Bringing playfulness to disabilities

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ABSTRACT
This article presents the design case of a robot companion targeted at children who are prevented from playing normally, due to cognitive, developmental or physical impairments. The robot design presents some distinctive qualities. From an instrumental viewpoint it reflects inclusiveness and social exchange. It enables inclusive play activities that promote confidence and self-esteem. All children blossom as children with different abilities, including "fully able" children, collaboratively achieve success, in games that are fun for all. A specific effort in the design was spent in creating consistency between the form, visual qualities, and the behaviours of the robot, in order to enable play scenarios that were specifically targeted at autistic, mild cognitively-impaired and severely motor-impaired children.

Author Keywords
Robot companion, inclusive games, modular design, smart textile design.

ACM Classification Keywords
H5.m. Information interfaces and presentation, Hm. Miscellaneous.

INTRODUCTION
Children with a disability not only experience the physical and psychological consequences of their impairment in the short-term but their disability profoundly affects the development of their social skills for their whole life. For full participation in society, communication and social interaction skills are fundamental: both of these skills can be acquired during play in childhood, and robot companions can play a key role in supporting the development of such skills.

Iromec (www.iromec.org) is a robot companion that promotes play in physically and cognitive impaired children – in particular autistic, motor-impaired and mild cognitively-impaired children. A key issue for the design of Iromec has been to understand the needs and expectations of disabled children, to enable and support play activities in all their richness through a range of design solutions. The objective is to have disabled children moving, exchanging, experimenting and having fun, regardless of their cognitive or physical ability levels. By offering exciting activities that entice children to participate, the robot not only helps them reap the physical benefits of exercise, but also provides opportunities for them to learn, share, express feelings, set goals, and function independently.

USER STUDIES
The design process combined the principles of User-Centered Design (UCD) and Scenario-Based Design [1]. In fact user involvement was required not simply to increase the effectiveness of the resulting system, but also to define play scenarios, tweak concepts and functionality to better answer user needs, come up with different ways to use the technology, and develop new social practices around the possibilities opened up by the robot. Concepts, mock-ups and working prototypes underwent multiple design iterations. Each evaluation informed the redesign of the next prototype, and the user requirements were progressively refined and elicited in a continuous user research cycle.

The user requirements elicitation process was organised in several panels of experts organized by the project’s partners in various European countries (Spain, Italy, The Netherlands, Austria, UK). The panels involved professionals from different special education schools, teachers, therapists (e.g. psychotherapists, speech therapists, play therapists, physiotherapists, occupational therapists), as well as parents and family members. A common methodology was used in all the panels’ interviews consisting of an introduction to the project, followed by a story-telling session where the members of the panel provided insight into the current play of the children and its characteristics, together with specific examples of the children’s play [2]. The session usually continued with a brainstorming discussion around pre-set questions that aimed to find possible activities to be carried out with the assistance of a robotic companion; the role of the robot in the social play context; characteristics of the environment where the robot could be of added value; functionalities...
suitable for the target groups; possible critical aspects of the children’s behaviour and needs that such a robotic toy could address; ethical issues, wishes and other information considering robot toys.

In parallel with the expert user panels, other fieldwork research has been carried out including:

- The use of the cultural probes method [3] with disabled children in order to obtain inspirational material about the children’s wishes, preferences, viewpoints and daily practice of play. The children collected small objects they usually play with, took photographs, and recorded brief notes. All the probes were used as a source of inspiration for the concept design.
- Field observations were conducted at primary schools of structured and spontaneous play activities.
- “Construction workshop”. This was a hands-on activity where the therapists and the teachers played with cardboard boxes with different shapes, different materials and sensors. It was an exploration and construction activity supported by simple materials of different shape and dimensions, physical connectors to assemble the robot and sensors used to reflect upon the robot’s appearance and the play scenarios.
- Contextual enquiries were conducted with children with different disabilities and their parents to document the use of toys and the “hacking” practices necessary to adapt the toys to the specific abilities of the children.
- Workflow and scenarios of the current therapeutic and educational activities were examined. In particular the scenarios were defined to illustrate the context of play, the educational and therapeutic objectives, artefacts (both material artefacts as devices, and conceptual artefacts as rules, practices, roles etc.) and social relationships.

