EAI Endorsed Transactions
on Creative Technologies Research Article EAI.EU

Designing intelligent games adapting to children's playing maturity

Emmanouil Zidianakis*, Kalliopi Stratigi, Danai Ioannidi, Nikolaos Partarakis, Margherita Antona, Constantine Stephanidis

Foundation for Research and Technology – Hellas (FORTH), Institute of Computer Science, Heraklion, GR-70013, Greece

Abstract

Play is a voluntary activity in which individuals involve for pleasure. It is very important for children because through playing they learn to explore, develop and master physical and social skills. Play development is part of the child's growth and maturation process since birth. As such, it is widely used in the context of Occupational Therapy (OT). Occupational therapists use activity analysis to shape play activities for therapeutic use and promote an environment where the child can approach various activities while playing. This paper builds on knowledge stemming from the processes and theories used in OT and activity analysis to present the design, implementation and deployment of a new version of the popular farm game as deployed within an Ambient Intelligence (AmI) simulation space. Within this space, an augmented interactive table and a three-dimensional avatar are employed to extend the purpose and objectives of the game, thus also expanding its applicability to the age group of preschool children from 3 to 6 years old. More importantly, through the environment, the game monitors and follows the progress of each young player, adapts accordingly and provides important information regarding the abilities and skills of the child and their development over time. The developed game was evaluated through a small scale study with children of the aforementioned age groups, their parents, and child care professionals. The outcomes of the evaluation were positive for all target groups and provided significant evidence regarding its potential to offer novel play experience to children, but also act as a valuable tool to child care professionals.

Keywords: Ambient Intelligence, Games, Serious games, Occupational Therapy, Interaction, Augmented Reality, Mixed Reality, Touch based interaction, Virtual character simulation, Virtual assistant, Interactive tabletop surfaces, Pervasive computing.
ACM Classification Keywords
H.5.2 [User Interfaces]: Evaluation/methodology, Input devices and strategies, Interaction styles, Prototyping
I.2.7 [Natural Language Processing]: Speech recognition and synthesis
C.2.4 [Distributed systems]: Distributed applications

Received on 29 August 2016, accepted on 08 June 2017, published on 03 July 2017

Copyright © 2017 Emmanouil Zidianakis *et al.*, licensed to EAI. This is an open access article distributed under the terms of the Creative Commons Attribution licence (http://creativecommons.org/licenses/by/3.0/), which permits unlimited use, distribution and reproduction in any medium so long as the original work is properly cited.

doi: 10.4108/eai.3-10-2017.153154

1. Introduction

Development is considered as a process of growth and maturation that each individual undergoes throughout his/her life span. Salkind describes development as "a progressive series of changes that occur in the predictable pattern as the result of interactions between biological and environmental factors" [[29]]. In 1978 the psychologist Elizabeth Hurlock outlined ten principles of development that are still considered as fundamental in understanding the processes and issues in human development [[16]]. According to those principles, development involves qualitative and quantitative changes, and is a product of intrinsic maturation and learning opportunities provided

* Email: zidian@ics.forth.gr

from the individual's environment. The human developmental pattern is predictable. Children are naturally inclined to create play situations and explore their environments. Through play they learn, practice and improve skills, involve in social roles and experience emotions. Play is widely used in therapy to treat children's emotional and behavioural problems because of its responsiveness to their unique and varied developmental needs [[5], [19], [20], [22], [30]]. Play is one of the areas of human occupation that OT focuses on, and appropriate activities for children are widely used in order to evaluate and facilitate the development of their skills and abilities.

Today's interactive technologies provide the means to achieve a radical transformation of play much beyond desktop computers games. According to [[6]], a large number of products is available to young children that incorporate interactivity such as activity centres, musical keyboards, and radio-controlled toys. This range of toys and devices is part of a move towards pervasive or ubiquitous computing in which technology blends into the environment and is not necessarily visible. Ambient Intelligence (AmI) refers to electronic environments that are sensitive and responsive to the presence of people. The AmI paradigm builds upon pervasive computing, ubiquitous computing, profiling, context awareness, and human-centric computer interaction design [**Error! Reference source not found.**]. AmI environments offer opportunities for supporting the playing needs of children and can support a variety of ways in which ICT can be integrated into playing situations. Having in mind that play is the dominant medium in pre-school education and that games can be effective tools in early care interventions, it is important to create appropriate games that support and enhance children's learning and development. Designing and creating playing experiences under the perspective of Ambient Intelligence has the potential to provide enhanced gaming experience to all and in particular to children. Such games are facilitated by systems and technologies that: (a) are embedded in the environment, (b) can recognize children and their situational context, (c) are personalized to their needs, (d) are adaptive in response to young children interaction and (e) are anticipatory to children's desires without conscious mediation.

The Farm Game presented in this paper is tailored to the needs of children aged from 3 to 6, and supports playing through tangible interaction with physical objects. Puzzles on the theme of farm animals are very popular among young children and also a concept widely used for assessing child developmental. Using a state-of-the-art technological infrastructure, encompassing an augmented interactive table and a three-dimensional avatar, as well as a combination of tangible and intangible (virtual) objects, the developed Farm Game extends the gameplay and the age applicability of a traditional a wooden animal's puzzle. This is achieved by increasing the difficulty and playing demands according to developmental standards for ages up to 6 years. Based on the developmental expectations for child's play performance in age related activities, a number of specific activities have been selected and four levels of difficulty have been defined, in conjunction to the expected ability of the child to complete a task. The game also supports runtime adaptation based on the child's actual playing performance. Furthermore, through interaction monitoring, the game becomes capable of following the progress of each young player, adapt accordingly and provide important information regarding the abilities and skills of the child and their development over time.

2. BACKGROUND & RELATED WORK

The driving forces of this research work are the theories of Child Development, the practice of OT and IT domain knowledge regarding the usage of technology for children's - play and learning.

2.1. Major Theories of Child Development

Theories of child development provide a basis in order to explore and understand the human factors involved in a child's play. A number of theories exist in the area of early childhood development that attempt to explain how young children develop and learn. Some of the prominent theories of development and their basic assumption are:

- **Cognitive- Developmental Theory:** the basic assumption is that development is the result of the person's active participation in the developmental process in interaction with important environmental influences. According to Jean Piaget [[57]], development is a discontinuous process characterized by abrupt changes from stage to stage. Lev Vygotsky emphasized the role that culture and outside influences play in leading the individual from one developmental level to the next [[16], [31]]. According to Vygotsky, play is a source of development and creates the zone of proximal development (ZPD). Vygotsky's original conception of ZPD has been expanded, modified, and changed into new concepts such as "scaffolding", describing the support given during a learning process which is tailored to the needs of the student with the intention of helping the student achieve his/her learning goals [[53]]. ZPD can be used in various learning contexts where task modeling, gradient and guidance/coaching are needed.
- **Behavioral theory**: considers development as a function of the laws of learning. Environment has important influences on growth and development. Its main impact is in the area of systematic analysis and treatment of behaviour [[16]].
- **Psychodynamic theory**: initially developed by Sigmund Freud, refers to the individual differences as

well as normal growth resulting from the resolution of conflicts of human beings [[16]].

