Human-centred Design Methods:
Developing Scenarios for Robot Assisted Play Informed by User Panels and Field Trials

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Abstract
This article describes the user-centred development of play scenarios for robot assisted play, as part of the multidisciplinary IROMEC[1] project that develops a novel robotic toy for children with special needs. The project investigates how robotic toys can become social mediators, encouraging children with special needs to discover a range of play styles, from solitary to collaborative play (with peers, carers/teachers, parents etc). This article explains the developmental process of constructing relevant play scenarios for children with different special needs. Results are presented from consultation with panel of experts (therapists, teachers, parents) who advised on the play needs for the various target user groups and who helped investigate how robotic toys could be used as a play tool to assist in the children's development. Examples from experimental investigations are provided which have informed the development of scenarios throughout the design process. We conclude by pointing out the potential benefit of this work to a variety of research projects and applications involving human-robot interactions.

Keywords: Robot Assisted Play, Human-Centred Design, Assistive Technology, Human-Robot Interaction

1. Introduction

The work presented in this article is conducted within the EU project IROMEC (Interactive Robotic Social Mediators as Companions) that develops a novel robotic toy for children with special needs. The project emphasises the important role of play in child development as a crucial vehicle for learning about the physical and social environment, the self, and for developing social relationships.

IROMEC targets children who are prevented from or inhibited in playing, either due to cognitive, developmental or physical impairments which affect their playing skills, leading to general impairments in their learning potential and cognitive development and may result in isolation from the social environment. The project aims to empower these children to prevent dependency and isolation, develop their potential and learn new skills by development of a robot-supported play environment which meets the users' expectations for a safe and reliable, versatile and tailorable, ready to use and affordable system. The developed robotic system will be tailored towards becoming a social mediator, empowering children with disabilities to discover the range of play styles from solitary to social and cooperative play, and provide opportunities for learning and enjoyment involving other children as well as carers/teachers or

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parents who “join in” the game with the robot.

In recent years various robotic systems have been used in research to mediate interaction for people with and without special needs. Life-like robots, e.g. artificial pets such as the baby seal Paro, the teddy bear Huggable (Wada and Shibata 2007; Stiehl et al. 2006), and humanoid robots such as the robotic doll Robota and the child-like Kaspar (Dautenhahn and Billard 2002; Robins et al. 2004a; Robins et al. 2004b; Robins et al. 2005) were used to engage people in personal experience stimulated by the physical, emotional and behavioural affordances of the robot. Most of these robots, when built, focused on the technological innovation aspects. User needs, requirements, and scenarios of how to use the robots in concrete applications are often only considered at a later stage. Although the IROMEC project recognizes the importance of the impact of technology on its users, the approach taken is based on ongoing consultations with panels of expert users (i.e. teachers, therapists, parents) throughout the design and development stages in order to develop a novel robotic system at the end of the project’s lifetime that will meet specific needs of various target user groups.

The following subsections provide introductions to key themes behind our research, i.e. the importance of play in child development (1.1), an introduction to our target user groups (1.2) and an overview of different play types (1.3). Section 2 presents scenario building blocks (2.1) as used in IROMEC and discusses the methodological approach of the development of play scenarios in IROMEC (2.2) which, in addition to an extensive literature review (section 3), is based on two main sources of input, i.e. expert panels (section 4) and experimental investigations (section 5). Results lead to the formulation of outline scenarios for robot assisted play (section 6) which is the main outcome of this study. A discussion of the results and final conclusion and future work (section 7) finalize the article.

1.1 Play and Child Development

Play is essential to children’s development process as it contributes to the physical, cognitive, social, and emotional well-being of the individual. Theorists from different viewpoints agree that play occupies a central role in children's lives, and that its absence provides an obstacle to the development of a healthy child. As early on as infancy, play activity creates and uses auxiliary stimuli and is a crucial part of the child’s development (Vygotsky 1978). Vygotsky argued that the biological foundation of behaviour is intertwined with the changing social condition, both are inseparable components at each stage of a child’s development. Winnicott, too, emphasized the importance of cultural experience in what he called potential space between the individual and the environment, e.g. baby and mother, child and family, individual and society (Winnicott 1971). Bruner (Bruner 1990) has argued that the motivation for play, and that play itself, is socially constructed. Meaning is learnt in a social way within a particular context (Bruner 1990; Powell 2000). Contemporary work in activity theory also shows how children’s play is socially and culturally constructed (Hakkarainen 2003). Given the scientific evidence, the importance of play for children’s development has also been recognized by the United Nations High Commission for Human Rights[2] as a right of every child.

1.2 Target user-groups

The IROMEC project targets children who are prevented from playing, either due to cognitive, developmental, or physical impairments or due to medical conditions.

With the aim to develop scenarios that are suitable for children with different types and grades of disability, different main user groups were considered (e.g. children with physical impairments such as Cerebral Palsy, Spina Bifida, motor impairment, bed restricted children,

[2] Office of the United Nations High Commissioner for Human Rights. Convention on the Rights of the Child. General Assembly Resolution 44/25 of 20 November 1989, article 31. Available at: http://www.unhchr.ch/html/menu3/b/k2crc.htm

children with cognitive impairments and disabilities such as Autistic Spectrum Disorders, mental retardation[3], Down syndrome, children with both physical and cognitive impairments etc.). A comprehensive literature review related to play activities of children from some of these target user groups using existing technology has been carried out (see section 2.3 and Table III). In consultation with expert professionals, the user panel discussions (see below) showed high correlation in needs between some of these target user groups and two main categories were identified: the physically impaired group of children and children with cognitive impairments. It was found that in this broad categorization, many needs of the remaining groups can also be addressed. Our target groups have been focused further into three specific categories:

- AUT - children with autism
- MMR - children with mild mental retardation
- SMI - children with severe motor impairment

1.2.1 Children with autism (AUT)

Autism here refers to Autistic Spectrum Disorders, a range of manifestations of a disorder that can occur to different degrees and in a variety of forms (Jordan 1999). The exact cause or causes of autism is/are still unknown. Autism is a lifelong developmental disability that affects the way a person communicates and relates to people around them. People with autism often have accompanying learning disabilities[4]. The main impairments that are characteristic of people with autism, according to the National Autistic Society (NAS 2008), are impairments in social interaction, social communication and imagination (referred to by many authors as the triad of impairments, e.g. (Wing 1996). This can manifest itself in difficulties in forming social relationships, the inability to understand others' intentions, feelings and mental states, difficulties in understanding gesture and facial expressions, difficulty in understanding metaphors, having a limited range of imaginative activities etc. People with autism usually show little reciprocal use of eye contact. They also have a tendency toward repetitive behaviour patterns and resistance to any change in routine. In addition some people with autism have hyper-sensitive sensory conditions. Touch can be excruciating, smell can be overpowering, sound, even at an average volume can hurt, and sight can be distorted (Gillingham 1995).
As autism can manifest itself to different degrees and in a variety of forms, not only might children in different schools have different needs, but also children in the same school might show completely different patterns of behaviour from one to another, and might have different or even some contradictory needs.

1.2.2 Children with Mild Mental Retardation (MMR)

Mental retardation has been defined as a multidimensional construct based on the following five dimensions: intellectual abilities, adaptive behavior, participation, interactions and social roles, health and context (Luckasson *et al.*, 2002). Children with mental retardation, also referred to as intellectual disabilities or learning disabilities (for example children with Down syndrome), might have trouble with playing because of their intellectual limitations and cognitive disabilities. They have reduced attention ability and might not understand the meaning of the proposed play, and/or the meaning of the language used to play; some also have speech limitations.

1.2.3 Children with Severe Motor Impairments (SMI)

Motor impairment is a subclass of physical impairments. Physical impairments often heavily affect activities such as: mobility, communication, autonomous self care, learning activities,

[3] The term *mental retardation* is currently being used in different European Countries. In the UK, the term used is *learning difficulties* following the Disabilities Discrimination Act.
[4] For detailed diagnostic criteria the reader is referred to DSM-IV-TR, the Diagnostic and Statistical Manual of Mental Disorders, American Psychiatric Association, (2000) and ICD-10, Classification of Mental and Behavioural Disorders, World Health Organisation, Geneva (1993).

interpersonal interactions, play and many participation areas, including social relationships, social life, and education. Children with physical impairments may also present additional impairment such as sensory (deafness, blindness) and/or cognitive impairments.
Physical impairment could affect both gross and fine motor skills.
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. Examples include abnormal postures and neurological movement disorders. This group often has no possibility to play with materials by themselves and have very limited experience in some important aspects of play. In addition there is a higher risk of becoming socially isolated as they often have no, or very limited, access to any game that peers in their environment are playing. All of these limitations often cause developmental delays.

In addition to targeting different user groups, IROMEC also acknowledges the fact that there are different types of play with various functions and benefits from a developmental point of view. In the following section, a brief survey of different types of play is provided.

1.3 Types of play

Numerous types of play have been identified in the literature (an in-depth review can be found in (McMahon 1992)). In the context of the IROMEC project for the development of play scenarios we have decided to adopt the ESAR system[5] (Garon et al. 1996). Inspired by the Piaget theories on child development, the ESAR system identifies five different types of play: exercise play, assembling play, symbolic play and play with rules.
Exercise play involves the continual repetition of an action for the immediate pleasure it gives. The repetition of actions such as biting, throwing, sucking, beating, manipulation, babbling, moving, etc., may be considered forms of exercise play, and may or may not involve the use of toys. This type of play is also being refer to as *sensory motor play* that consists of simple repetitive muscle movements with or without objects (e.g. repetitive motor movements) (AIJU 2008). This activity is done merely for the enjoyment of the physical sensation it produces (Rubin 2001; Santrock 2006).
Assembling play involves assembling, stacking, piling, joining and fitting pieces together, etc. This type of play takes place when the child sets him/herself a specific aim - to build something - and through a series of coordinated movements or actions, achieves this aim. This is also related to *constructive play* which is the manipulation of objects for the purpose of constructing or creating something (Santrock 2006). Construction may also manifest itself as teaching another how to do something (Rubin 2001).
Symbolic play: during symbolic play children can differentiate fantasy from reality. They substitute one object for another, and act toward them as if they were these other objects (Santrock 2006). Play is no longer constrained by an object's physical proprieties (Volkmar 2005). It is the type of play in which the child ascribes different kinds of significances - some more obvious than others - to objects; he or she acts out imaginary events and real-life scenes through role-play of fictional or real characters. Through symbolic play, children imitate adults, pretending to be daddies, mummies, doctors, teachers, hairdressers, lorry drivers, etc., and this category includes all games in which the adult world is recreated in one way or another, be it through everyday situations or fictional characters.
Play with rules – this is play that involves a series of instructions or rules which players have to learn and observe in order to achieve a given aim. Play with rules is of fundamental importance in that it helps to socialize children, teaching them how to win and lose, take turns, observe rules, and respect the opinions and actions of fellow players.
Here the child accepts rules, adjusts to them and controls his actions and reactions within the given limits (Rubin 2001). The child and/or their playmate(s) may decide the rules of the game. Moreover, this type of play has a vital role in learning different types of knowledge and skills, and helps developing language, memory, reasoning, attention and reflective thinking.

[5] It is the acronym of the French words: Exercise, Symbole, Assemblage, Régle.