From the initial fieldwork, the primary users of the robot have been identified: autistic, mild mentally-retarded and severely motor-impaired children. All of them have difficulties in playing alone or with others but their difficulties require different types of support during play. For example, the autistic children have considerable difficulties in social interaction, in particular in understanding others’ intentions and feelings, as well as gestures and facial expressions. They usually show little reciprocal use of eye contact and a tendency toward repetitive behaviour patterns. For these reasons it is important that the robot has a very simplified and unexpressive face, preferably with physically embedded parts like eyelids that can be manually opened or closed during play to reduce the expressivity, and that the games are repetitive with a clear sensory reward. In this respect, imitation and turn-taking games (Figures 1 and 6) are specifically suited to autistic children.

Mental retardation usually involves multiple dimensions, from retardation in intellectual abilities and adaptive behavior, to participation in social interactions. Children with mental retardation have reduced attention ability and might not understand the meaning of the proposed play. Therefore suitable play scenarios for them are coordination and sensory stimulation games (Figure 3 and 5).

Children with motor impairment are limited in their ability to play due to limitations in their movement, if they are able to move at all. Cause and effect games and pretend play are the most suited play activities for this user group (Figure 2 and 4). The expressivity of the robot plays a fundamental role in these kinds of games so it is desirable for the robot to be able to display a wide range of facial expressions.

**THE DESIGN OF PLAY SCENARIOS**

From the initial user studies a set of twenty play scenarios were defined in close collaboration with the expert panels [4]. The educational and therapeutic objectives of each scenario have been classified with reference to the World Health Organization’s International Classification of Functioning, Disability and Health in the new version (2007) for Children and Youths.

Examples of play scenarios are:

*Turn taking:* an exercise play where two or more children exchange the robot in turn. The scenario can be played in “sensory reward mode” to augment expressivity and feedback with sounds and animated graphics. The main target users are autistic children and the educational objectives are to improve mobility, cognitive flexibility and basic interpersonal interaction.

*Make it Move:* a cause and effect game where the robot’s movement is controlled by clapping hands. The main target users are severely motor impaired children and the educational objectives are to improve the sense of self and the awareness of the child’s own body and identity.
Follow-me: a coordination game that consists of playing with a robot that follows the child. Other children can compete to attract the attention of the robot in order to be followed. The primary educational objectives of this scenario are related to energy and drive functions and to improve motivation to act and to feel in control. The scenario aims to develop the understanding of cause and effect connections and to improve attention to mobility. The main target group are mildly mentally retarded children.

Dance with me: an imitation and rule game where a child makes the robot ‘dance’ – i.e. either the child or the robot initiates a dance to the rhythm of pre-recorded music and the other imitates the choreography to ‘dance together’. The scenario is addressed to severely motor impaired children with the objective of improving spatial awareness and the control of simple voluntary movements.

Get in contact: a sensory stimulation game played by one or more children. The adult has a supportive role during the activity to stimulate storytelling and to control the behaviour of the robot. The main target user group is represented by mildly mentally impaired children and the educational objectives are mainly related to the improvement of perceptual and emotional functions.

Imitation: an imitation game where the adult operates the robot remotely and controls its behaviour. Once the child has practised all of the robot’s possible movements, the adult asks the child to initiate similar movements for the robot to copy. After a while, the adult reveals that they are operating the robot, and the game continues. Because the child knows that actually they are playing with the adult through the robot, this might encourage the child to have more eye contact with the adult as well as sharing in the excitement and fun. The play scenario is mainly targeted to autistic children and has a number of educational and therapeutic objectives: to improve proprioception, to improve the sense of self and the awareness of one’s own body and identity, to improve focusing, maintaining, shifting, dividing attention and joint attention and to stimulate basic interpersonal interaction like turn taking and gaze shift.