- **Biological and Maturation theory**: is based on the idea that biological factors and the evolutionary history of the species determine the sequence and the content of development [[16]].

2.2. Development of child's play skills

According to [[54]], child's play develops in several stages from passive observation to cooperative purposeful activity. There are many ways of categorizing play behaviours and skills. However, there are some common elements that can be used to distinguish play from other types of activity: (a) play is entertaining and enjoyable, (b) it is energetic, incentive and self-chosen activity, (c) allows the player to create or/and modify the play situation, (d) involves pretending and imagining, (e) the outcome is less important than the process and (f) play relatively has no rules; games have rules. **Table 1** illustrates typical play behaviours and skills of play development in the age range from two to seven years old (adapted from [[54]]).

Table 1: Typical play behaviours and skills

Age	Typical Play Behaviours and Skills
2-3 years	With the increase in use of language during this period, the child engages in symbolic and pretend play and begins to shift from parallel play to more interactive forms of play; talks to himself during play and begins to use language when playing with others; shows a variety of emotions during play and likes to role-play adult roles; may enjoy action figures, dolls and other pretend people; may continue to be possessive of toys; likes to imitate, gross motor play incudes using playground equipment with some assistance, learning to ride a tricycle, jumping with both feet clearing the ground together, simple ball play (e.g. kicking and tossing a medium sized ball) and running around, climbing and dancing; fine motor play includes painting and scribbling; large construction toys and insert puzzles and more complex cause – effect toys that introduce preschool concepts such as colours, shapes, letters, and numbers; continues to be interesting in picture books, enjoys sensory play like Play Dough (clay), water and sand play.
3-5 years	Engages in creative and group play, and associative play dominates by the 4th year of age as the child learns to share and take turns and is interested in friends; continues to enjoy role-playing and dressing up, and creating elaborated pretend play situations; may begin to play simple board games, such as checkers or Candyland[1] ; with respect to gross motor play, the child becomes proficient in playground equipment, including being able to pump a playground swing; likes to ride a bike with training wheels; may begin to participate in more structured recreational activities, such as swimming, dance, and skiing; enjoys running around, jumping, hopping, climbing, and ball playing; manipulative play skills include painting and colouring, simple drawing, coping basic shapes and same letters, scissors use and simple craft activities, construction toys and computer play; begins to develop an interest in the finished product of construction play; may became more interested in television and may begin to play video games.
5-7 years	Enjoys games with rules, such as board games, and becomes much more involved in organized sports and recreation in the community, learns specific skills such as swimming, skating and bike riding or playing a musical instrument, and preferences for certain play activities became more prevalent; plays well with others and enjoys social interaction and play to reach a common goal, understands concepts of cooperation and competition, and the importance of friendship increases; independence during play increases with the extensions with neighborhoods and the homes of peers; secondary play and leisure activities (watching TV, reading, and playing computer games or video games) may also increase.

2.3. Knowledge models and Assessment tools of child's development

A variety of tools is used by childhood professionals in order to record issues involving functions and structures of the body, activity limitations and participation restrictions during the development of children. The work reported in this paper is based on the International Classification of Functioning, Disability and Health for Children and Youth (ICF-CY) of the World Health Organization (WHO) as a universal modelling framework [[37]]. ICF-CY provides an essential basis for the standardization of data concerning all aspects of human functioning and disability in the pediatric population by taking into account two relevant issues: (a) the dimensions of childhood disability which include health conditions, disorder, impairments, activity limitations as well as participation restrictions, and (b) the influence of the environment on the child's performance and functioning.

[1] Candyland is a simple racing board game which requires no reading and/or minimal counting skills.

Development tests are used to measure a child's developmental progress from infancy through adolescence. They may help to indicate early signs of a developmental problem and discriminate normal variations in development among children, depending on the age of the child. Such assessment tools are designed according to the expected behaviours and skills of children at a specific age. The types of developmental assessment principles include: (a) developmental screening to identify children with special needs, developmental delays or school difficulties, (b) diagnostic evaluation, depending on the screening, to confirm the presence and extent of a disability, (c) readiness tests to assess a child's specific skills and (d) observational and performance assessments to provide ongoing information about a child's development.

Types of development tests are [[55]]: (a) infant development scale, (b) sensory-motor tests, (c) speech and hearing tests, (d) preschool psycho-educational batteries, (e) tests of play behaviour and (f) social skills and social acceptance tests.

There are many scales commonly used to evaluate and measure developmental skills, such as: (A) the Gesell Developmental Schedules [[12]], an instrument to measure the status of a child's motor and language development and personal-social and adaptive behaviours and, (b) the Denver Developmental Screening Test, one of the most widely used assessment tools established for preschool children [[10], [11]]. The Denver Developmental Screening Test (DDST), commonly known as the Denver Scale, was originally designed at the University of Colorado Medical Center, Denver USA and aims at screening cognitive and behavioral problems in preschool children. More specifically, it enables the professionals to identify children whose development deviates significantly from that of other children of the same age, while warranting further investigation to determine if there exists a problem requiring treatment. The revision and update of DDST, Denver II , is a widely accepted pediatric screening tool for ages up to 6 years old frequently used for testing the domains of: (a) personal social (such as smiling), (b) fine motor adaptive (such as grasping and drawing), (c) language (such as combining words), and (d) gross motor (such as walking). The scale reflects the percentage of a certain age group able to perform a certain task. In the current research work, the Denver Scale II has been used as evaluation tool.

2.4. Occupational Therapy for children

OT is a client-centred health profession concerned with promoting health and well-being through occupation [[35]]. Play is one of the areas of human occupation that OT focuses on, and appropriate activities for children are widely used in order to evaluate and facilitate the development of their skills and abilities. Activity Analysis is an important process used by OT therapists to understand the various demands that a specific activity requires for execution. The Activity analysis process also reveals the tasks which are involved during a play activity. Monitoring of those tasks, can facilitate the assessment of the child's play performance and capacity and the extraction of useful indications about child's developmental state. Play performance is a measurement concept that can describe what tasks a child does while playing in a specific context and environment. Capacity is a measurement concept that indicates the highest probable level of functioning that a child may reach at a certain moment as found in the domain Activities and Participation of ICF-CY [[37]].

Assessing play performance

For assessing play performance, a thorough and systematic process is needed for addressing the factors that may affect child's functionality and identifying the context related factors as well as the interrelations among them. All factors are interrelated and can be grouped according to their nature and origin as: (a) **child factors**, (b) **performance skills**, (c) **activity demands** and (d) **context and environment**. **Child factors** are factors related to individual or population characteristics that may affect performance while playing. **Performance skills** are observable, concrete, goal directed actions that the child uses to engage in play situations [[9]]. **Activity demands** are the aspects of an activity, including the objects and their properties, required actions and skills, space and social demands, required or underlying body functions and structures and timing and sequencing needed to carry out the activity (play a game). **Context and environment** consist of a variety of interrelated conditions that may influence child's performance. Context refers to cultural, physical, social, spiritual, temporal and virtual circumstances. The term environment refers to the external physical and social conditions that surround the child and space in which play occurs [**Error! Reference source not found.**, **Error! Reference source not found.**].