We consider that play evolves through different stages but the transition between them need not be linear (e.g. a child can move from sensory motor play to constructive play without passing through symbolic play).

Given the identified user groups and the types of play that the project intends to support, an important step towards the design of a novel robotic toy is the development of scenarios that will ultimately determine and reflect the new robot's functionalities. The development of play scenarios is the central theme of this article. The next section describes the methodological approach and its outcomes in detail.

2. Design process

The design process adopted in the IROMEC project is built on and combines the methodological principles of the User-Centered Design (UCD) and the Scenario-Based Design (SBD) processes.

UCD is places the user at the centre of the design and development process with the aim of creating a system or a product that meets user needs and is usable (ISO, 1999). It has been described in a number of books, originating from Norman and Draper (1986) and Nielsen (1993), and it has gained a position in the ISO (International Organization for Standardization) standards. The ISO 13407 identifies four main activities of UCD (illustrated in **Error! Reference source not found.**), that are: understand and specify context of use, specify the user and organizational requirements, produce design solutions, and evaluate designs against requirements.

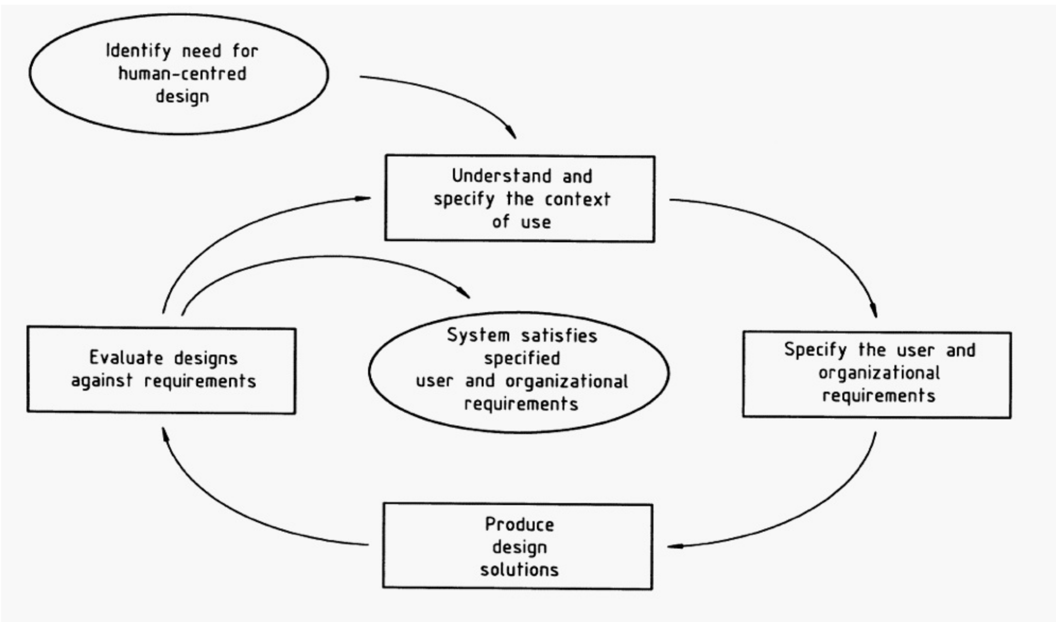

Figure 1. ISO 13407 standard for human-cantered design processes for interactive systems

A drawback of UCD that made the IROMEC process inspired by UCD principles but not adopting it rigidly is that, as mentioned by Nesset and Large (2004, pp.141), "*user-centered design refers to a process undertaken once the technology has already been developed and released onto the market*".
In the IROMEC project a major objective is the development of a novel robotic toy to support children with special needs in play activities; an objective that cannot be reached considering technology already available on the market.
Inspired by the UCD process, children with special needs, as well as their carers, have been involved in the IROMEC project at every step of the project: from the very beginning of the

project when the robotic system was still in the conception phase, before the production of any prototypes, to the final evaluation of the IROMEC final robot design.

The other methodological principles that inspired the IROMEC design process is the Scenario-Based Design (SBD). In the field of human computer interaction, scenarios have been used as tools in various stages of system development, from problem definition to envisioning solutions, helping all stake holders to contribute to the analysis, design and evaluation of systems. Carroll (Carroll 2003) described SBD as ‘a family of techniques’, describing the use of future systems at early points in their development. They can be in the form of textual narratives describing an activity in its context, video mock ups, storyboards of annotated cartoon panels or physical situations that contrive to support certain user activities. Designers have long used scenarios to organize, justify, and communicate ideas. Scenarios are being used as vocabulary aids that are accessible to the users so they (the users) can be involved in the design process and help to define the technology they will use. Scenarios serve as central representations throughout development cycles, first describing the goals and concerns of current use, and then being successively transformed and refined through iterative design and evaluation processes (Carroll 2003). Scenarios help envision the outcome, provide a basis for testing and stimulate thinking about possible outcomes.

In the IROMEC project we have adopted the concept of scenarios and used it for an additional purpose. Here, scenarios are seen as higher level conceptualizations of the *‘use of the robot in a particular context’*. Scenarios are used not only as intermediary steps or tools in the design and development process of the robot, but more importantly, as *play contexts* which allow users to evaluate specifically implemented functionalities of the final outcome of the project, i.e. the IROMEC robot.

To formalise the scenarios used in the IROMEC project, a unified structure was adopted and modified from the SBD methodology (Carroll 2003) and is described in Table I.

TABLE I Scenario structure

Actors/ Roles	This identifies the roles of the different actors involved (children, therapists, parents...) highlighting the relationships among them. How are they involved in the activity? Is it appealing to all the participants?
Type of play	Is the activity a sensory motor play, and/or a symbolic play, and/or a constructive play, and/or a game with rules?
Activity description	Description of what happens as the activity is carried out. This points out the objectives of the different users who are taking part in the activity.
Activity model	Can the activity be simplified into an identifiable set of phases? This also highlights recursive passages and sequences.
Place/ Setting	Description of the characteristics of the physical or virtual context, including the environmental qualities, the space organization, and the morphology. Is the location of the activity affecting what is going on or is it irrelevant?
Artifacts/ media	Tools that are supporting the activity.
Time/ Flow	Which is the average duration of the activity? Is duration critical? Is the activity following a schedule? Does it repeat over time? Is it following a rhythm or a recursive pattern?
Keywords	Highlights of values of the activity with respect to the actors involved.

The next section describes the user-centred development of play scenarios for robot assisted play, as part of the IROMEC project that develops a novel robotic toy for children with special needs.

2.1. Development of play scenarios in IROMEC

Error! Reference source not found. shows the two-phase process adopted in the IROMEC project of developing play scenarios[6], from building preliminary concepts for play scenarios

[6] The process is divided into two phases. This article presents the developmental process of phase 1 only. Phase 2 will be presented in a future publication.

and the formation of outline scenarios for robot assisted play in phase one, to the completion of scenarios for robot assisted play and robotic mediators in phase two.

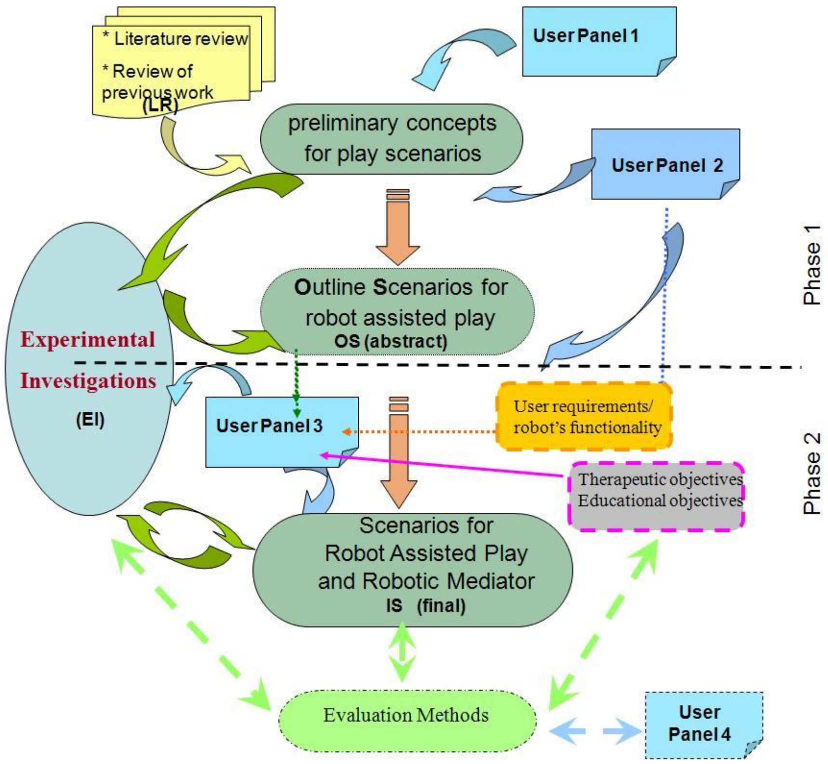

Figure 2. The developmental process of scenarios for robot assisted play.

The process uses the following three intermediary sets of scenarios in various stages of phase one, leading to the development of the final core scenarios for robot assisted play and robotic mediators in phase two:

- scenarios derived from literature review - prefixed 'LR';
- scenarios used in experimental investigations of user requirements - prefixed 'EI';
- high level outline play scenarios – prefixed 'OS'.

A comprehensive literature review (See section 3 below) related to play activities of children from different target user groups provided knowledge on the play activities, limitations and needs of the children, gave inspiration to the concept generation of the IROMEC systems, and highlighted important aspects to be considered in the future development of play scenarios for the IROMEC systems. Alongside the literature review, several panels of expert users (different panels of teachers, therapists, parents related to the different target user groups) were organised in order to initially collect further important information related to the play activity of children with special needs, to elicit initial requirements for the IROMEC system and later to provide feedback during the various stages of the project, that will inform the development of the play scenarios as well as the robot design (See section 4 below). Note, the different stages of the scenario development occur in a fixed sequence (preliminary concepts, outline scenarios and finally scenarios for robot assisted play), but the sources of input (literature review, user panels, experimental investigations) can occur concurrently (e.g. experimental investigations were ongoing during most of the scenario development process).

Various aspects of the user requirements, as expressed in these user panel meetings have been implemented in play scenarios that focus on specific play activities and on different robot behaviours and have been investigated in field trials using existing available technology (see

Section 5 – Experimental Investigation of Play Scenarios). The aim of these trials was to investigate user interaction aspects relevant to different parts of play scenarios, Any available technology that could implement the specific *aspect* of a scenario that was under investigation could be used. The focus of the trials was not on the development of technological solutions but on the investigation of the children behavior in the context of specific aspects of play scenarios related to user requirements.

The feedback from the experimental investigation of various concepts of play scenarios together with the outcome of further consultation with the panel of expert users are then merged to form the Outline Play Scenarios (OS) that reflect the user requirements and are not related to any specific technological solution/robot.
The Experimental investigation also highlighted important aspect of robot design, related to the specific user groups, to be considered in the future robotic implementation.

