male or female ones, as shown in figure 6.

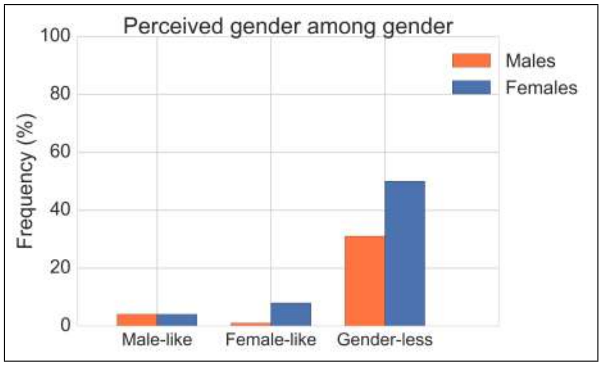

Fig. 6. Frequency of robot gender as extracted from children's drawings.

Regarding the depicted functionality, we can see differences depending on gender (Figure 7). In the case of the chores- or pets-related robots, the frequency of these functions in the drawn robots is equally divided between genders (2% for each gender in chores-related robots and 11% in the learning-related ones). The main difference comes from the defense-related robots, all of them drawn by boys (16% of the total amount of drawings), which also explains the fact that in the other functionalities (health, learning, and playing) the frequency of robots drawn by girls is higher. This is mostly evident in the learning-related ones, where a 2% of the drawings were produced by boys, and a 13%, by girls.

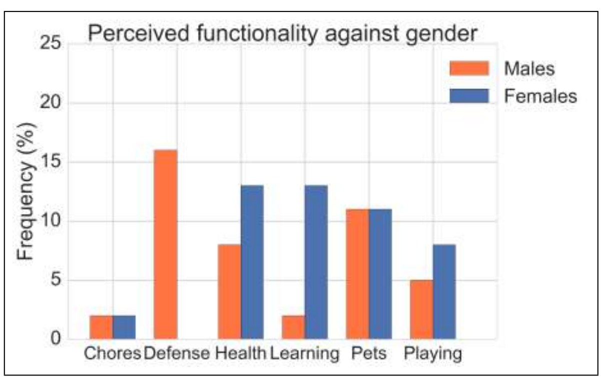

Fig. 7. Fig. 7. Frequency of robot functionality as extracted from children's drawing'.

4) Differences in size, body features, and facial expressions: Children tended to draw genderless robots compared to male or female ones, while there was no interaction between gender and functionality (Figure 6). In terms of body features, all robots were drawn with eyes and almost all had a mouth and hands (Figure 8).

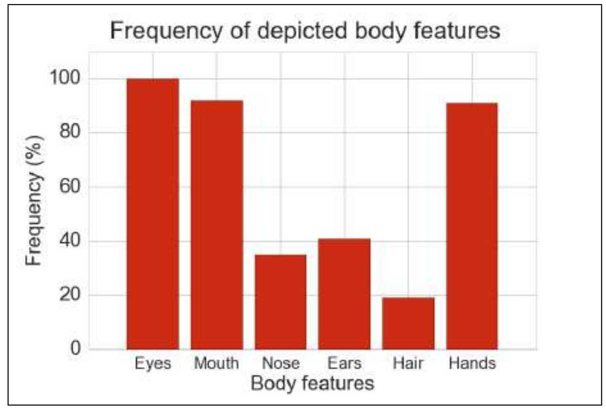

Fig. 8. Frequency of body features present in the drawings.

In terms of facial expressions, 48 children drew a robot with a happy face whereas 74 children drew a robot with neutral facial expression. In total, 30 children drew themselves with the robot. All drawn children with the robot displayed a happy facial expression while the frequency of drawing the child larger (n = 10), smaller (n = 10) or equal (n = 10) to the robot was evenly distributed.

IV. Discussion and Conclusion

Robots will soon become an almost ubiquitous part of our daily lives [18]. Therefore, we investigated the characteristics children expect from robotic companions in educational settings and how they envision them in terms of design and functionality. To do so, a sample of 142 children between nine and ten years old interacted with three different robots whose morphology ranged from non-anthropomorphic (CodiBot) to anthropomorphic. Here, we varied the level of anthropomorphism, as we presented two anthropomorphic robots: the Nao and the Zeno, with the latter being classified as highly expressive and with a human-like face.

Children were asked to rate each robot in preference and evaluate the interaction. Additionally we asked them to draw a robot of their preference and we analyzed their drawings. From this sample, 34 of them interacted with the Zeno robot in a one-to-one interaction focused on physical exercise. Meanwhile, the children that did not interact with the robot were drawing their robots or watching the interaction. At the end, children answered the questionnaires. Our results put in evidence that children preferred humanoid robots that resemble machines than humans in terms of morphology. In terms of gender, most of them envisioned a genderless robot, similar to what has been observed in [7].

We observed several similarities between drawings within the different groups, which suggests that children did affect each other during the drawing activity. Indeed, group members are likely to imitate the behavior of other members of the group (nesdale2001social) and mutually influence their artwork (boyatzis2000naturalistic). It is possible that children's designs may have been influenced by the media (bushman2006short) or their previous interaction with the three robots, as we observed several similarities with the Nao robot.