Activity Recognition

Relevant studies in the domain of activity recognition for monitoring children's developmental progress have focused more on the recognition part than on the 'play' aspect. KidCam is a prototype system designed to study the use of computer technology to support the early detection of children with special needs [[18]]. LENA is a commercial system designed to help monitor language development in children, from new born to four years old [[21]]. Observation of social games between parent and child, such as peak-a-boo and patty-cake, can be important in the early detection of developmental delays. When studying an infant's social ability in research studies, psychologists assess a child's behaviors using recorded videos, such as home movies. Work by Wang et al. [[33], [32], [34]] focuses on developing computer vision techniques to automate video filtering and behaviour coding of parent-infant social games, and in particular algorithms to automatically detect and classify social games from unstructured videos.

2.5. Play and technology

Toys have always reflected the latest developments in science and technology, from music boxes to electric trains to computer games and robots. Today's toys contain embedded electronics that appear to have the capacity to adapt to the abilities or actions of the player, seem to interact with one another or with a computer or smart phone [[13]]. Children often use new media in traditional ways, bypassing the technology. Technology is rarely the most important feature of a toy. If a toy is no fun to play with, no amount of technology will increase its desirability as a play object. Children are discriminating users of technology [[14], [15], [24]]. For example, whether a toy 'talks' did not appear to affect how children aged 3 and a half to 5 years old, played with it [[7]]. However, play with electronics and digital toys, like all entertainment, is fun and help children cope with the world as they understand it. Children bring their imaginations with them to each play experience. Regardless of whether the toy contains a microchip or not, play nourishes development on every level: cognitive, emotional, physical and social [[13]].

Psychomotor Skills and Cognitive Development for Tangible Interaction

Children between 3 and 4 years are in the preoperational stage. This means that at this age children begin to develop symbolic functions (language, symbolic games, mental image, imitations), and visual-manual coordination and perception appear. These abilities may for example help children coordinate their hand movements with their drawing while painting, developing also a sense of space limitation and thus trying to respect the boundaries of the painting material. The next developmental focal point comes in the age of 3 to 6 years, where children are in the gross skills development stage (wide movements, general and visual-motor coordination, muscular tone, balance, etc.) and it is only later on (around 7) that children begin to acquire fine motor skills (fine and precise movements, phonetics, etc.) [[48]].

With regards to cognitive development, most educational game activities for children between 3 and 6 years focus on the development of the emotional level, helping children to improve their relationships with themselves and with others, using objects as an important element of support in communication. Children investigate the properties and behaviour of objects: acting and establishing relationships with the physical elements, exploring and identifying them, recognizing what effects they produce, detecting similarities and differences, and then comparing and quantifying and so on. In this way, the child goes from manipulation to representation. This is the origin of the incipient logical and mathematical skills. Once the body information is automated, children begin to accede to the symbolic level, and, gradually, they can form mental pictures of things, beings and objects, and can assign them different meanings.

The pedagogical values of object manipulation have been promoted by Maria Montessori [[49]]: "Children build their mental image of the world, through the action and motor responses; and, with physical handling, they become conscious of reality". The physical handling of materials is also seen as beneficial by Alibali and DiRusso [[50]] who came to the conclusion that children can better solve problems handling materials than they can the same problem with only pictures. Chao et al [[51]] called this concept the "tool of mental sight". Tangible technologies give children more freedom for exploring, handling and thinking about object properties and their possible effects in the digital world. When combined with learning, these digital manipulative elements are thought to provide different kinds of opportunities for improving the child's reasoning about the world, by means of examination, exploration and participation [[30]] [[31]].

Tangible User Interfaces for play

Historically, children have played individually and collaboratively with physical items such as building blocks, shapes and jigsaw puzzles, and have been encouraged to play with physical objects to enhance a variety of skills [[23]]. Tangible interfaces aim to open up new possibilities for interaction that blend the physical and digital world together [[17]]. Resnick created the term 'digital manipulatives' to extend the tangible interface concept for the educational domain [[26]]. 'Digital manipulatives' are defined as familiar physical items with added computational power which were aimed at enhancing children's learning. Tangible interfaces have the potential to provide innovative ways for children to play and learn through novel forms of interaction [[25]]. Example of a tangible interface for play and learning is the 'I/O Brush', where children play using special paintbrushes which they can sweep over the picture of Peter Rabbit in the classic storybook [[28]]. Chromarium is a mixed reality activity space that uses tangibles to help children aged 5-7 years experiment and learn about colour mixing [[27]]. The Telltale system is a technology enhanced language toy which aims to aid children in literacy development [0].

Tabletop Interfaces for Children

Tabletop interfaces for children with multitouch interaction have been explored as a means of augmented play experience. Tabletop applications mainly implement classical games, like jigsaw and board games, by combining them with tabletop technologies such as the Smart Jigsaw Puzzle Assistant [[42]] and the False Prophets [[43]], respectively. These games are usually oriented to general audiences. In the domain of education similar attempts such as Ticle tabletop [[44]] explored collaborative educational games that support teaches in transmitting mathematical concepts. In the same content research has been conducted towards developing tabletop hardware that operate in conjunction with tangible objects as a means of prototyping tabletop games for children [[41]].

Other works focus on exploring the social benefits of collaborative tabletop games for children with disabilities such as the SIDE Project [[26]] that aimed to improve the social skills of adolescents with Asperger's Syndrome. Furthermore research has been also conducted regarding the development of games on a tabletop device to support social competence training for children with Autism Spectrum Disorder. The aforementioned suite of games has been designed to use patterns of collaboration to support therapists in their use of Cognitive-Behavioral Therapy.

Embodied agents as tutors in educational applications

The use of embodied agents that take the role of tutors in educational applications [[46]] has been considered adjunct to normal learning. Autonomous pedagogical agents are mainly found in applications for adults and are less often seen in applications for very young children. The SAGE (Storytelling Agent Generation Environment) project [[47]] is one example that does apply to young children; this proposes a physical storytelling implementation with stuffed animals and verbal interaction, which allows children to explore their own identity.

3. Fusing OT and intelligent environments for novel adaptive play experiences

ICT technology provides the means to produce games that employ the environment to offer novel play experiences to children. However, little work has been conducted so far to offer games that employ developmental theories and OT practice in order to monitor and adapt to child's development. Currently, such monitoring is practiced for the targeted age group mainly through games played by children while occupational therapists are evaluating their behaviour. In the development of the Farm Game, OT expertise has been employed both for the design of the game, so as to meet the needs of their common practice, but also for providing the knowledge for the monitoring and adaptation logic employed by the game. The Farm Game builds upon child development theories and the definition of expected skills and tools to provide the scientific basis for the rationale of the game. Analysis of activity and play performance were employed to design and shape the adaptation needs of the game, allowing it to evolve together with children' developmental requirements. Activity recognition is employed to monitor interaction with the game.