During the next phase of the project, these OS scenarios will be further developed, against specific therapeutic and educational objectives, and will reflect and utilise the specific functionalities to be implemented in the IROMEC robot and its various modules. It will take into account results of ongoing experimental investigations of the different functionalities of the IROMEC robot which will be carried out with the different target user groups as well as further consultations with user panels, to form the core set of scenarios for robot assisted play and robotic mediators. This development of the final play scenarios against specific objectives, together with the development of evaluation methods will be reported in future publications.

3. Literature Review

In order to understand the play needs of the user groups, and to investigate how robotic toys could be used as a play tool to assist in the children's development, a comprehensive literature review related to play activities of children from different target user groups using existing technology were carried out by several researchers involved in the project. In total, 64 conference papers, journal articles and books were read and summarised. A selection of these that were considered most relevant to the IROMEC project were analysed in depth, and thus represented one data source for the IROMEC scenario development. The review resulted in preliminary play scenarios of children with and without special needs playing with a wide range of animated, lifelike robotic systems as well as mobile or modular systems (see Table II). These preliminary scenarios provided important information regarding play activities, limitations, needs, and the range of interactions that computer or robotic devices can facilitate, thus providing important inspiration to the concept generation of the IROMEC systems, and highlighted important aspects to be considered in the development of play scenarios. Note, the literature review was carried out end of 2006/early 2007 and thus only literature available at that time was included.

TABLE II Literature review providing preliminary concepts for Play Scenarios

References	***User group***	***Play Type***				***Solitary play***	***Collaborative play***
		EX	**AS**	**SY**	**RU**		
(Blotcher and Picard 2002)	AT	✓				✓	
(Weir and Emanuel 1976)	AT	✓				✓	
(Michaud and Théberge-Turmel 2002; Michaud, Duquette and Nadeau 2003)	AT		✓				
(Strickland 1996; Strickland 1998)	AT	✓				✓	
(Michaud and Théberge-Turmel 2002; Michaud, et al. 2003)	AT	✓				✓	
(Michaud, et al. 2006; Duquette, Mercier and Michaud, 2006; Michaud, et al. 2007a; Michaud, et al. 2007b)	AT	✓				✓	
(Werry, Dautenhahn and Harwin 2001; Werry, Dautenhahn and Harwin 2001; Werry, et al. 2001; Dautenhahn, et al. 2002; Dautenhahn and Werry 2004; Robins, et al. 2005)	AT	✓				✓	✓
(Dautenhahn and Billard 2002; Robins, et al. 2004a; Robins, et al. 2004b; Davis, et al. 2005; Robins, et al. 2005)	AT	✓			✓	✓	✓
(Hornof and Cavender 2005)	PC	✓				✓	
(Schulmeister, et al. 2006)	MI	✓					✓
(Cook, et al. 2000; Cook, et al. 2005)	MI	✓	✓				✓
(Lathan and Malley 2001)	PC			✓		✓	
(Nadel, et al. 2000)	PC	✓		✓		✓	✓
(Stiehl, et al. 2006)	PC	✓				✓	
(Kronreif, et al. 2005)	TD MI		✓			✓	
(Lund, Marti and Palma 2004; Lund and Marti 2005)	TD PC		✓		✓		✓
(Kozima and Yano 2001; Kozima, Nakagawa and Yasuda 2005)	TD AT	✓				✓	
(Michaud and Théberge-Turmel 2002)	TD AT PC	✓				✓	
(Kozima and Yano 2001; Kozima, et al. 2005)	TD AT	✓				✓	✓
(Ackermann 2002)	TD		✓	✓			✓
(Raffle, Parkes and Ishii 2006)	TD		✓				✓
(Chioccariello, Manca and Sarti 2001; Chioccariello, Manca and Sarti 2002; Chioccariello, Manca and L. 2004)	TD		✓				✓
(Marti, Lund, Rullo, and Nielsen 2004)	TD		✓	✓			✓
(Lund, Klitbo and Jessen 2005)	TD	✓			✓		✓
(Robins, et al. 2007)	AT	✓				✓	✓

Legend

User group: AT (children with autism or other cognitive impairments)
PC (children with physical and cognitive impairments)
MI (children with motor impairments and bed restricted children)
TD (typically developed children)

Play type: EX (exercise play) AS (assembling play) SY(symbolic play) RU (play with rules)

3.1 Robotic systems in education and therapy

In recent years there have been many examples of the usage of interactive systems in the therapy or education of children with special needs. Such systems include virtual reality or virtual environments e.g. (Strickland 1996, Strickland 1998). Therapists and teachers are increasingly using virtual reality tools to teach social and life skills (e.g. recognising emotions, crossing the road, learning where and how to sit down in a populated cafeteria). The regulated computer environment that virtual reality can offer is used to help people with autism rehearse problematic real life situations and learn how to better cope with the real world (Strickland, 1998). Similarly, computer based interactive simulations in areas such as food, play and hygiene have been found effective in enhancing appropriate functional communication in natural classroom settings (Hetzroni & Tannous 2004). Another example of interactive computer technology that has been used to help children with autism to learn how to recognise social displays of affect is the Affective Social Quest (Blotcher & Picard 2002). Here, a multi media system synthesizes interactive social situations using an animated show containing emotionally charged video clips. The child, communicating with the system via toy-like objects (dolls with different emotional expressions), can be prompted by the system to identify the displayed emotion, or can explore different emotional situations by themselves.

Mobile robots and modular robotic systems too were developed to facilitated learning and interaction, and to be used as assistive technology in rehabilitation. In some early work in the 70's, Weir & Emanuel (1976) investigated the use of a remotely controlled mobile robot as a therapeutic or educational device for one child with autism and reported positive effects of a LOGO turtle on a seven year old boy. In this work the robot did not have any autonomous behaviour, nor did the child have any direct physical interaction with the robot. The robot was operated remotely by the child by pressing buttons in a box.

Remote controlled robotic systems have also been used for interactive play with children with profound physical disabilities. These children have limited access to play activities and as a result the children may have problems in developing cognitive and linguistic skills. Their cognitive and social development can be improved by giving them the same play opportunities as their peers without disabilities. Assistive technology can help them reach the cognitive steps of their chronological and/or mental age (Besio 2001).
The GIR-T system is an interactive robotic rehabilitation tool, disguised as a toy, which can be controlled via body movement, voice activation, or 'gestures' to provide therapeutic educational and entertainment value for children with Cerebral Palsy (Lathan & Malley 2001). Cook et al. (2000) showed examples of how a child with severe disabilities can control and play with Lego Mindstorm™ robots using head mounted switches, and a switch adapted remote control. This setting was found to be a valuable tool for children to learn through play interactions. Another example of utilizing a remote controlled system in play activity involves a robotic arm which was used to provide an alternative method to engage in turn-taking play with an adult (Schulmeister et al, 2006). Here the children were able to experience, independently, the mediated manipulation of real objects in the context of a play activity and to demonstrate an ability to interact and to carry out a sequence of steps to complete a play task. Another example of an interactive remote controlled robot, that is part of an assistive technology system, is CosmoBot (Brisben et al 2004). This robot targets children with special needs (in particular children with autism and cerebral palsy) and has been developed to be used both in professional settings, such as clinical settings or schools, and in home settings.

Learning through manipulation is also being demonstrated with the use of more abstract modular robotic systems e.g. 'Backpacks', u-Texture, 'Playware'. Playpacks are modular physical components that children can incorporate into robotic creations that help them learn about motion and investigate the basic kinematics principles that underlie the behaviour of their specific creations (Raffle el al. 2006). u-Texture is a board type smart material , which has a built in computer and sensors. u-Texture can be connected with other u-Textures to form various shapes, and can recognize its entire structure. It is able to change its own behaviour autonomously through recognition of its location, its inclination, and the surrounding environment (Ohsawa et al. 2005). Playware is the technological concept of physical building blocks (tiles) each with its own processing, sensing, actuation, and communication capabilities, where the different physical configurations of these building blocks will result in different overall behaviours of the system (**Error! Reference source not**

found.). Tiles were developed for a children's playground and allow the implementation of games that encourage children to engage in physical activity in social settings (Lund et al. 2005).

The concept of manipulative technology also presented by Lund and Marti discussing the technology of I-BLOCKS (Lund et al. 2004, Marti et al. 2004, Lund & Marti 2005). The concept is implemented as a set of building blocks called I-BLOCKS (implemented in LEGO™ DUPLO bricks) with individual processing and communication power. Using the I-BLOCKS system, children can partake in 'programming by building' and thereby construct interacting artefacts in an intuitive manner without the need to learn and use traditional programming languages. This technology has been implemented also in a rehabilitation setting to support linguistic scenarios for children with dyslexia, and used also to support children in developing emotional knowledge by allowing them to recognise, control and explore emotions by constructing characters' physical and emotional traits.

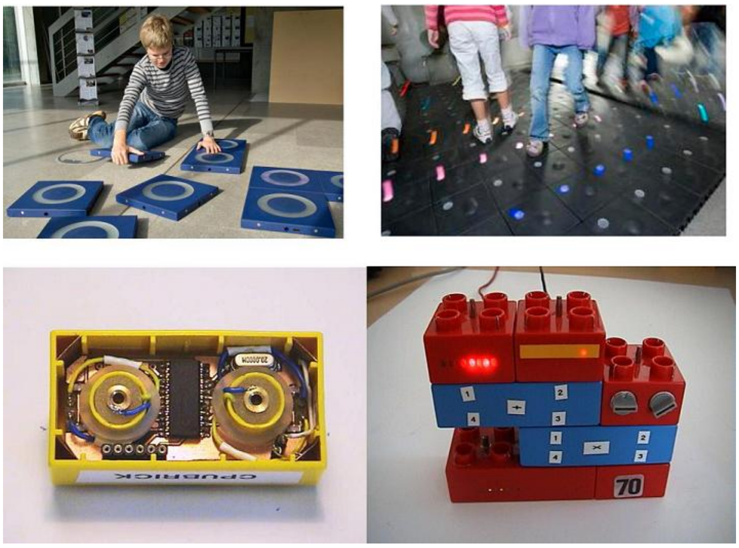

Figure 3. Playware, and modular tiles (up), I-BLOCKS (down) are examples of manipulative technology and modular robotics (photos courtsey of H. Lund).

Modular robotics and manipulative technology as described in the above play scenarios can highlight important design issues that have been considered for the IROMEC system and its play scenarios:

- Manipulation of modular components promotes exploration learning and taking initiative, allowing the participants to express desires, intentions, and aesthetics in what they build.
- The flexibility provided by modular components facilitates learning, allows variation in activities and in complexity that enables children with different developmental levels to engage with the system according to their abilities.
- Immediate feedback can play an important part in motivating the children.
- Combining basic expressive traits together allows the presentation of more complex behaviour.

Mobile robots are also being used as assistive technology for children with disabilities. Michaud et al studied the use of mobile robotic toys in helping children with autism develop social skills (**Error! Reference source not found.**). They explored various robotic designs (e.g. a spherical robotic ball 'Roball', a robot creature with arms and a tail, a mobile humanoid structure on wheels 'Tito') each with particular characteristics, and presented playful interactions of children with autism with these robots (Michaud & Théberge-Turmel 2002, Michaud & Caron 2002, Michaud et al 2003, Michaud et al 2005).