CONCEPT DESIGN
The design intentions in constructing the robot included the following:

- To develop a solution that provides the maximum number of features in order to address different types of play scenarios for different categories of users.
- To apply a modular approach that permits a high level of flexibility and specialization in the use of the robot and an easy adaptation to the child’s abilities.
- To support the child’s interaction with the robot in two main settings: one stationary (i.e. to be used on the table to enable different kinds of imitation games, see Figure 6), and the other one mobile, to emphasise the use of the free movement in the space and to enable different games like turn taking, coordination game, cause and effect games etc (Figure 2, 3, 4).

During the inspirational phase of the design, the main questions considered were related to the robot appearance and how the combination of the appearance with the visual language and behaviours could contribute to the definition and expression of the particular identity of the robot itself. Different possibilities have been explored to create a consistency between form, visual qualities and behaviours.
As a result of a series of iterations of specific play scenarios that can be enabled by different configurations, the final design choice was based on a modular robot that can be configured as a horizontal, mobile robot supporting movement and coordination games (a vehicle with a cartoon-like appearance) and as a vertical, stationary configuration to support mimic and imitation games (anthropomorphic, cartoon-like appearance). This solution allows us to obtain a broad flexibility in the play activities with the same robotic system.

From a structural point of view the final design is composed of three main typologies of elements (Figure 7):

- the mobile platform, developed by Robosoft (www.robosoft.fr)
- the interaction module, that can be easily plugged/unplugged to the mobile platform following a “plug and play” philosophy. A connector interface serves as a mechanical locking system between the interaction module and the mobile platform and allows power and data transmission. The interaction module (developed by Profactor, www.profactor.at) is equipped with a high-level control system that provides editing of “play scripts” through the graphical user interface, by means of XML-description. It consists of a body, whose digital screen skin can display different visual effects, thus supporting identity, expression and feedback; a head with a digital display for both expression and orientation; and arms, to guarantee basic manipulation features. The interaction module measures 35x55x17 cm. The head (22x12x17 cm) rotates along the vertical axis to produce right-to-left (and vice versa) movements, or/and to simulate situations in which the attention of the robot is attracted towards a specific direction.
- some ADD-ONS and COATING elements (Figure 8) provide a rich level of interactivity and expressivity. The robot is also equipped with external control buttons.

The robot can be used in an autonomous or controlled way using external remote controls.

In term of interactivity the mobile platform supports all the interaction patterns based on the physical movement of the robot in the space. The interaction module adds to the robot’s movement three interaction layers:

- Sound layer: original sounds have been created to structure and articulate the play experience. They have been designed to give the impression of a living entity without any specific human or animal connotation. Sounds are used to assign a tempo to the activity, to structure spatial and proximity relations, to anticipate an intention to act, to underlie the effect of an action and externalise the robot’s perception.
- Physical actions layer: allows movements of the interaction module in the stationary configuration, such as turning the head or performing some basic manipulation, such as grabbing and/or holding a small object. In the current implementation of the robot the arms have not yet been integrated.
- Expression layer (Figure 9) displays both the emotional status of the robot and dialogues with the users (action trigger and feedback). This layer is supported by the combination of visual representations on a digital display skin and on the head. The head performs different levels of facial expressions; the skin is a touch screen display whose main feature is to display both visual patterns for showing its emotional status and some controls that facilitate direct interaction with the robot.
Add-ons components

The Add-ons are simple passive components that can be added to the robot for emphasizing particular aesthetic and functional aspects. Different masks can be mounted on the head to hide parts of the face and to reduce the expressiveness (Figure 10). This feature is specifically designed for autistic children whose competence level in processing facial expressions can vary considerably in relation to the severity of the cognitive impairment. The combination of digital and physical components allows us to experiment with several setups, in order to find the solution that best fits the needs of the children.

Interactive coating modules

A set of interactive coating modules can be mounted on the robot’s body to obtain different tactile and visual effects. The coating modules embed smart textiles that provide the robot with unusual visual, tactile and behavioural feedback resulting from material transformations.

Luminescent fabric modules

The Luminescent Fabric coating module (Figure 11) is made of coloured polyester and luminescent fibers. Different groups of luminescent fibers are woven into the fabric and can have different colours. They can be managed independently – being controlled by one inverter each. The components are plugged into the sides of the robot and light up when the robot moves. Different light patterns can be obtained: the lateral modules blink fast together when the robot moves straight, only the right (left) module lights up when the robot turns right (left), a slow blinking appears when the robot is in waiting mode. This mechanism is used to reinforce the feedback on the robot status, in particular during movements and coordination games.