Overall, this paper presents three main contributions: (a) the design of the Farm Game has been conducted in collaboration with occupational therapists so as to embed aspects of their work and therapeutic procedures, (b) OT expertise has been employed to create the adaptation logic of the game by employing activity analysis based on the ICF-CY [[36]] and Denver II scale together with runtime interaction monitoring and statistical analysis and (c) the game itself was developed using a distributed service based architecture were technology is embedded in everyday objects and deployed within an AmI simulation space. Within this environment, physical and digital objects, an augmented tabletop surface especially designed for children, a virtual avatar and an adaptation infrastructure coexist and cooperate to provide a unique playing experience to children, while also maintaining and expanding the therapeutic qualities of the augmented puzzle game.

4. Technological & software infrastructure

The design of the game was conducted in the basis of an existing technological infrastructure that includes an augmented interactive table called **Beantable** [[38]] and a cross-platform remotely-controlled three-dimensional avatar called Max [[39]]. Beantable is an augmented interactive table supporting preschool children development. It is made up of technological components that offer the child the opportunity to engage in virtual (–based) play situations either alone or with the presence of a virtual partner called Max. The "means" that the child can use during interaction include: (a) force-pressure sensitive table surface, (b) physical object recognition, (c) speech recognition, (d) gesture recognition, (e) body movement recognition and (f) force-pressure and orientation sensitive pen [[38], [40]]. A typical instantiation of **Beantable** is presented in Figure 1 (left) and contains the interactive tabletop itself together with two augmented artefacts: (a) a secondary display device (iPad mini) presenting Max and (b) a smart pen.

Max is a remotely-controlled three-dimensional avatar that can act as a guide, assistant or information presenter for novel, cross-platform Ambient Intelligence (AmI) edutainment scenarios (see **Figure 1** right) [[39]]. The role of Max depends on the client-application's requirements. In order to achieve natural communication channels both non-verbal and verbal communication are essential. Non-verbal communication includes full body animation and facial expressions. For example, when idle, the virtual character is never motion-less due to an undulating body animation and eyes blinks randomly, giving the impression that he is alive. Max can also present multimedia content on the television contained in the scene. The requirements of the AmI client applications are propagated remotely. Examples of remote invocations include real-time 3D biped skinned animations, text-to-speech, producing facial expressions and presenting multimedia content.

Figure 1. Beantable: An augmented interactive table (Up), Max: Cross-platform three-dimensional avatar (Down)

For analysing children play performance and monitoring developmental functions a novel framework called Bean is employed that aims to monitor, evaluate and enhance pre-school children's skills and abilities through playing in Ambient Intelligence environments. The framework includes: (i) a model of children development based on the ICF-CY model and the Denver – II assessment tool, aiming at early detection of children's potential developmental issues to be further investigated and addressed if necessary; (ii) a reasoning mechanism for the automated extraction of child development knowledge, based on interaction monitoring, targeted to model relevant aspects of child's developmental stage, maturity level and skills; (iii) content editing tools and reporting facilities for parents and therapists [[52]]. An example of the reporting functionality is presented in the following figure where the child's measured developmental scores are compared with the estimated measurements from the Denver – II assessment tool. As shown in this figure in the Current inferred capacity graph the expected capacity of a targeted activity is shown together with the inferred by the Bean capacity and the average capacity of children of the specific age. This analysis may help professionals identify targeted activities that a child is scoring less that the expected and the average capacity of the targeted population.

5. Designing a farm game that adapts intelligently to children's play maturity

During design, it was decided to organize the game into four levels, each one for addressing the play developmental needs of a specified age range between 3 to 6 years. In each game level there are selected activities, divided into two categories, namely specific and general. Each specific activity is targeted at a particular game level and is related to child's matured abilities according to the Denver II scale. General activities can be considered as prerequisites for the targeted specific activity (e.g., Watching, Listening). To identify these activities an activity analysis was conducted. Based on the data stemming from the activity analysis and OT expertise, the adaptation logic of the game was elaborated and the physical design of the game was conducted.

Figure 2. Max: Report produced while playing the Farm game

5.1. Adaptation Logic

The main adaptation concept employed is that the game is responsible to monitor and evaluate the play performance and commit a representative score to the adaptation infrastructure mechanism. The latter provides the child's profile which consists of basic information such as name, surname, birthdate, etc., as well as problems involving functions and structures of the body, activity limitations and participation restrictions. Furthermore, it analyzes the play performance of the current level's specific activity and makes appropriate adaptation suggestions back to the smart game. The analysis is conducted using time series forecasting methods (i.e. weighted moving average). Data are collected from the first playing session of a game and repeatedly after some period of time, i.e., after one month or after a number of sessions. Through statistical analysis the reasoning mechanism extracts the current child's capacity in the execution of various activities and estimates the developmental rate based on the entire interaction history (i.e., play performance commitments). The analysis is conducted using time series forecasting methods (i.e., weighted moving average). The recorded data are imported to the time series in order to generate the developmental curve of the targeted specific activity of the currently active game level. In the weighted moving average model, every play performance value is weighted with a factor from a weighting group. Thus, recent data have greater influence. This approach was chosen because more recent play performance data are more representative and reliable than older data. Therefore, the reasoning mechanism is able to react more appropriately to a change in the play performance during playing. The accuracy of this method depends largely on the choice of the weighting factors which were determined with the help of early childhood professionals. The selected factors are W15 = 15, W14 = 14 … W1 = 1. The capacity of a required activity (AC) is the product of the following formula where Wt is the weighting factor, Vt is the value of the play performance, n is the number of the weighting factors (n = 15) and AC is the average value representing the child's capacity to execute a required activity.

$$AC = \frac{\sum_{t=1}^{n} W_t \times V_t}{\sum_{t=1}^{n} W_t}$$

Using this analysis, the recorded data are imported to the time series in order to generate the developmental curve of the targeted specific activity of the currently active game level. Through statistical analysis the adaptation infrastructure mechanism can not only isolate possible activity limitations and extract the current child's capacity in executing the underlying activities, but also it estimates the developmental rate. As a result, the adaptation logic is able to identify children whose play performance deviates significantly from the average population of their age. At the same time, this implies that further investigation is recommended to determine if there are any developmental problems that require special care. Additionally, using this information, the game can adapt to the child's evolving skills so as to choose the most appropriate level according to child's estimated abilities.

5.2. Design & Gameplay

The game presented in this paper has been deployed in vitro within the AmI classroom simulation space of the FORTH-ICS AmI research facility as shown in Figure 3. The deployed technological infrastructure includes: a) the Beantable, and b) the avatar Max both as a playmate running on an iPad mini installed on top of the Beantable and as a standalone avatar to assist children during evaluation in a large 55" display. Furthermore within the AmI simulation space the adaptation logic is deployed to capture interaction data and produce the appropriate decisions for adapting the game appropriately.