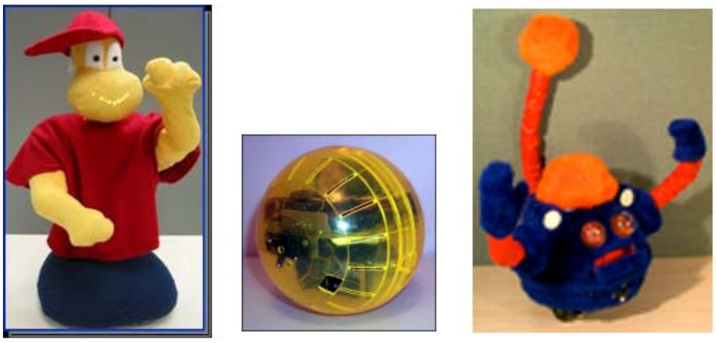

Figure 4. Different robotic designs for playful interactions (photos courtsey of F. Michaud).

Progressively more research is focused on developing robotic systems that can help children with autism in developing social skills. In particular, (Feil-Seifer and Mataric, 2008) describes socially assistive robots (SAR) with the goal of encouraging and facilitating social behaviour in children with autism through embodied social interaction.

Quantitative and qualitative techniques for evaluating interactions of a single child with autism with a non-humanoid mobile robot were presented e.g. in (Dautenhahn et al. 2002, Werry et al. 2001b, Werry 2003). It was shown that individual children paid acute attention to the robot, enjoyed interacting with it, explored the robot's various behaviours, and in one case even tried to 'help' the robot in its obstacle avoidance behaviour. Also, a comparative study was carried out in order to compare the impact of the robot with that of a non-robotic toy. The statistical analysis of behavioral observations revealed that children with autism directed significantly more eye gaze and attention toward the robot, supporting the hypothesis that the robot represents a salient object suitable for encouraging interaction. In a later study with pairs of children with autism, Werry et al. (2001a) illustrated the non-humanoid robot's ability to provide a focus of attention and shared attention. The robot's role as a mediator became clearly apparent in how the children interacted with other people present in the same room, including child-teacher, child-investigator and child-child interactions.

Increasingly, researchers are developing humanoid robots that can interact with people in the same way that people interact with people. Scassellati for example, used an upper-torso humanoid robot, called Cog to research how a robot can naturally communicate with humans using joint attention behavior (Scassellati 1999, Scassellati 2001). Breazeal and Scassellati studied social learning in robotics using imitation (Breazeal & Scassellati 2002). Breazeal used the interpretation of human social cues as one of the architectural elements built into the sociable 'infant' robot Kismet (Breazeal 2002). At the same time, researchers are using robotic systems to study the development of social skills in people. Fasel et al. used simulated and robotic systems to explore the development and dysfunction of shared (joint) attention in toddlers with and without developmental disabilities such as autism (Fasel et al. 2002). Kozima and Yano worked with a humanoid robot (a robotic human's upper body, called Infanoid) that could create and maintain basic joint attention with a human (Kozima & Yano 2001a). More recently Kozima et al. (2005b), developed a small creature-like robot, Keepon, which is very simple in appearance. They reported that the robot promoted spontaneous play in children with developmental disorders, and that they observed the emergence of social communication with the robot and another person (**Error! Reference source not found.**).

While an extensive literature review can provide an important starting point for the development of scenarios, the opinions of and feedback from experts are a crucial source of information.

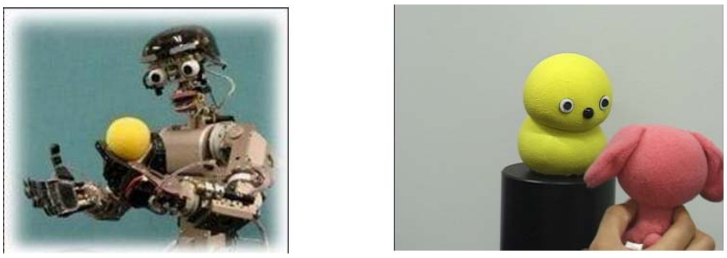

Figure 5. Infanoid (left) & Keepon (right) – exploring joint attention and other social communication behaviour (photos courtsy of H. Kozima).

4. Expert panels

Several panels of experts were organized by the project’s partners in various European countries (i.e. Spain, Italy, The Netherlands, Austria, UK), in order to collect important information related to the play activity of children with special needs. 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. In the following sections, after considering methodological issues of involving users in the design process, we report on the results from panel meetings organised in Austria, Italy, the Netherlands and the UK.

4.1 Users in the design process

The conceptual and methodological frameworks for the design of interactive artefacts have taken into consideration the close relationship between people in their complex social environments and artefacts: people’s actions are intertwined with the artefacts they use. By acting in the world, people transform their environment and are influenced by these transformations. Within cognitive science different recent (or re-discovered) theoretical approaches voice this understanding - Situated Action, Activity Theory or Distributed Cognition (a discussion of the pros and cons of each theory is beyond the scope of this paper, please see (Salomon 1993; Nardi 1996)). The influence of these approaches on the methodologies utilized in the design process of interactive products spans from the workplace to home or educational contexts e.g. (Carroll 2003; Olson and Olson 2003; Rogers and Pennington 1991).

One important issue regarding the design and evaluation processes of interactive products is the involvement and role of end users in the design teams and project design loop. Some approaches consider users in a more reactive fashion where they are evaluating prototypes or final products. Some other approaches consider the need to include users as full members of the design team. Scaife and Rogers (Scaife, et al. 1997; Scaife and Rogers 1999) proposed the notion of Informant Design, where the central point is to acknowledge the need to consider how different stakeholders with different knowledge/abilities/needs can inform the design at different stages of the development by being prompted by different types of material/artefacts/prototypes. Our studies regarding the design of a robotic toy for children with special needs followed a similar approach. It created a framework that includes different phases for the elicitation of requirements from different users and evaluation of prototypes. In our case, users are not only the children that will play with the toys but also the carers, teachers or parents who might set up the scenario for play and either be part of the play scenario involving the child and the robot, or they may guide/direct the children’s interaction with the robot without necessarily being involved in the play directly.

The user panels we conducted are part of the initial design phase of the project in order to find out about the children’s interest, in the context of a play scenario, their likes and dislikes, their abilities and needs. Thus, the user panels were set up to elicit initial requirements and give us some understanding of the design space we are facing. Given the nature of impairment of our target user groups it was not possible to directly include the children in the interviews. Instead we turned to the carers, teachers, parents, therapists and expert researchers in order to tap into the extensive knowledge they possess regarding the daily interactions and activities of children with autism. The involvement of the children occurred through exploratory studies where we tested specific design issues in the light of conceptual frameworks or theories regarding the specific impairment. Furthermore, involving professional carers in our initial efforts also enabled us to understand their own likes and dislikes and the ways they envisage the use of robotic toys in therapy or care.

4.2 Methodology in User Panels rounds

A common methodology was used in all the panels' interviews. This included a short presentation of the project and the aim of the panel meeting, followed by a power point presentation that presented the aims and objectives of the project and gave examples of related previous work. The presentation was 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.

The session continued with a brainstorming discussion amongst the panel members around pre-set questions that aimed to find out:

1. possible activities to be carried out with the assistance of a robotic companion;
2. the role of the robot in the social play context;
3. characteristics of the environment where the robot could be used;
4. functionalities suitable for the target groups;
5. possible critical aspects of the children's behaviour and needs that such a robotic toy could address.

The Italian user panel also included interviews 'at a distance'. The participants were first contacted by phone and e-mail, to obtain their willingness to be involved in this part of the project and to inform them about IROMEC's aims and about the purpose of this first phase of 'user needs analysis'. Then they received the same presentation used in the face-to-face meetings, together with a questionnaire that included open ended questions inviting further suggestions and comments.

4.3 Panel of experts for children with Autism

The user panel meetings related to children with autism gave insights into the characteristics of the children's play: type of play (e.g. solitary play, playing alone but in parallel to others, collaborative play, etc), movement of child and toy in the play activity, the importance of imitation and turn-taking games with other interactors, and so on. The panel also provided input for design requirements related to familiarity, choice and controls, complexity and modularity, appearance, behaviour, environment and context.

4.3.1 Participants and setting

The panel of experts involved professionals from different schools, as well as parents and family members of children with autism. The panel consisted of seven teachers from three different schools (Bentfield Primary School in Stansted Mountfitchet, Essex; Middleton School in Ware, Hertfordshire; St. Elizabeth School in Much Hadam, Hertfordshire), five therapists (psychotherapist, speech therapist, play therapist, physiotherapist, occupational therapist) and two parents and family members, and it has been carried out in UK.

Five different panel meetings in different locations were organized. All panel meetings were tape recorded and reports were compiled addressing the key characteristics of the children's play and the key points concerning the design of a robotic toy that might assist the children's play, a summary of which is presented and discussed below.

Because of the variety of abilities and behaviours of the children, a variety of points are made, some are complementary and some appear contradictory. We have to remember that both the children and their environments are very different.

4.3.2 The play context

Bentfield Primary School is a mainstream school with approximately 220 typically developing pupils. The school also has an Enhanced Provision Unit to cater for nine pupils with various learning difficulties and physical disabilities. These pupils, each accompanied by a Learning Support Assistant, pursue their own unique curriculum and are integrated in the mainstream classes, according to their age group. They participate in any class activity that they are able to.
Play description: according to the teachers, the children here *do not have the desire* to play and do not get involved in anything "playful" other than their own "obsessive" activity (e.g. playing with running water or moving sand, moving rice grains, moving cars and trains). They can play interactive games with others if they are told to, but they will need to be instructed and supported during the game, otherwise they very quickly return to their "own thing".

Middleton School is a special school for children with moderate learning difficulties, with approximately 92 pupils. The school also has a small base of special classes for children with autism.
Play description: part of the children's routine in this school is starting the day with free un-directed play time. Children are encouraged to do physical games (such as football etc.) outside but also can choose any game indoors. The incentive is to give them time to do what they choose to do – their own time, their chosen space. It also provides an opportunity for them to engage in their "obsessive" activities (some always play with sand, others always play with trains, others always play with spaceships etc). The children expect it as part of their routine, and they accept when play time is finished and they happily continue with the next, structured, activity of the day. They are more manageable and more focused after that period of play time.

St. Elizabeth School is a specialist residential school that offers education, care and health support for up to 80 young people in the 5-19 age range who have epilepsy and associated disabilities (such as learning difficulties and autism). This includes up to 12 day placements for young people who commute from home.
Play description: most of the children will not engage on their own initiative in what we term as "play for pleasure" unless they are told to. Some might, but for a very short time, but if they do so it always involves the same game (e.g. puzzles, jigsaw, etc.).

In the meeting with therapists, carried out in the University of Hertfordshire, the play context can be described as: the children play solitary and interactive games as well as imaginary and role playing games, however some feel at loss when they appear to want to play with others but do not know how; they do not have the capability of holding the pre-knowledge required (e.g. when acting out a scene from TV programs).

At the meeting with parents and family members, they described their children's play as liking physical games like chasing, solitary games (e.g. intricate arrangements of objects) as well as interactive games. One child likes to initiate interaction with others where there is a less rigid structure. When playing together with a shared object sometimes there seems to be an unspoken negotiation; they can get to an agreement without speaking. Of course there are occasions when a child insists on playing alone.