Contrarily to what we could expect, only the Nao was depicted in the drawings although all children interacted the same amount of time with each robot. Additionally, two children per group interacted with the Zeno robot performing the healthy living task, however, none of these children drew a robot that resembled the Zeno. Thus, any resemblance with the Nao robot cannot be explained by the exposure time with the robot. These resemblances are consistent with children's preferences since the Nao was rated first in liking and in accordance with earlier work that suggests that bodily features should not be identical to humans [36], [7] but instead have some human-like characteristics.

As a limitation, we must say that not all the children interacted with the three robots in the same order, as they were divided into smaller groups (between two and three people) that rotated turns and were also able to move freely among them. Thus, we cannot provide results regarding the effect of interaction order on their expectations from robotic companions.

Another conclusion that can be extracted from the drawings is the heterogeneity of expectations children have from robotic companions. The robot's expected functionality is not always constrained to one specific field: children see robots as multipurpose tools, mainly related to educational and domestic purposes (drawing a of figure 9 represents an example). Additionally, children's image of robots as defense-related agents (e.g. soldiers, policemen, etc) cannot be ignored; they are possibly influenced by cinema culture, as suggested in [3]. A representation of each type of functionality can be found in Figure 9.

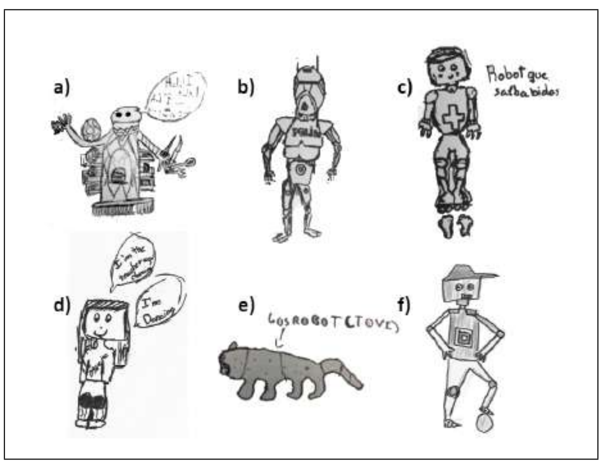

Fig. 9. Drawings depicting the six types of functions defined: a) Chores (an example of multipurpose one, as it also relates to playing), b) Defense, c) Health, d) Learning, e) Pets and f) Playing.

Consistently with [15], we found gender differences in the kind of scenes sketched by children: boys produced more defense-related robots and drawings including aggressiveness situations; girls depicted more details in terms of clothing. Moreover, girls used a larger part of the page, as already observed in [21].

As previously stated, we highlight the importance of inviting children to co-design robots to properly assess their expectations and needs. Moreover, although studies like the current one provide insights about the expected morphology and functionality of robots for children, we should not forget that other aspects have to be considered. When designing educational robots for children, we also have to consider the goal these children would like to achieve with them.

This work mainly focused on the collaborative design of robots with children. A way to systematically explore collaborative design would be to ask children to draw their robot of preference without previously allowing them to interact with it. Currently, robots meant to be used by children are designed by adults, neglecting children's perceptions and attitudes towards robots. The active participation of children in the design of smart technology is advocated by [11] as they are likely to provide valuable feedback to the design process that better addresses their interests and needs.

Extracting constructive information can be done with a variety of methods, ranging from writing, interviews and drawing [19]. Additionally, children can be presented with various robotic platforms whose morphology gradually varies from mechanical to anthropomorphic ones, as in our case the "step" from machine-like (CodiBot) to human-like (Nao, Zeno) was great both in terms of functionality and morphology. Nonetheless, the current study provides valuable insights on robot design that is created for children by children.

The present study primarily addressed the design of robotic applications in terms of morphology and functionality. The examination of the attribution of emotional states, mental capabilities, perceived personality and interaction styles of robotic platforms goes beyond the scope of this study, however, such issues need to be addressed in future work. Finally, given the fact that the role assumed by the robot affects how users perceive it [35], [5], a systematic approach is needed to ensure the robot's role meets children's expectations.

The fact that learning-related robots (those depicted as teaching or were reported in writing as robots to learn or robots to do homework) were not the most frequently depicted in the drawings should not be a constraint for the use of educational robots. Instead, it should be seen as a demonstration of the heterogeneity of the functionality that robots can have for children. The most popular functionality of robots was either related to health or pets. One could take advantage of their popularity and design educational robots to scaffold children's learning process in subjects related to them, like biology or chemistry.

The three main body features present in the drawings are eyes (depicted in all of them), followed by mouth and hands, which relate to the expected anthropomorphism of the robots. The result from this study is then a prototype of a robot with anthropomorphic (but machine-like) characteristics that does not resemble any specific gender. From a technical perspective, the focus of the design should be centered in its eyes, mouth, and hands and from a functional perspective, it seems that multiple functionalities are preferred as opposed to a single one.

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