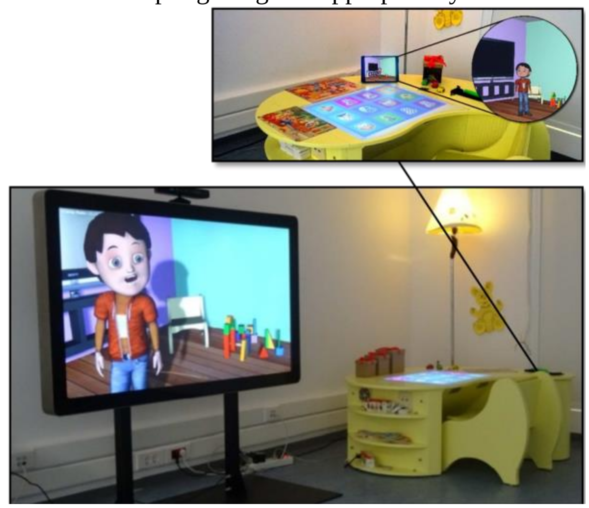


Figure 3. The game setup

The design of the game was based on an actual physical puzzle game. The puzzle pieces were used to act as the physical part of the game, while the background was provided digitally on the **Beantable**'s surface. Wooden pieces, including physical objects and the identity card, were scanned in order to create their virtual counterparts employed in the game. Special visual markers (i.e., fiducial symbols[2]) were added on the bottom side of the physical pieces (see **Figure 4** Left) which are recognizable by the system. Additionally, in the case of identity cards, lanyards were placed on the top of the physical objects as shown in **Figure 4** (Right). Children store all the physical items in a box called the "Farm Box", which also has a visual marker attached.

Figure 4. Physical items and attached visual markers (Left) / Tagged "identity cards" with lanyards (Right)

[2] http://reactivision.sourceforge.net/

The game is started through the Beantable's startup screen by selecting the image of the "Farm". At the beginning of this game, Max asks the child to place his identity card on the surface as shown in

Figure 5 (Left). The system recognizes child's identity card and remotely requests his profile from the adaptation infrastructure mechanism. Using the profile, the system initializes the game accordingly, and Max welcomes the child with his/her name. At this point, Max asks the child to find and place the "Farm Box" on the Beantable's surface as shown in

Figure 5 (Right). Thereafter, the game will be started at the level corresponding to the child's profile, while Max explains the relevant instructions. If no action is performed, after waiting a period of time, Max says a "Good bye" message, and the game is terminated.

Figure 5. Waiting for the identity card (Up) / Waiting for the "Farm Box" (Down)

First Level (from age 3 to 4)

At the first game level, the child has to place the physical objects from the "Farm Box" in the correct virtual positions on the digital game board presented by Beantable (see **Figure 6** Left). Each virtual position is presented in the form of a black and white representation of an animal's picture. The child can remove or leave the physical objects on the surface without getting any feedback (see Figure 7 A). The system recognizes the matching between the physical object and its virtual position as a success, even if the object is not properly oriented. When a match is achieved, the corresponding image of the animal within the virtual game board is coloured (see Figure 7 B). For each successful matching the system rewards the child with the reproduction of the animal's sound. While playing, the system counts the errors occurred for each virtual position. These errors, as well as child's progress, are continuously reported to the adaptation infrastructure mechanism for analysis as described in section 4. In this context, an error is defined as placing any incorrect item in a specific virtual position. When the errors of a specific virtual position are more than 3, the corresponding animal sound is produced. If the child tries to place a wrong physical item onto a virtual position that was previously successfully completed, the related sound is activated, and this is also calculated as an additional error. On the contrary, every time that the child places a physical item onto the correct position, which has been completed successfully in the past, the sound for this item is activated as well. When all the physical objects are placed successfully the game round is finished. When finishing the game at any level, two phases are initiated:

- **Congratulation phase**: Max congratulates the child by saying a random message such as, “Congratulations”, “Bravo”, “Very well”, etc. The system also informs the adaptation logic about the end of this round.
- **Free play mode**: At the end of the “congratulation phase”, the free play mode starts. During this mode, the child can interact with the system without errors being signalled. In that case, the system considers successful any movement that results to a correct matching of physical objects to every virtual position on the game board. In this way, the child can create his own play situation and enjoy the game undisturbed. When the child stops interacting with the game for a few seconds, this mode is disabled.

After the completion of the aforementioned stages, the system checks the presence of physical items on the surface. In this case, Max requests the child to collect the remaining physical items from the table. If the child reacts promptly, the system proceeds to the next step. Otherwise, the system will close the game. After the completion of the previous task, Max produces the next message “Will you continue?” At this point, the system is waiting for speech input. If the child answers “Yes”, the system will start a new round at a level corresponding to the child’s abilities which are inferred by the adaptation logic.

Figure 6. An indicative instance of the first level (Up) / An indicative instance of the second level (Down)

Second Level (from age 4 to 5)

The system has similar functionality as in the first level. In the second level, the child has to place more physical items to their virtual position (see
Figure **6** Right). Moreover, the game logic is extended to account for proper object orientation recognition. In case of correct matching, the black and white image of the animal is turned to coloured and the corresponding sound is played. During the game, if the child faces significant difficulty to properly match the game items, the adaptation logic (which monitors continually the game interaction) informs the system that the child has to play at a lower level for the rest of the round. Thereafter, the child will continue the game playing in free play mode (without errors being signalled). In case that the child prefers to play again, the system calls the adaptation logic to get information about the starting level of this round.

Third Level (from age 5 to 6)

In this level, a round of this game is considered completed when the child has placed all the physical objects on the virtual positions and properly oriented (see

Figure 8 Left). The physical items must remain in their virtual positions until the end of this round. When the child places all the physical objects on the virtual positions, the system will check the matching of these items. If the child has placed successfully all the physical objects onto their corresponding locations on the interface, the round of this game is completed and the system starts the "Congratulation phase" followed by the "Free play mode".

Fourth Level (from age 6 to ~7)

In this level, the functionality remains exactly the same as in third level, but the board of the virtual positions is created using the mirrored and the normal outline of each physical object (see Figure 7 C, D). An example of a game round at the fourth level is shown in

Figure 8 (Right). A round of game is considered completed, when the child places the required physical objects on their corresponding virtual positions properly.