4.3.3 Key characteristics of children's play

The following summarizes the characteristics of children's play as described by the panel of experts of children with autism.

Play themes:

- *Collaborative* - e.g. re-telling a familiar story, in turns, with another person.

- *Rule play games* - e.g. a board game, they initiate the game and choose a particular person to play with. However some children *don't* necessarily like board games, or structured rule-games/activities – because often the rules are breached and emotionally they can get upset when the rules are broken.
- *Imaginary play and role play* - some children do play imaginary games and role play but in a very repetitive manner. Role play is usually an enactment of a TV program, some children always have to be the same character. Also the episode *has* to reach the end. Other children when playing role play with others, are very rigid about their ideas and are unable to accept other people's ideas.
- *Solitary play* - is usually very repetitive e.g. always watching the same TV program, printing off the same pictures from the computer or always playing with building bricks.
- *Solitary imaginary play* (e.g. with a Cindy doll) – *acting out scenes from real life.* This could be from TV scenes or what the child has seen, but also could be emotions the child herself was/ had been experiencing. It can be a vehicle to express something she does not yet know how to deal with in real life. *Play is not only about interaction,* the child could play solitary games and use it to work through things they find difficult in real life. *They discover that it is affecting them or others – they learn causality.*
- *Playing alone but in parallel to others* - e.g. playing individually with a train set or in the sand, but at the same time being aware of others playing next to them with similar objects.
- *Some children are at the level of touch /physical sensory level* - their play has a "mechanical" nature to it. Although others participate in instructed interactive games, this occurs in very "mechanical" ways.

Movement:

- The *child's own movement* – running around etc., or watching something moving on its own, against the non-moving environment (e.g. car racing on tracks). *Objects that move around can become the subject of joint attention.*
- Some children are attracted by movement of objects and enjoy the anticipation of an event at the end of the movement (e.g. a rolling ball falling off a table, a bell, sound of a wind-up clock etc).
- *Sensory reward* - they would not want to participate in a game *unless there is a sensory reward* element, this reward could be movement, sound, light – preferences are different from child to child.

Imitation:

- Some children might respond positively when *being imitated*. Imitation can then be developed into a turn-taking activity. It also might promote taking the initiative, e.g. one child was thrilled when people copied him. He took the initiative and was excited by the fact that *he was in control* – people copied him and repeated what he did.
- However, some children can get really irritated when being imitated.
- *Interactors* - they often seem to play better with an adult than with another child (they don't appear to take any notice of another child in the vicinity).

4.3.4 Key points concerning the design of a robotic toy

The following summarizes what the panel of experts see as the main aspects to take into consideration when designing a (robotic) toy that could assist the play of children with autism.

Familiarity:

- A toy that is *unfamiliar* can be *unsettling* – so it *needs to have built-in familiarity* (familiar aspects in looks, sensory output, behaviour etc.), e.g. if it is a doll then it needs a familiar set of clothes that can be taken on and off.
- On the one hand the robot needs to show some structured behaviour so the children know what to expect, but the behaviour should also evolve continually, and thus help to sustain the children's attention after the novelty wears off.

Choice and control:

- *Choice* - it is VERY important that the child is able to make choices. The robotic toy should have a range of *features that are familiar to the specific child* (e.g. safe objects/pieces of music/colour of lights) — *to let the child choose.* Some children prefer a toy that can produce sounds and/or lights etc, so that children can *not* only watch it, but are actively involved in 'making the interaction happen', exploring the toy etc.
- The robot could be covered by cloth or other material in order to provide more sensory experience.
- The robot could be adapted to a particular set (a living room for example) that provides a context that also can be explored at home.
- Control buttons are required - *simple controls on the object itself* (as an alternative to remote control) – pushing the button for example – which results in the movement /reaction of the toy and it also *gives the child the control* over the toy's behaviour.

Complexity and Modularity:

- It needs to be modular - different children would want different levels of technology (e.g. light and sounds) - for some children something very simple with a very limited level of technology might feel quite good; while others would need more complexity to sustain their interest. It needs to be modular and adaptable according to each child's particular preference and at the same time it needs to be *adjustable* as some children are more sensitive than others. For example some children like music very much – however a lot of the music on children's toys is not necessarily interesting to the children; *it needs to be modular and adjustable to the specific child* – one child may like Mozart, while another likes children's rhymes etc.
- It needs to be interactive, but starting with very simple interactions and gradually getting more complex – e.g. like pressing buttons that cause the robot to move, or change lights or both.

Appearance:

- Some children like the tactile quality of fur; others like the sense of hard plastic.
- Some children are frightened by big eyes - they will scratch them; others like to see eyes.
- The robot should not be too human-like. However having "eyes" could be useful for some children and might encourage interaction (similar to the eyes, for example, on "Thomas the Tank Engine" etc). This needs to be a modular feature as for some children it is painful to look at eyes. Possibly having a symbolic/ "mechanical" face (e.g. like a matchstick person's face or a "Smiley" face with dots and lines).
- The toy should not be in a human form but have more "machine-like characteristics", e.g. a rigid toy that produces a sequence of actions.
- Appearance – a two dimensional type of object – like cartoons – simple, without too many details.

Behaviour:

- *"Trigger action"* – each child has a different "action" that stimulates him/her (a "trigger action"). In order to motivate the child, the robots must have something similar that will be familiar to the child. Because each child with autism might have

different "trigger actions", the robots need to be modular enough to offer different "trigger actions" as appropriate to each child.
- Physical manipulation of the object needs to be encouraged. The child needs to be able to manipulate it. The robot's behaviour needs to *depend* on the action of the child. At the same time it is hoped that the robot will encourage the children to move and maybe to stretch different body parts.

Environment and context:
- The environment should be supportive allowing the children to interact and to make mistakes. It is important that they are received sympathetically even when they don't get it right.
- Companionship - such as a partner to play with the child – responsive to the child's movement, receptive and responsive to the child's actions.

4.3.5 Discussion of results
The user panels clearly highlight the fact that the robotic toys may be used in different contexts (at home, at different schools), by diverse children who show strong likes and dislikes as well as a wide range of abilities and needs. To summarize, there is a need to consider the following aspects when designing a robotic toy for children with autism:
- the different types of play according to the specific child's abilities;
- the different physical settings that can influence the type of play and interactions (for example, what kinds of movement are possible in a specific physical setting?);
- the complex intertwining of appearance and its influence on the interaction.

The results from the user panels present the following robot design challenges:
- How to accommodate the needs of different children in a certain setting (in a particular school)?
- How to accommodate different settings (different schools, home etc)?
- How to accommodate the progression of the child according to therapeutic/educational goals?
- How can the carers of the children adjust the robots' characteristics to the needs they envisage?

As stated above, autism has a wide range of manifestations where children might display completely different patterns of behaviour from each other (a variety interaction styles can be seen in **Error! Reference source not found.**).

Figure 6. Characteristics of the children's play as described by the panel of experts are being tested in experimental investigations.

The results discussed above show that children with autism might have different or even contradictory needs. The challenge in providing a high degree of flexibility in an assistive tool to answer these needs, implies that there is a strong requirement for a *built-in modularity* that could be accessed by the users, *and to their choosing.*
Also, an important issue to consider in future work concerns the interface that the robot provides to the children (interaction modalities etc.), but - equally important - the interface to carers/teachers/parents who may want to change settings and fine tune the robot's behaviour.

4.4 Panel of experts for children with Mild Mental Retardation

The user panel meetings related to children with mild mental retardation, also referred to as intellectual disabilities or learning disabilities, outlined several characteristics of play witnessed in school and in therapeutic settings. Additionally, the panel provided requirements for design originating from the play environment and play sequences related to challenges and complexity in behaviour and use, triggers for motivation to play and possibilities for control. Due to the heterogeneity of this target group, abilities and behaviour of children vary a lot. Generalised statements as mentioned above have to be individually adapted for a specific child.

4.4.1 Participants and setting

Several user panel meetings relating to children with mild mental retardation have been organised in different locations in the Netherlands and in Italy. Among the panels of experts were professionals from different schools and rehabilitation centres, as well as parents and siblings of children with mild mental retardation. Parents, brothers and special education teachers of children with cognitive and multiple impairments were part of user panels in Siena. At the rehabilitation centre "Peppino Scoppa" Foundation in Angri/Napoli, Italy, therapists (speech therapists, psychomotor therapists, physiotherapists and occupational therapists) and neuro-psychologists have been involved in analysing the requirements of blind children, hypo-acoustic children, and children with mild mental impairment, Downs Syndrome, attentional disorders, learning delays, language disorders and affective and socio-relational disturbances. In parallel, panels took place in the rehabilitation centre Heliomare in the Netherlands, which is a major rehabilitation centre for people with physical impairments, whether or not in combination with cognitive impairment. The centre includes both specialised treatment and education centres for children and juveniles (4-20 years). Additional occupational therapeutic expertise was contributed by Adelante, a special school and rehabilitation centre for children with motor impairment and intellectually disabled children aged 0-20 years in South Limburg, the Netherlands. Finally a meeting was held at St Marie, an audiological-diagnostic centre for children with communication disorders in Eindhoven, the Netherlands. This concerned mainly children with autistic spectrum disorders and children with Downs Syndrome.

4.4.2 The play context

In general, the children have several educational lessons during the day with 1-2 integrated therapeutic sessions per day. There is time for free play during the school day and the therapeutic sessions involve a lot of play situations as well.

4.4.3 Key characteristics of children's play

The characteristics of children's play as described by the panel of experts of children with mild mental retardation can be characterised as follows: Children with mental retardation may have trouble playing because of their intellectual limitations and cognitive disabilities. They have reduced attention ability and might not understand the meaning or the rules of the proposed play, and/or the meaning of the language used to play; since the children may also have speech limitations. Important aspects of play for children with mental retardation are as follows:

Children with intellectual disabilities often show delays or uneven skills, difficulty in structuring their own behaviour, or a lack of sustained attention. These may be illustrated in play through differences in preferred play material (i.e. preference for structured play materials). Many of the children with mental retardation show repetitive behaviour, or "obsessive preference for activities. For example, some always play with sand, others always play with trains, or others always play with spaceships etc. They often show decreased play strategies, decreased curiosity, a need for external cues, and inflexible methods of exploration. This leads to a decrease of imagination and decreased symbolic play behaviour. The children show less transfer of learned skills to other situations, and less spontaneous play. They often play alone but in parallel to others – e.g. playing individually with a train set or in the sand, but at the same time being aware of others playing next to them with similar objects. Playing is initiated by some children on their own initiative. However most children will not engage on their own initiative in play for pleasure unless they are told to. Some further description of play characteristics as mentioned in the panels include:

- It can be interactive rule play e.g. a board game, and they initiate the game and choose a particular person to play with, but mostly they play in a "mechanical" way.
- It can be solitary play – like building bricks.
- Some can play imaginative and role play games, but in a very repetitive manner.
- Some are at the level of touch/physical sensory level – their play has a "mechanical" nature to it and they can use turn-taking.