Pressure sensitive textile module

A Pressure Sensitive Textile coating module (Figure 12) has been developed fixing a soft woollen cover on top of two metallic and conductive layers separated by an isolating layer. The conductive layers are made of steel wires while the isolating layer is composed of coloured polyester or transparent PA6 monofilament depending on the type of connection to the commutation. The fabric works like a switch: whenever the child strokes a sensitive area the robot laughs, emitting sounds. This module enables the “Tickling scenario” that consists of an exploration of the robot’s body to discover where it is sensitive to tickling. The tickling zones change dynamically and children have fun in trying to guess where the robot is more sensitive. The game has been developed to improve perceptual functions such as auditory, visual, tactile and visuospatial perception as a basic form of communication in sensory stimulation games.

The interactive fur module

The “interactive fur” (Figure 13) is made of a soft woollen cover with static and moving hairs. The static hairs are knotted on a copper knitted fabric covering a dome-like fiberglass shell. The moving hairs are fixed to the copper fabric, but their lower part is connected to a Nitinol spring (Figure 14).
A total of 20 moving hairs are distributed on top of the shell. The central part of each Nitinol spring is connected to an electric wire wrapping around the hairs. The Nitinol springs are fixed to the inner part of the dome shell by means of screws, and the electric wires are inserted through holes in the shell itself. When electricity passes from one extremity of the spring to the center, the other extremity contracts. In this way, the electric wire at the centre of the spring moves left and right together with the hair around which it is wrapped. The movement of the hair can be controlled in its timing, intensity and form. Since the hair is inserted in the copper fabric, which is not elastic, the movement of the lower part of the hair is transformed into a rotation of the hair, which in some cases can reach more than 100°. When half of the spring contracts, it is necessary to wait at least 20 seconds for it to cool down before the other half of the spring can contract. This makes the effect of the moving hairs seem quite natural, similar to the fur of an animal. Different implementations and controls of this module have been developed, embedding different kinds of sensors like proximity and sound sensors. When the child approaches the robot the fur moves, and the movement of the hairs correspond in timing and intensity to the movement of the person. If the child moves towards the robot quickly, it reacts with a fast movement of the fur. If the child crosses the robot from the right side, the fur reacts from the corresponding side. A similar behaviour can be obtained if the interactive fur is connected to audio sensors. If the child whispers to the robot from the right side, as she talks to the robot in the “right ear”, the fur raises gently starting from the right side. It is usually more fun for children to shout in order to frighten the robot. In this case the fur reacts suddenly and the robot moves away. This module is used to reinforce the robot’s behaviour in coordination and cause and effect games.

CONCLUSIVE REMARKS
The robot is currently being experimented with in primary schools and institutions in Spain, Italy, The Netherlands, Austria and the UK. Initial trials in a primary school in Siena (Italy) involved children with different cognitive and physical disabilities over a period of two months. All children involved in the trials, both disabled and typically developed, had fun playing together regardless of their different abilities. The play scenarios have been clearly understood and the children interacted appropriately with the robot, respecting the game rules, but also inventing new games. The robot played a fundamental role in mediating social relations among the children. Dynamics of peer-to-peer learning spontaneously emerged. The modularity of the robot was a key feature for stimulating creativity and symbolic play.

From a design viewpoint the robot has some distinctive qualities:
- Instrumental qualities – since the design choices reflect inclusiveness and social exchange.
- Aesthetic qualities – both in the robot appearance and expressiveness, thanks to the combination of digital and physical components.
- Innovation: the smart textiles produced and implemented in the additional modules are innovative and the related technology can be exploited in different domains.
- Ethical qualities and groundedness: the design process was centred on the children and their needs. Children, parents and teachers were involved from the very beginning and regarded not as objects of study, but as active agents within the design process itself.
- Impact: the modular design of Iromec can address the needs of a wide and variegated set of users. This feature increases the likelihood of the robot having a significant impact on current educational practices.

REFERENCES