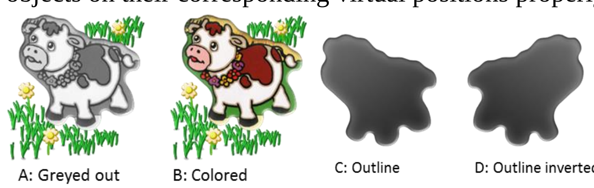


Figure 7. Alternative instantiations of virtual animals

Figure 8. An indicative instance of the third level (Up) / An indicative instance of the fourth level (Down)

5.3. Implementation details

The game has been implemented in the Microsoft C# programming language. For rendering the virtual UI of the game, the Windows Presentation Foundation (WPF) was employed. Taking into account the distributed features provided by the deployment within an AmI simulation space, a service oriented middleware was used [[56]], which provides access to a number of low level services offering the necessary functionality. This functionality includes a physical object recognition service provided by the interactive table surface. This service employs the TUIO protocol [[38]] to transmit object recognition information to the game. The same protocol is used to translate touch actions identified on top of the table surface to native touch events captured by WPF. Additionally the two instantiations of Max within space (one on the large display and the playmate on the iPad mini) are also exposed and can be controlled by the game. Finally, the game captures and propagates interaction data about child's play performance to the adaptation infrastructure mechanism which produces and propagates adaptation decisions.

6. Evaluation

A small scale evaluation of the farm game was conducted in order to explore usability, playability and applicability in the context of OT daily practice. Fourteen children, their parents, two occupational therapists, a psychologist and a special education teacher participated in the evaluation. Each child played the farm game while the child's parent(s) and the experts were observing. An observation room for parents and occupational therapists was set-up in a remote location from the space where the actual evaluation was conducted. In this observation space, a projector was projecting live video from the evaluation space, while a personal computer was showing information regarding the current play performance achieved by the child. The children were encouraged to play freely without any external interventions by adults as shown in Figure 9. After each evaluation session, children and parents were required to fill in a post-test questionnaire developed separately for each user group. Experts completed their questionnaire after the completion of all the evaluation sessions. Table 2 presents some indicative questions included in the questionnaires together with the ranking method employed. For creating the questionnaires, the heuristics for evaluating playability were employed. These constitute a comprehensive set of heuristics for playability specifically tailored to evaluate video, computer and board games [[8]]. The interaction of children with the game was recorded in consensus with their parents, so as to allow post-test evaluation of their interaction with the system.

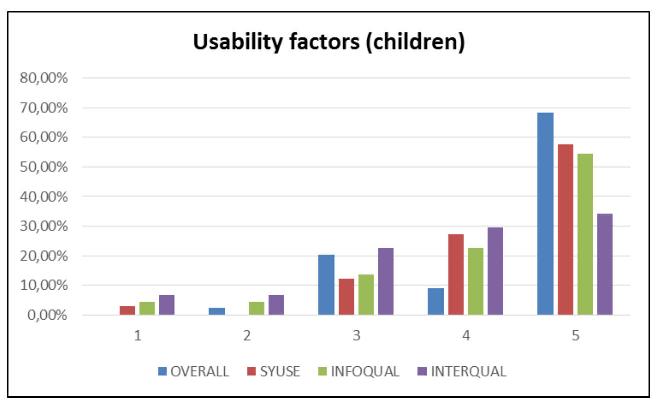
The evaluation results were extracted through an analysis of the recorded sessions and the results of the questionnaires. The recorded sessions were analyzed by usability experts to produce recommendations regarding further improvements of the game, while the questionnaires were used to calculate quality factors. Overall, four factors were calculated. The OVERALL factor expresses the overall satisfaction of the users regarding the system (calculated by the average of all the answers' grades). The SYUSE factor measures the satisfaction of users when using the system, while the INFOQUAL measures the information quality provided by the system. Finally, INTERQUAL is a factor that captures user satisfaction regarding the interface provided by the system. The linking of questions to the calculated usability factors is also presented by Table 2.

Figure 9. Young children participating in the evaluation

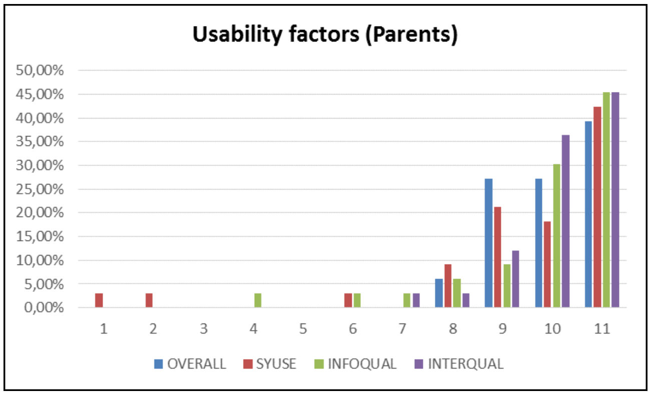
Table 2: Indicative questionnaires for each group

Children's Questionnaire sample (☹☹😐☺☺)
OVERALL
• How much did you like the game?
• Was the game too short, too long or just fine?
SYUSE
• How much different was this game from the traditional one?
• How often will you play this game?
• Did you have enough time between turns?
INFOQUAL
• How hard was for you to understand how to play?
• Did you know all the animals of the farm?
INTERQUAL
• Are there enough options that you can do when playing?
• The size of the playing board and the pieces was too large, too small or fine for you?
Parents questionnaire sample (Yes/No, 1 to 10 and free text)
OVERALL
• Was the playing time satisfactory for the player?
• Was the game amusing and entertaining for your child?
SYUSE
• How much encouraging/ attractive for your child you find the presence or interaction with Max?
• Was there any safety issues?
INFOQUAL
• Did you find the game suitable for your kid's age?
• Was it easy for the child to use/interact alone/without the presence of an adult with the Beantable?
INTERQUAL
• Did you liked the use of physical toys for playing the game?
• How much did you like the graphics /interface
Experts Questionnaire sample (Yes/No, 1 to 10 and free text)
OVERALL
• How enjoyable was the game to replay
• Was the theme proper for the age range is proposed for?
SYUSE
• Were the goals of the game clearly presented to the child?
• Was the game gradually increasing player's abilities?
INFOQUAL
• Does the game present enough short – term goals throughout the game for ensuring entertainment / fun?
• Was player's failures resulted into positive feedback?
INTERQUAL
• How much immediate was the feedback received?
• Did the game provided enough information to get started?