4.4.4 Key points concerning the design of a robotic toy

This section summarizes what the panel of experts see as the main aspects to take into consideration when designing a robotic toy that could assist the play of children with mild mental retardation. For this target user group it would be preferable if the robot:

- Is interactive, and is able to start very simply, gradually getting more complex – e.g. like pressing buttons that cause the robot to move, or changing lights or both.
- Increases their attention span.
- Motivates and stimulates them, maybe with sounds and lights; these need to be adjustable as some children are more sensitive to sounds and lights than others.
- Encourages them to move and maybe to stretch different body parts.
- Lets them learn from this interaction and improve the effectiveness of their action on the environment.
- Is similar to a two-dimensional object, like cartoons, simple, without too many details.

4.4.5 Discussion of results

Children with intellectual disabilities show less opportunity to play by comparison with typically developing children. In a nutshell, the panels concluded that there may be an added value for a specially designed robotic toy addressing the needs of these children and enhancing their development of social skills and sense of self-efficacy. However, the user panels are not unanimous on the need for inclusion of this target user group at this stage with a novel robotic toy. They commented that, especially in rehabilitation and educational settings, there are already a lot of toys on the market and professionals know how to adapt toys to make them suitable for these children. However, there might be a benefit for a robotic toy to be given to all children of younger age with mild mental retardation or with moderate mental retardation.

4.5 Panel of experts for children with Severe Motor Impairment

The user panel meetings related to children with severe motor impairments gave an overview of possibilities of play and characteristics of the children's play in an educational and therapeutic context. It also provided information about design aspects like size, control options etc. and ideas about which requirements the robot system should fulfil.

4.5.1 Participants and setting

All the participants involved in the panels have been working in the field of rehabilitation, or education and research involving children with physical impairments for many years. In Austria mainly teachers from a special school were involved. The Austrian's panel consists of nine teachers, one kindergarten teacher, and one carer from the residential school. Four panel meetings were organized at the Waldschule and carried out with two team members of the IROMEC project team. The University of Valle D'Aosta research team organized five different user panel meetings (both face to face and at distance) in Italy. The Italian's panel included teachers, researchers, university professors, and rehabilitation and Assistive Technology professionals. In addition, a group of parents took part at the panels. After the meetings reports were compiled addressing the key points concerning the design of the robot system and characteristics of the children's play. During the discussions it was shown that the variety of abilities is high so some information is complementary and some appear contradictory. It should be noted that, as well as children with autism, children with physical disabilities are also very different.

4.5.2 The play context

Waldschule (Wiener Neustadt, Austria) is a special education school for children with physical and multiple disabilities at the age of 6-15 with about 100 children. The school offers small classes for max. eight children and each child pursues his/her own curriculum. Attached to the school is a residential house for the children to live there or be there after school.
Play description: The children have the possibility to play during the day after their learning phase, and after finishing their tasks. Usually they play alone and depending on their degree of disability they play games like puzzles, memory games etc. Once a week they have gym lessons where they play cooperative games. In the residential school the children can play for pleasure all different kinds of games in the afternoon.

The panels of experts involved in Italy come from different towns, working in different contexts, being both parents and professionals, researchers and therapists. For these panels it is possible to summarize the information related to three main play contexts:
Play activity in School: Disabled children attend public schools with typically developing children. During the first cycle from 3 to 6 years old play is the main way to propose and develop educational activities. There is a direct involvement of adults and teachers with a greater involvement of cognitive and social ability than motor ones and these two facts make participation easier. After this period play becomes possible only during free time between lessons without any help or control of adults. Free play is generally physical (football, hide and seek…) and involvement is more and more difficult.
Play activity at Home: At home problems arise when motor impairments prevent autonomous play activities and parents have to add to their usual care and assistance the responsibility of play time. It is common that electronic games and TV becomes the main activity during leisure time at home.
Play activity in Rehabilitation setting: Play is the only way to makes physical and speech therapy acceptable for children. For this reason professionals use every possible strategy to invent and use play as a mean of intervention.

4.5.3 Key characteristics of the children's play

The following summarizes the characteristics of the children's play as described by the panel of experts of children with motor impairments.

Play themes

- *Exercise play*: for this type of play enjoyment is very important. Repetition of games/activities give children with disabilities a sense of safety. Setting something in motion is fascinating for this target group. This kind of play is often solitary and sometimes together with other children.

- *Assembling play*: Most of the children with physical disabilities have no practical experiences in constructing things because they are not able to do that by themselves. Children need an assistant for construction – a robot system could be such an assistant. Children like to play together.
- *Symbolic play:* This kind of play depends on the experiences of the child (e.g. playing for example with an invisible friend or masquerading as different persons they know from TV etc.).
- *Play with rules*: This kind of game is difficult for children with physical disabilities to play without help. With the help of their teachers, children enjoy playing board games with their peers.

Children with motor impairments have really poor play skills, and lack of autonomous initiative and onlooker play behaviours are commonly observed. Younger children have a strong need of participation in peers' play activities as they usually have few opportunities to play with peers, especially with children without any disability (siblings and classmates) while older children may need to be supported in solitary play by letting them play alone when nobody is around.

Assembling play, symbolic play, and play with rules appear to be especially important for this target group as the most common play type they exhibit is a very simple exercise play.

It also has to be taken into account that children with motor impairments really love movement play, while they absolutely cannot do it, so their need to use their body in play activities should be considered.

Use of toys

The population of children with severe motor impairments is highly challenged in the use of common toys, even if mediated by adapters, switches or other AT devices. A way to interact with these play materials should be considered to provide to these children more play opportunities.

Playfulness

Play should not be interpreted as a mere tool for education or therapeutic interventions, but rather, a source of genuine joy in natural, inclusive settings. The panel participants underlined the difference between "playful" and "playful-like" activities, putting a strong focus on playing for the *pleasure to play***,** not for obtaining pre-determined educational results.

4.5.4 Key points concerning the design of a robotic toy

The following summarizes what the panel of experts see as the main aspects to take into consideration when designing a (robotic) toy that could assist the play of children with severe motor impairments.

General remarks

The robot system has to be stable because system breakdowns lead to frustration.

For children with physical disabilities the play itself should be in the foreground with a tendency from learning towards creative play.

The accessibility of robot's functionalities deserves attention as the direct manipulation of the robot could be impossible for the target children.

Choice and control

For children with physical disabilities it is necessary to have the possibility of a remote control for the robot system. The remote control should be flexible and adapt to the needs of each child (possibility to use different devices). Using control devices gives the children control over the robot's behaviour. The devices should be wireless.

Children should be able on the one hand to play alone and make choices for themselves (music, lights, etc) but on the other hand they should not be allowed to access system settings, parameters etc. – this should be done by teachers, therapists etc.
For this target group the robot system/toy could be used in an additional way as an assistant for constructive play or board games.
The panels pointed out the importance of allowing the children to make decisions autonomously while playing, selecting the activities and the robot functionalities with the aid of assistive technology devices. The possibility of operating the robot at distance, through a remote control, should be a suitable means of interaction in a play setting. The panel's participants also express the need for the robot to act as an assistive device itself, helping the children to reach, bring and manipulate standard toys, so contributing to limit the tendency to repetitiveness in their behaviour.

Complexity and Modularity
Because of the wide range of disabilities and different preferences of the children it is essential to have the robot system adaptable and modular. Some children will use the remote control, others can control it direct, some children need visual feedback, other need acoustic feedback etc.
The system needs to be modular because children need different levels of difficulty, so some would need a low level of technology and others would need a high level of technology.
The robot should have some *basic functions* but it should also support the implementation of *additional functions*, so that it can be used at a basic or at a more complex level and it can also give the possibility of supporting the child's learning, offering him/her new challenges as he/she learns to manage it. For these reasons robotic systems to be used as play mediators with children with severe motor impairments should be based on *modular components*, so that they can adhere and respond to the children's cognitive and motor resources, and so that they can offer them innovative and rich play proposals.
Technical complexity should match with a simple and intuitive use of the robot: apart from an initial training period mediated by the adult, the robot should be used in a *total autonomous way,* alone or with the peers.

Appearance
For children with physical disabilities it is important that the robot system is robust and attractive for children. It should look likeable and not monstrous so that children get frightened. Robustness is important so that the risk of injury is very low (children are sometime not able to estimate the risks).
The design should be colourful and not too big so that the system is portable.
Expressiveness is a highly recommended feature to foster symbolic play. The basic structure of the human face should be respected.

Behaviour
The robot should be *strong* and *obedient* so that it lets the children feel strong and autonomous in their turn and also lets them do things they cannot do otherwise.
Robots should also give these children the possibility to act in the world around them in a more spontaneous way, expressing a wide range of emotions and displaying different behaviours, for example being spiteful or making noisy play activities. The presence of active functions is highly recommended.

Environment and context
The play with the robot system should not be limited to the table – the interaction with the toy/robot system should be able in different environments, also on the floor etc.
Children should be able to play alone without the help of their teachers, therapists, nevertheless the interaction child + toy/robot and/or child + toy/robot + child are important too for social learning.

The environment should be supportive – it should be possible to make mistakes and get feedback in a positive way.
The robot should let the child play (both alone and together with others) in *normal contexts of life* (the home, crowded places, schools, kindergartens, summer sites) and it should not only be designed for rehabilitative and/or educational activities.
Open spaces (gardens, lawns, training ground schools, etc.) have been identified as very interesting contexts for robot use, because they are often inaccessible and desirable.

4.5.5 Discussion of results

The user panels emphasized that a robot system/toy can have an added value for children with physical disabilities if it is modular and adaptable to the needs of each individual child.
The participants pointed out the need to consider the introduction of a robotic toy as a way to promote autonomous play and genuine playfulness in ecological inclusive settings. To reach this goal the freedom to choose the play activity and the possibility of directly operating the robot are needed. To better match the needs of this specific target group the robot should also have assistive functions, allowing children with disabilities to do actions that are impossible or difficult for them.
Due to the very different motor and communication abilities of children with motor impairment, the possible ways to control the robot should be very adaptable.
To foster assembling play, symbolic play and play with rules seems to be more important than the promotion of exercise play as children with severe motor impairment are usually lacking in these play types.
The results from the user panels present the following robot design challenges (similar to the results from autistic children):

- How to accommodate the progression of the child according to therapeutic/educational goals?
- How to accommodate the needs of different children in a certain setting?

Another important aspect is that the system has to be easy to use for the teachers, therapists etc and the system has to be stable, otherwise the teachers and children will be frustrated.

In addition to literature review and expert panels, experimental investigations are an important source of input in IROMEC for the development of play scenarios. Thus, investigations with different user groups have been carried out throughout the process of scenario development. Below we illustrate these experimental investigations in the format of selected case studies.

5. Experimental Investigation of Play Scenarios

Various aspects of the user requirements, as expressed in the user panel meetings, were implemented in experimental play scenarios and investigated in field trials using existing available technology. The results of these trials are documented in play scenarios that reflect the specific play activities. The field trials also highlighted important aspects for the robot's design. This task is of an on-going nature in order to feed into both the design of interactions, and to the robot design, and helps to form the final scenarios for robot assisted play and robot mediators.
In the following section, case study examples of these experimental investigations are presented. These included a limited number of participants[7], with the aim to provide feedback on the scenarios and to gain information about robot requirements that will feed back into the design process of the robot.

5.1 Trials with children with autism

[7] Note, as mentioned in section 2.2, these small scale user studies are not aiming to evaluate any effect that potential robot might have on the users. Long term evaluation of the effect of the IROMEC robot against the therapeutic and educational developmental objectives of the children will be done in large scale studies once the development of the robot will be completed and result s will be reported in future publications.

The trials took place in three schools in the UK (Bentfield School in Essex, Middleton School in Ware, and St Elizabeth's School in Much Hadam).
The trials were designed to allow the children to have unconstrained interaction with the robots with a high degree of freedom, and to build a foundation for further possible interactions with peers and adults using the robot as a mediator (Robins, et al. 2004a; Robins, et al. 2004b; Werry, et al. 2001; Werry, et al. 2001). In all schools, the trials were conducted in a familiar room often used by the children for various activities. Before the trials, the humanoid robot was placed on a table, connected to a laptop. The investigator was seated next to the table. The robot was operated remotely via a wireless remote control (a specially programmed keypad), either by the investigator or by the children (as per the play scenario). The mobile robot was placed on the floor in an area big enough for the participants and/or the robot to move around. The children were brought to the room by their carer and the trials stopped when the child indicated that they wanted to leave the room or if they became bored.

5.1.1 Ethics

The Experimental Investigation phase has been approved by the Ethics Committee of the University of Hertfordshire. In addition, all researchers involved in this phase applied for an Enhanced Disclosure, and an Enhanced Criminal Record Certificate was issued by the Criminal Record Bureau (CRB) before any trial took place.
Parents were informed about the nature and practices taken in the research, and they gave their consent for the participation of the children in the research and for the publication of the work within the scientific community.
The headteachers of the schools where trials took place, were regularly consulted, and were continuously made aware of trial procedures and outcomes.
In the light of the nature of the population that participates in this research, the trials were conducted in the presence of the child's carer or therapist. During the trials, the experimenter and the carer consulted each other as needed, constantly aware of the well-being of the child (and the robot). Trials would stop if the children exhibited any sign of distress.

5.1.2 Participants

The teachers/therapists at St Elizabeth's School selected 4 children (child A age 7, child B age10, child C age 11, and child D age 15) all diagnosed with autism, to participate in the study. Child A and child C have very limited language skills, used to express some needs, and child B and child D have a reasonable command of language understanding and expression. Child D pays rigid attention to their own choice of activity, engages in solitary play or work, shows no interest in the activities of other children and is highly distractible in activities led by the adults around (teachers/therapist). The other children understand simple directions associated with routines, might take part in work or play with one other person and take turns in simple activity with adult support. Child C requires one-to-one support to maintain his/her attention, and to perform most collaborative activities.

5.1.3 Artifacts

Two robots were used in the trials (one robot at a time):
a) KASPAR - a 60 cm high humanoid child-sized sitting robot developed by the Adaptive System Research Group at University of Hertfordshire (see **Error! Reference source not found.** left). The main body of the robot contains the electronic boards, batteries and motors. KASPAR has 8 degrees of freedom in the head and neck and 6 in the arms. The face is a silicon-rubber mask, which is supported on an aluminium frame. It has 2 DOF eyes fitted with video cameras, eye lids that can open and shut and a mouth capable of opening and smiling. It has several pre-programmed behaviours that include various facial expressions, hand waving and drumming on a tambourine that is placed on its legs. A more detailed description can be found at http://kaspar.feis.herts.ac.uk.

b) LEGOROBOT - a small mobile robot that was developed specifically for a simple turn-taking and sensory game for children with autism. It is equipped with an on/off button for movement, activity buttons on each side, a set of coloured lights on the top, and an additional white light at the centre (see **Error! Reference source not found.** right).

Figure 7. The two robots that were used in the experimental investigations: KASPAR (left) and LEGOROBOT (right). Both robots were designed in the Adaptive Systems Research Group at University of Hertfordshire.

5.1.4 Examples of trials

As stated above, the trials investigated various user requirements (see section 4.3.3 above) and were used as an aid to the main task of forming play scenarios for the IROMEC robot. Although a detailed description of these trials is beyond the scope of this article, the following section presents two examples of play scenarios investigated in these trials.

1) Example of an Experimental Investigation scenario with the humanoid robot

Following the user panel advise about children who might respond positively when being imitated, and that imitation can then be developed into a turn-taking activity, and possibly promote taking initiative, a play scenario was devised around an imitation game, taking into consideration various aspects of user requirements as expressed by the panel (e.g., movement, imitation, choice and control, complexity and modularity – see section 4 above). In this scenario two children with autism are involved in a turn-taking and imitation game. The two children are seated in front of the humanoid robot (Kaspar) that is placed on a table. One child is controlling the robot (using a remote control) and the other is imitating the robot's behaviour (see Figure 8).

The objective of the scenario is to engage the children in an interactive play activity and in an imitation game where they are in control of the activity. These enable the actors to play together an imitation game (mediated by the robot).

Figure 8: Example of Experimental Investigation scenario of robot mediated interaction between peers (Kaspar).

The activity can be described as sequences of imitation phrases, where one child controls the robot and the other child imitates its movements. The game starts when the first child – operating the robot remotely - changes the robot's posture. The other child imitates the action.

The leading child has to wait for the imitating child to imitate the robot correctly before moving to the next step (e.g. changing the robot's posture). After a few rounds, the children exchange roles.

2) Example of an Experimental Investigation scenario with a stationary inanimate robot
Following the panel's advise about the need for sensory reward elements in order for children to participate in games (reward that could be sound, light, movement – preferences are different from child to child), a turn taking game for sensory reward was devised. It implemented aspects raised by the user panel such as turn taking, physical manipulation, anticipation, taking initiative etc.
In this scenario two actors are involved in the game, a child and an adult. The adult has a supportive role – to respond to the child's initiative, or to take the initiative and encourage the child to play, when needed. As this is a very repetitive game, the adult needs also to introduce variation in the way the game is played (vocal sounds, tone of voice, etc).
The game is played using the stationary inanimate robot (Legorobot), and consists in a turn-taking game with a sensory reward. The robot is placed on the floor and the participants are sitting around it (see Figure 9). The objective of the game is to engage the child in a collaborative turn-taking game with another person, whilst having enjoyment and sensory rewards (lights) as a result.

Figure 9. Example of Experimental Investigation scenario of a turn-taking game with a sensory reward (Legorobot).

The game starts with repetitive actions to enable the turn-taking (press one button and the red light goes on, press the other button, the red light goes off and a green light goes on), and is designed in a such a way that the buttons have to be pressed in turns, otherwise nothing happens. The repetitive actions are followed by something different and new (press the first button for the third time and a white flashing light goes on). Then the whole sequence can start again and can be repeated as many times as the participants like. In this specific experimental investigation, several variations can be introduced (e.g. sound can be introduced by each person calling out the colour of the light before it appears).

5.2 Trials with Children with Severe Motor Impairments

The experimental trial took place in the classroom of the participants and lasts about one hour. The trial was designed to test aspects from user requirements and to get additional information to formulate the final scenarios. In that trial the children should have the possibility of acting autonomously and influencing their environment in a playful way and get positive feedback.

5.2.1 Ethics

The experimental investigation related to children with severe motor impairments has been carried out in "Waldschule". The parents of the children were informed of the IROMEC project and gave their permission for attending the trials. The children were informed by their teachers the days before that team member of the IROMEC project came to play with them, the children already knew the people from former projects.

5.2.2 Participants

Two children with severe motor impairments participated. Both of them were 12 years old. One child was able to control his wheelchair by himself and the other one needed very high assistance and was not able to control her upper extremity. The developmental age of both children was not clear – estimation from the teacher: child one 9-10 years and child two was totally unclear because her high need of assistance.

5.2.3 Artifacts

For the experimental trial the “Mumo-Software” and a panel PC with a webcam was used (MUMO is a software module which enables children with physical disabilities to make music through movements). A screen shot of the MUMO software’s user interface is presented in **Error! Reference source not found.**.

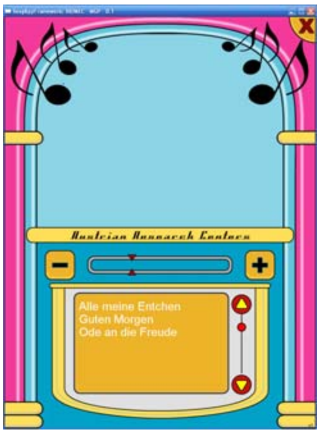

Figure 10: Screen shot of the MUMO software’s user interface

5.2.4 Examples of trials

This section provides an example of an Experimental Investigation scenario with a stationary platform with a child playing alone. The adult has a supportive role to explain the game and in emergency cases or if the child does not know how to proceed. The panel PC with the webcam is placed in front of the child (sitting in his/her wheelchair). The aim of the game is that the child moves body parts and through the movements a song is played – when the movements stop the music stops too. Having fun and moving and controlling body movements are the main purpose. After one song is finished the game can be started again with the same song or another could be chosen.

As the people from the user panel pointed out that acting autonomously is important for children with severe motor impairments the trial was conducted to that fact. Although the game was very easy for the children it was great fun to have the experience of controlling the song with their movements without help. For future trials it would be more interesting for the children to have a list of different songs they already know and like and also have variations of the game. For example one idea could be that the robot system is driving while the children control it via body movements. It could be shown that children enjoy doing something autonomously but they also need a challenge in playing a game over a longer period of time. The different types of games should be regarded in the formulation of scenarios having a wide variety of different types. It should be avoided that children with physical disabilities have the possibility of playing only e.g. exercise games. The challenge is to have a system which can be used autonomously by this target group.

6. Synthesis: Outline Scenarios for Robot Assisted Play

As explained above, the preliminary concepts of play scenarios (scenarios derived from the literature review, user panel rounds, and scenarios used in the experimental investigations) helped to form the *Outline Scenarios* for Robot Assisted Play (Table III).

TABLE III Outline Scenarios for Robot Assisted Play

Scenario (title and characterization)	**User group**	**Social mediation**	**Play Type**				**Solitary play**	**Collaborative play**
			EX	**SY**	**AS**	**RU**		
Turn taking - with a mobile robot	AUT	**H**	✓			✓		✓
Push it - Cause & effect, turn-taking	AUT	**H**	✓			✓	✓	✓
Turn taking - for sensory reward	AUT	**H**	✓					✓
Imitation game - Imitation game	AUT	**H**	✓					✓
I am in control - Imitation game	AUT	**H**	✓					✓
Hide & Seek - Spatial perception	MMR	**M**				✓	✓	✓
Express yourself - Cause & effect	MMR	**L**	✓				✓	✓
Musical sequence - Reproduce a sequence	MMR	**H**				✓	✓	✓
Follow-Me - Be in control	MMR	**H**	✓		✓		✓	✓
Vibration – Sensory reward & stimulation	MMR	**L**	✓				✓	
Catch me if you can - Planning & cooperation	MMR	**H**	✓			✓	✓	✓
Drawings - Expressiveness	MMR	**H**	✓	✓	✓		✓	✓
Find it! - Cause & effect	MMR	**M**	✓		✓		✓	✓
Peek a boo - Explorative game	MMR	**L**	✓				✓	
Construct my own robot - Collaborative & constructive	MMR	**H**			✓			✓
How do I feel? - Constructive & exploring emotion	MMR	**H**		✓	✓			✓
Bring me the ball - Cause & effect	SMI	**M**	✓				✓	✓
Make it move - Cause & effect	SMI	**M**	✓				✓	✓
Dance with me - Imitation	SMI	**L**	✓		✓		✓	
Build a tower - Solitary & constructive	SMI	**L**			✓		✓	
Mirror emotions - Control expressions	SMI	**L**		✓			✓	
My pet and me - Pretend play	SMI	**L**	✓	✓			✓	
Playing a character - Pretend play	SMI	**H**		✓				✓
Simulated board games - Board game	SMI	**H**				✓		✓

Legend
User group: AUT (children with autism) MMR (children with mild mental retardation)
SMI (children with severe motor impairments)
Social mediation: H (high) M (medium) L (low)
Play type: EX (exercise play) SY (symbolic play) AS (assembling play) RU (play with rules)

These are abstract scenarios that reflect the users' requirements and which are not restricted to any specific technological solution.