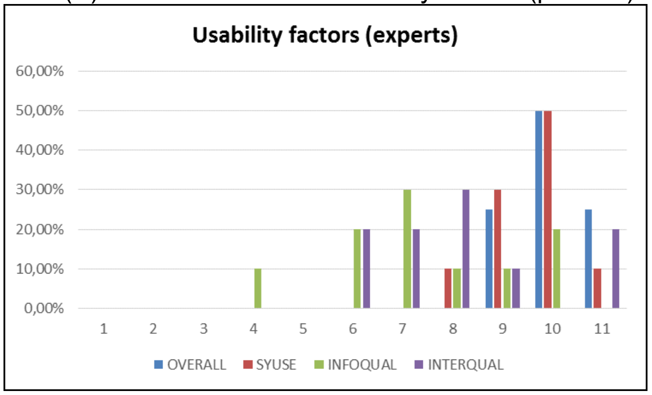
Error! Reference source not found. Figure 10 (A) represents these factors for children. The **OVERALL** factor shows that children were generally satisfied (~75% of children scored 4 and 5 to all questions) by the overall usability of the system. However, there are 20,45% of the children who state that they were not fully satisfied. The **SYUSE** factor shows that children were generally satisfied (~85% of children scored 4 and 5) by the overall satisfaction by using the system. However ~15% of the users state that they were little or not satisfied. Regarding the quality of information (**INFOQUAL**) ~76% of the users scored 4 or 5. However, there are ~24% of children that scored 1 to 3 which implies that are is a substantial amount of users that requires some form of improvement in the way that information is presented. Regarding the interaction quality (**INTERQUAL**) ~64% of the users scored 4 and 5. However, there are ~22% of the users that scored 3 and ~13% that score 1 and 2 which implies that is a substantial amount of users that requires some form of improvement in their interaction with the game. In the case of parents, Figure 10 (B) shows that the game scored well in all the calculated usability factors with scores for 8 to 10, gathering the majority of their goals for all usability factors. Experts rating was also very positive (see Figure 10 (C)) and this was also expressed during the informal interviews conducted after the completion of the evaluation. The experts commented very positively both the design of the game and the adaptation mechanism used to dynamically adapt the game to the developmental characteristics of children while playing.



(A) Usability factors (children)



(B) Combined chart of usability factors (parents)



(C) Combined chart of usability factors (experts)

Figure 10. Evaluation Results

One important goal of the evaluation was also to gather comments from users so as to help the improvement of the game. The collection of these comments was done by discussing with them in the context of informal interviews after the completion of the evaluation. **Children** commented that sometimes Max was unable to understand their answers. Some children noticed that the game remained the same between levels (although the virtual positions and the background were randomly selected). The majority of the children commented that the fourth level was not quite similar to the previous ones and seem to be surprised. Some **parents** (mostly of older children) commented that the game should give feedback every time the child places a physical object to its correct virtual position. For example, a visual or an audio feedback to give the feeling that the item is correctly placed as happening in the actual traditional game. Moreover, parents think that the voice of the Max should be louder and less computerized. **Child development experts** aptly commented that Max did not introduce the rules of the game. In detail, the game should demonstrate the "how to play" guidelines only for the first time the child chose to play. Furthermore, child development experts noticed that on the one hand Max was very slow in his reactions and additionally that the game's idle time was expiring too early without allowing children to think or plan how to play. They also expressed their concern about the size of the secondary screen presenting Max that in their opinion should be bigger. Finally, child development experts found that the monitoring and adaptation logic of the fourth level should not be as tolerant as it was.

7. Discussion and future work

This paper has presented the design, implementation and initial evaluation of a popular puzzle game in an AmI simulation space. Through the environment, the game can monitor and follow the progress of each young player, adapt accordingly and provide important information regarding the abilities and skills of the child and the inferred development progress over time. This has been achieved by employing OT knowledge both during design and for forming the adaptation logic employed by the game. The design of the game involves the use of an interactive table for preschool children and a remotely-controlled three-dimensional avatar. The produced version of the game has been evaluated in the context of a small scale study with children of the aforementioned age groups, their parents, as well as child care professionals (Occupational therapists, a psychologist and a special education teacher). The results of the evaluation were positive for all the aforementioned user groups, but also generated feedback regarding possible improvements of the game in the future. In the case of children, the game in general was proven to be suitable for all age groups and this was also mirrored in the way the adaptation mechanism was functioning while playing.

Acknowledgements

This work is supported by the FORTH-ICS internal RTD Programme 'Ambient Intelligence and Smart Environments'.

REFERENCES

[1] Aarts, E.H.L., Marzano, S. (2003) The New Everyday: Views on Ambient Intelligence. 010 Publishers, Rotterdam

[2] American Occupational Therapy Association. Occupational therapy practice framework: Domain & process. Amer Occupational Therapy Assn(2002).

[3] American Occupational Therapy Association. Occupational therapy practice framework: Domain & process. 2nd edition. Amer Occupational Therapy Assn (2008).

[4] Anannу, M. (2002) Supporting children's collaborative authoring: practicing written literacy while composing oral texts. In *Proceedings of the Conference on Computer Support for Collaborative Learning*, Boulder, pp. 595-596

[5] Axline, V. M. (2012) Play therapy. Random House LLC.

[6] BECTA. Keyboard Skills in Schools. (Information sheet.) British Educational Communications and Technology Agency, Covertry. http://www.becta.org.uk/technology/infosheets/index.html (2001).

[7] Bergen, D. (2004) Preschool children's play with 'talking' and 'nontalking' Rescue Heroes: Effects of technology-enhanced figures on the types and themes of play. Toys, Games, and Media, pp. 195-206

[8] Desurvire, H., Caplan, M., & Toth, J. A. (2004) Using heuristics to evaluate the playability of games. In *CHI'04 extended abstracts on Human factors in computing systems* 1509-1512. ACM.

[9] Fisher, A. G. (2006) Overview of performance skills and client factors. *In H. M. Pendleton, & W. Schultz-Krohn (Eds.)*, Pedretti's occupational therapy: Practice skills for physical dysfunction, 6th ed., pp. 372–402.

[10] Frankenburg, W. K., Dodds, J., Archer, P., Shapiro, H., & Bresnick, B. (1992) The Denver II: a major revision and restandardization of the Denver Developmental Screening Test. Pediatrics, 89(1), pp. 91-97.

[11] Frankenburg, W. K., Goldstein, A. D., Camp, B. W. (1971) The revised Denver Developmental Screening Test: Its accuracy as a screening instrument. The journal of Pediatrics, pp. 988-995.

[12] Gesell, A. (1925) Developmental Schedules.

[13] Goldstein , J. (2012) Play in children's development, health and well-being. Brüssel: Toy Industries of Europe.

[14] Goldstein, J. (2004) Electronic games in and out of school. In International Journal of Early Childhood Education, pp. 77-87.

[15] Goldstein, J. (2011) Play and technology. In *A. D. Pellegrini (Ed.), Oxford Handbook of the Development of Play*. Oxford University Press.

[16] Hurlock, E. B. (1978) Child growth and development. Tata McGraw-Hill Education.

[17] Ishii, H, Ullmer, B. Tangible bits: towards seamless interfaces between people, bits and atoms. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems* (CHI 1997), pp. 234-241

[18] Kientz, J. A. (2008) Decision Support for Caregivers through Embedded Capture and Access. PhD thesis, *College of Computing, School of Interactive Computing, Georgia Institute of Technology*, Atlanta, GA, USA.

[19] Kottman, T. (2001) Adlerian play therapy. In *International Journal of Play Therapy*, pp. 1–12.

[20] Landreth, G. L. (2012) Play therapy: The art of the relationship. Routledge.

[21] Lena. World Wide Web electronic publication, http://www.lenababy.com Retrieved May 05, 2008.

[22] O'Connor, K. (2001) Ecosystemic play therapy. In *International Journal of Play Therapy*, pp. 33– 44.

[23] O'Malley, C., Fraser, D. S. (2004) Literature review in learning with tangible technologies.

[24] Plowman, L., Stephen, C., McPake, J. (2010) Growing Up with Technology: Young Children Learning in a Digital World. London: Routledge.

[25] Price, S, Rogers, Y, Scaife, M, Stanton, D., Neale, H. (2003) Using 'tangibles' to promote novel forms of playful learning. In *Interacting with Computers*, pp. 169-185

[26] Resnick, M., Martin, F., Berg, R., Borovoy, R., Colella, V., Kramer, K., & Silverman, B. (1998) Digital manipulatives: new toys to think with. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems* pp. 281-7

[27] Rogers, Y, Scaife, M, Gabrielli, S, Smith, H., Harris, E. (2002) A conceptual framework for mixed reality environments: designing novel learning activities for young children. In Teleoperators & Virtal Environments.

[28] Ryokai, K, Marti, S and Ishii, H. I/O brush: drawing with everyday objects as ink. In *Proceedings of the ACM SIGCHI Conference on Human factors in Computing Systems* (CHI 2004), Vienna, Austria, ACM Press, pp. 303-310

[29] Salkind, N. J. (2004) An introduction to theories of human development. Sage.

[30] Schaefer, C. (2001) Prescriptive play therapy. In *International Journal of Play Therapy*, pp. 57–73.

[31] Vygotsky, L. S. (1967) Play and its role in the mental development of the child. Soviet Psychology.

[32] Wang, P., Abowd, G. D., Rehg, J. M., Arriaga, R. I., (2009) Automatic retrieval of mother-infant social games from unstructured videos. In *Electronic Proceedings of the International Meeting for Autism Research*.

[33] Wang, P., Abowd, G. D., Rehg, J. M. (2009) Quasi-periodic event analysis for social game retrieval. In *Proceedings of IEEE International Conference on Computer Vision*.

[34] Wang, P., Westeyn, T., Abowd, G. D., Rehg, J. M. (2010) Automatic classification of parent-infant social games from videos. In *Electronic Proceedings of the International Meeting for Autism Research*

[35] WFOT:http://www.wfot.org/AboutUs/AboutOccupationalTherapy/DefinitionofOccupationalTherapy.aspx

[36] World Health Organization (Ed.). International Classification of Functioning, Disability, and Health: Children & Youth Version: ICF-CY (2007).

[37] World Health Organization. International Classification of Functioning, Disability and Health: ICF. (2001).

[38] Zidianakis, E., Antona, M., Paparoulis, G., & Stephanidis, C. (2012) An augmented interactive table supporting preschool children development through playing. In *Proceedings of the 2012 AHFE International Conference (4th International Conference on Applied Human Factors and Ergonomics)*, San Francisco, California, USA, 21-25 July 2012, pp. 744-753.

[39] Zidianakis, E., Papagiannakis, G., & Stephanidis, C. (2014) A cross-platform, remotely-controlled mobile avatar simulation framework for AmI environments. In *SIGGRAPH Asia 2014 Mobile Graphics and Interactive Applications* (p. 12). ACM.

[40] Zidianakis, E., Partarakis, N., Antona, M., & Stephanidis, C. (2014) Building a Sensory Infrastructure to Support Interaction and Monitoring in Ambient Intelligence Environments. In *Distributed, Ambient, and Pervasive Interactions* (pp. 519-529). Springer International Publishing.

[41] Marco, J., Cerezo, E., Baldassarri, S., Mazzone, E., & Read, J. C. (2009, September). Bringing tabletop technologies to kindergarten children. In Proceedings of the 23rd British HCI Group Annual Conference on People and Computers: Celebrating People and Technology (pp. 103-111). British Computer Society.

[42] Bohn, J. (2004) The Smart Jigsaw Puzzle Assistant: Using RFID Technology for Building Augmented Real-World Games. Workshop on Gaming Applications in Pervasive Computing Environments at Pervasive 2004.

[43] Mandryk, R.L., Maranan, D. S., and Inkpen, K.M. (2002) False prophets: Exploring hybrid board/video games. In Extended Abstracts of the Conference on Human Factors in Computing Systems. 640-641.
[44] Scarlatos, L. L. (2002) TICLE: using multimedia multimodal guidance to enhance learning. Inf. Sci. Inf. Comput. Sci. 140, 1 (Jan. 2002), 85-103.
[45] Piper, A. M., O'Brien, E., Morris, M. R., and Winograd, T. (2006) SIDES: a cooperative tabletop computer game for social skills development. In Proceedings of the 2006 20th Anniversary Conference on Computer Supported Cooperative Work
[46] Lester, J. C., Stone, B. A., and Stelling, G. D. (1999) Lifelike Pedagogical Agents for Mixed-initiative Problem Solving in Constructivist Learning Environments. User Modeling and User-Adapted Interaction 9, 1-2 (Jan. 1999), 1-44.
[47] Bers, M. U. and Cassell, J. (1998) Interactive Storytelling Systems for Children: Using Technology to Explore Language and Identity. Journal of Interactive Learning Research 9(2) 183-215.
[48] Gallahue, D. L. 1989. Understanding Motor Development: Infants, Children, Adolescents (2nd ed.). Indianapolis, Indiana: Benchmark Press.
[49] Burnett, Alice. (1962) "Montessori Education Today and Yesterday." The Elementary School Journal 63: 71-77.
[50] Alibali and diRusso, 1999. The function of gesture in learning to count: More than keeping track. Cognitive Development. v14. 37-56.
[51] Chao L. L., J. V. Haxby and A. Martin, (1999) Attribute-based neural substrates in posterior temporal cortex for perceiving and knowing about objects. Nature Neurosci., pp. 913–919.
[52] Zidianakis, E., Ioannidi, D., Antona, M., & Stephanidis, C. (2015) Modeling and Assessing Young Children Abilities and Development in Ambient Intelligence. In Ambient Intelligence (pp. 17-33). Springer International Publishing
[53] Vygotsky, L. S. (1978). Mind in society: The development of higher psychological processes. Cambridge, MA: Harvard University Press.
[54] Shelley E. Mulligan (2003). Occupational Therapy Evaluation for Children, “Table 3-2: Development of Play Skills”, pp. 101 - 104.
[55] Knobloch, H., Pasamanick, B., Sherard, E. S. (1966). A developmental screening inventory, Department of Pediatrics and Department of Psychiatry, Ohio State University College of Medicine, Columbus, Ohio.
[56] Georgalis, Y., Grammenos, D., & Stephanidis, C. (2009). Middleware for ambient intelligence environments: Reviewing requirements and communication technologies. In Universal Access in Human-Computer Interaction. Intelligent and Ubiquitous Interaction Environments (pp. 168-177). Springer Berlin Heidelberg.
[57] Piaget, J., & Inhelder, B. (2008). The psychology of the child. Basic books.