These *outline play scenarios* (OS) are on a high level of abstraction, neither are they limited to the implementation or availability of specific robots, nor do they rely on specific technology (e.g. specific actuators/sensors). For example, in a turn-taking scenario with sensory rewards, the outline scenario does not specify the exact nature of the reward; it could be light, sound, movement, etc.
As stated above, these sets of scenarios will further be developed, in consultation with the user panels, in order to derive a core set of final play scenarios which will give users from the different target user groups possible ways of interacting with the IROMEC robot using specific built-in functionality. A very important aspect of play scenarios is to encourage play between pairs of children whereby the robot can serve as a mediator.
The tables below are an example of outline play scenarios.

TABLE IV Example of Outline Play Scenario for AUT children: ‘Turn taking for sensory reward’

Actors/ Roles	Two actors are involved in the game. These actors could be two children, or a child and an adult (e.g. teacher, family member, etc). When two children are playing the game, both actors have equal roles. When an adult plays with the child, the adult has a supportive role – to respond to the child’s initiative, or to take the initiative and encourage the child to play, when needed.
Play Type	Sensory motor play, game with rules
Activity Description	The game consists in a collaborative turn-taking activity with a mobile robot. The mobile robot has a start/stop activation mechanism that can be controlled by the user. The objective of the game is to engage the child in a collaborative turn-taking activity with another person (peer or adult). The motivations of the child are threefold: • the ‘cause and effect’ satisfaction and interest - i.e. when activating the robot, the robot moves; • the excitement of anticipation – waiting for the robot to reach the person (peer or adult); • engaging in a turn-taking game with another person. The motivation of the adult is to encourage the child to have social interaction in a collaborative play and also to respond to the child's initiative when taken.
Activity model	Sitting on the floor at a distance from each other, one user aims the robot towards the other user and activates the wheels of the robot causing it to move toward the other player. When the robot reaches the second player, they should stop the robot's movement, turn it around, re-activate it, and send it back towards the other player. This session can be repeated as many times as the participants want. There could be several variations of this activity, depending on the level of functionality implemented in the robot (e.g. sensors to detect people, to search, find and follow an object with a specific colour, etc.).
Place/ Setting	The game is best played on the floor in a room with a large empty space (although any floor space can be sufficient). Large space can allow the participants to go to different points in the room, or to run around and wait in anticipation for the robot to reach them.
Artifacts/ Media	A mobile robot with a start/stop user interface mechanism that also includes status and sensory displays (light, sounds, etc.).
Time/ Flow	The game is made up of a short sequence of actions. This basic phase can repeat itself many times, thus the duration of the activity is unlimited and can take place as long as the participants are interested.
Keywords	Turn-taking, enjoyment and excitement, social interaction during collaborative play, cause and effect, anticipation.
1 	2  3 

TABLE V Example of Outline Play Scenario for children with SMI: ‘Bring me the ball’

Actors/ Roles	One or two actors can be involved in this game. If only one actor is involved the robot is interacting with the child autonomously (child throws ball – robot brings it back). If two actors are involved one actor is taking over the control of the robot (manual and semiautomatic modes are possible).
Play Type	Sensory motor play
Activity Description	The game consists of playing with a ball (throw and bring it back). This play activity helps the child to experiment with cause and effect. When the child is playing alone with the robot s/he learns to roll, push the ball and to watch the ball move (sensing moving objects). Overall goals and motivations are fun and excitement. Anticipation where the ball would go to is another goal. One of the objectives of the game is to locate the ball in the room. Motivation could be to find a destination for the ball, where the robot is not able to find it or pick it. Child learns to follow the robot when it fetches the ball.

	When the child is playing with another child s/he is involved in a collaborative game. The child controlling the robot learns manipulator use (robot as tool) and to navigate in the room. If the semiautomatic mode is used the child activates and trains sequences and learns to sense moving objects (ball and controlled robot). A motivation for the child controlling the robot is optimization of remote control etc.
Activity model	The motor impaired child is sitting or lying on the floor. The child has a coloured ball and throws, pushes, or rolls it to a specific location (intended or not). The robot is able to move to the ball, pick it up, and bring it back to the child (ideally the location where the ball came from). Then the child has to pick the ball from the robot, and the robot moves to a random position in the room. When the child is playing with another child with motor impairment, the first child has (with the help of a special remote control) the possibility to take over the job of controlling the robot (move in room to ball, pick ball, bring ball to the other child, release the ball if picked up, move away). It is not necessary that all functions are performed by the child (e.g. the robot can run in a semiautomatic mode and the child has just to select different behaviour (such as 'go to ball', 'pick the ball', 'bring the ball to the other child', 'go to a random position'). The robot could have a sensory display when moving (e.g. light, sound, etc.) and could give sensory feedback when it performs the desired task. There are many recursive patterns included (find and move to ball etc.).
Place/ Setting	The game is played on the floor. It should be some free space that is neither crowded nor containing a lot of furniture. It should not be possible for the ball to be sent to a destination where the robot is unable to pick it up (otherwise additional help from a person would be needed); if that is included in the scenario it could be a goal for the child to push/throw the ball to a destination where the robot might not be able to access. Suitable for play and therapy sessions.
Artifacts/ Media	The artefact is a mobile robot equipped with sound and light effects, and a mechanism to pick up a small ball. Remote control interface that can be connected to special input devices.
Time/ Flow	The game is made up of a short sequence of actions. This basic phase can repeat itself many times, thus the duration of the activity is unlimited and can take place as long as the participants are interested.
Keywords	Enjoyment and excitement, social interaction during collaborative play

TABLE VI Example of Outline Play Scenario for children with MMR: 'Follow me'

Actors/ Roles	One child or two children can play with the robot.
Play Type	Sensor motor play, symbolic play
Activity Description	The robot simulates a dog, which is able to follow and stay in place if told to do so. When only one child is involved in the activity, s/he can tell the robot to follow him (until he tells the robot to stay where it is). When two children are involved in the activity, the robot can be guided with "follow-me" to another child or it can move only if the children are moving together. Excitement and enjoyment are the primary motivations and objectives. If the robot is able to carry things (e.g. within a basket) it might be used as a robot tool to bring items from A to B. In this case the robot functions as a tool as well as a toy.
Activity model	The motor impaired child is normally sitting in a wheelchair; the robot is close to the child on the floor. The child is able to activate the "follow-me" mode of the robot (either by activating a switch or by remote mechanism such as voice sound or remote control). When the child asks the robot to follow (e.g. with a command "follow me" or a switch input) the robot is able to follow with a specific predefined distance (e.g. 50 cm). When the child starts to move from A to B the robot will follow. If the child stops, the robot stops too. The robot can be paused by a "stay where you are" command. When two children are playing together the robot can be guided with "follow-me" to another child. With "stay where you are" the robot can be left at the other child who might then ask the robot to follow it. More children can be involved. A variation of the activity can be a cooperative game where the children have to move together in order to let the robot move (e.g. it only moves if both are moving).
Place/ Setting	This scenario is performed on the floor and ideally can be spread over more rooms. Used in play and therapy sessions but could be part of daily life activities in school (if used as tool to bring items from A to B).

Artifacts/ Media	The artifact is a mobile robot, equipped with sensors to detect child's movement and voice recognition system. It is also able to carry things (e.g. within a basket).
Time/ Flow	The game can be repeated as long as wished by the actors. The robot can be told to wait at a specific location by "stay where you are" and might be picked up later again. It should be possible to switch/change users (i.e. that another child is able to take over the follow-me → identification has to be clarified) for the variation Child/Robot/Child.
Keywords	Enjoyment and excitement

7. Conclusion and future work

Interaction with the environment is crucial to child development. Play provides stimuli that influence and control the behaviour of the child (Cohen 1976). Here, the interaction between the child and the environment is based on reciprocal stimulation that creates transitions of change and modification. This leads to refinement in the nature of the child's behaviour, which also becomes more orderly. The quality of the child's behaviour can be enhanced by this sequence of actions and reinforcements which becomes orderly and predictable, and could affect the speed with which he/she develops. This dyadic model of interaction with the environment could be implemented in robotic systems that can be used with autistic children to provide stimuli and reinforcement in a controlled manner (a gradual increase in complexity) helping the child learn basic social behaviour skills. Being a programmable system, a robot can provide various stimuli that could promote the child to interact with it in different ways. The ability to modify the response of the robot according to the way the child interacts, and to repeat this modified response, can make the cycle of actions and reinforcement orderly and predictable. Robotic systems could have both, a built-in modularity to accommodate different needs of different children as well as a built-in ability to gradually increase the complexity of the interaction thus providing more complex stimuli that may promote further learning (e.g. simple imitation games might become more complex turn-taking activities).

By providing a robot-supported play environment where the robot serves as a *social mediator*, the IROMEC project aims to empower children with special needs to prevent dependency and isolation, helping them develop their potential and learn new skills. The abilities, needs, and levels of development among the children in any given group vary significantly. As such, and regardless of any advanced technologies implemented in any robotic system, there cannot be a single 'general purpose robot' that will answer all the users' needs or facilitate all possible ways of interaction. This further reflects upon the importance of the approach taken in the IROMEC project which is based on ongoing consultations with panels of expert users (i.e. teachers, therapists, parents) throughout the design and development stages.

This paper reported on the development process of play scenarios for robot assisted play and a robotic mediator, utilizing the input from user panels and experimental investigations into the various stages of the development process in order to develop a novel robotic system that will consider specific needs of various target user groups. We presented the methodology and results from user-centred perspective trying to include as much as possible the needs and requirements of our target user groups. This process, in particular the user panels at multiple sites in different countries, occupied the multidisciplinary team of the IROMEC project for a significant amount of time during the first half of the project. However, such an effort is justified since for our particular user groups it was crucial not to push technology on them, but to develop technology (and in the context of this paper to develop scenarios) that are specifically adapted to their needs, abilities as well as therapeutic goals.

In the next step of our research, the outline scenarios described in Table III will further be developed, in order to reflect and utilise the specific functionalities to be implemented in the IROMEC robot and its various modules. They will be developed in consultation with the user panels, against specific therapeutic and educational objectives of the various IROMEC's target user groups.

The work presented in this article can benefit researchers outside the IROMEC project as it presents a general and user-centred approach of how to develop play scenarios for human robot interaction that is not limited to the specific user groups targeted in the IROMEC project and could be adopted in other projects. In addition, the outline play scenarios presented in this paper may be considered for use with other user groups or in other applications involving human-robot interaction (including entertainment and service applications).

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