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Foundations of a Smart Toy Development for the Early Detection of Motoric Impairments at Childhood

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Abstract

Introduction: Monitoring of neurodevelopment from birth until the age of six aims to enhance children's abilities and autonomy. Early detection of motoric impairments at childhood can facilitate necessary diagnosis and/or treatment. Ambient Intelligence (AmI) technologies could support future application domains like motoric impairments' detection at the home environment.

Objective: The creation of adequate smart monitoring solutions at home can provide professionals with reliable information about the health status of a child. Furthermore, toys and playing are crucial for the overall development of a human being. Hence, the aim of this research is to improve the exactitude of traditional evaluation methods by embedding sensors into daily life toys that provide professionals with added value supplementary evidence enhanced by Decision Support Systems (DSS). It will be possible to detect potential motoric disorders in a standard child's development that might keep undetected by traditional ways.

Materials and methods: A smart toy was designed by a trans-disciplinary team of professionals under a research consortium of Madrid universities supported by EDUCERE project. The main target of this nationally funded project is to create and evaluate innovative solutions to early detect neurodevelopment disorders and trigger requested actions of early intervention. This paper focuses on the "Smart Cube", an evolution of the traditional building blocks toy.

Results: The research led to validate a scalable methodology to push the creation of innovative smart toys for early prevention of disabilities. The implementation of a web based Decision Support System (DSS) allows to support the reasoning procedures required by the smart toy solution. Ongoing validation data paves the way for long scale field trials to be performed at 3 nursery schools.

Conclusion: The methodology allows the interaction between a trans-disciplinary team of professionals in order to undertaken the smart toys design and construction. Furthermore, toys verification stage needs to be measured in order to adjust diagnostic and therapeutic actions to pediatric patients.

Keywords

Children impairments, Intelligent healthcare, Motoric disabilities, Home embedded sensors, Smart toys, Internet of things, Building blocks.

Introduction

The disability prevalence estimations in the childhood change enough due to differences in the definitions and the wide range of methodologies and the existing of measuring instruments. The World Health Organization (WHO) and the World Bank declare in their report "World Report on Disability", that many cases of children with disability are still not identified, and do not receive diagnosis or treatment services from the health care entities [1]. Hence, early and effective identification of children with at risk for developmental disorders remains a pending task for the international community [2]. Accurate diagnosis of children's health status leads to better development results. Thus, early detection of developmental disorders in early childhood can facilitate necessary diagnosis and/or treatment actions [3,4], as well as the early adoption of intervention measures.

Furthermore, pediatricians and professionals working with children do not always detect the existence of neuro developmental disorders at early stages [5]. This evidence demands to develop medical information systems to facilitate non delayed referrals to

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the specialists. Thus, experts could identify disorders in the first neurodevelopment stages, suggest medical treatments and share them with authorized professionals involved in the child's evolution [3].

The Council of Children with Disabilities of the American Academy of Pediatrics pointed out in 2006 the possibility to identify infants with developmental disorders at the home scenario [5]. Thus, the personalized analysis of children's interaction with the daily life objects, such as toys or home furniture, could help to find out potential disorders on their neurodevelopment in a natural way [6]. This new smart environment for the child needs data acquisition from embedded intelligence sensor systems in order to provide an adaptable reasoning subsystem with real time data that supports decision taking according to scientific knowledge about the children´s evolution [6]. The service must take into account that usability, reliability and privacy of such systems are critical to guarantee a natural and safe interaction of the child, and this requires a user- center development approach [7].

The availability of smart monitoring solutions at home can provide physicians, physiotherapists and psychologists with reliable data about people's health status when required. This facility could trigger secondary and tertiary prevention activities to reduce disease related complications for children with musculoskeletal impairment, as stated by the World Health Organization and the World Bank [1]. Moreover, gross and fine motor skills are important foundation for the acquisition and the ability to perform many everyday functional and social activities. In fact, toys and playing are crucial for the overall development of a human being [8].

The aim of this article is to show the combination of EDUCERE adaptable home healthcare services [6], which use the potential of embedding sensors in Smart Toys (ST) and pieces of furniture according to the Internet of Things (IoT) paradigm, in order to carry out smart prevention and early attention of motor delays by monitoring and stimulating children's physical activities. In this way, it will be possible to detect potential disorders in a standard child development that might go unnoticed by traditional ways. The information collected from these ST will be treated by a Decision Support Systems (DSS) in order to carry out the process of decision making. The potential benefits of DSS in medicine were identified since the early 70s and received much attention over the past three decades [9]. Expectations were raised about its potential to increase productivity in a medical environment, to support diagnoses and other types of medical decisions, and to assist in medical training [10].

EDUCERE research methodology led to focus on the creation of the so called "Smart Cube" for children between one and three years old. Children like building block and the advantages of playing with these "toys" are clearly identified:

1. Building games help children to develop essential motoric skills such as to take, to hold, to pull, to lift and to drop.

2. While playing with building blocks, children develop fine and gross motoric skills. It helps them to acquire spatial concepts such as volume, weight, shape, parts distribution in space and the relationship between the parts.

3. A child also acquires some valuable concepts as opposed, for example, large-small, high-low, short-long, above-below.

4. Children learn to plan, organize and classify.

5. Building blocks contribute to social and emotional development as it shows the children that there are certain physical rules that must be accepted and this will help them in the future to better adapt to the standards in all life situations.

6. The building blocks help children to develop logical reasoning

7. This toy motivates kids to try to find creative solutions to problems that arise in building

8. Building activity brings out some problems whose solution motivates kids to put into stage creativity abilities.

These are some of the reasons why we have selected the building blocks and designed a prototype Smart Cube. But additionally cubes are included in most of intelligence and child development tests. This offers us the opportunity to validate the effectiveness of the cube as a tool for assessment of child development.

Materials and Methods

Participants

Even though the cube would be able to be used to assess psychomotor development of smaller babies around 6 months old for showing palmar grasp of cube, and eye-hand coordination. At this research stage and in order to test the first prototype developed, we will carry out our validation with children between 18, which can build a tower of 3 or 4 cubes, and 36 months old, which build towers of 9 cubes. Hence, by recording the pattern of movements of children we hope that smart cube can facilitate the early detection of psychomotor development difficulties such as: dyspraxia or developmental coordination disorder, attention and concentration deficits, Attention Deficit-Hyperactivity Disorder (ADHD), perceptual-motor dysfunction, kinaesthetic sensitivity problems, not to the same way that the other tests do, but more accurately, that is, detecting doubtful cases that can become a problem for children in the future.

Furthermore, in relation to cognitive development, we hope that Smart Cube can record different movements in children who do not have problems compared to children who are unable to organize and plan their movements to the tower, who have problems with working memory, following instructions or focusing attention on task.

On the other hand, the parameters recorded by Smart Cube are: the path, acceleration, balance, average speed, turning and stacking in a tower. From these data we get a pattern that can be analyzed and which will allow us to compare children who clearly presented normal scores on standardized tests, with children who score below average. We hope validate Smart Cube by this comparison and by the opinion of experts in child development.

Finally, gross and fine motor skills will be evaluated by analyzing certain characteristics of psychomotor pattern: (1) if there are difficulties in gross motor we expect to find poor timing, poor balance, problems with spatial awareness, trouble picking up and holding (Smart Cube will fall) or difficulty remembering the next movement in a sequence (for example, the child will place back the cube in the starting position before placing the next cube to do the tower), (2) if there are difficulties in fine motor we expect to find bad stacking without position correction, the cube can be gripped with the whole hand and not with the thumb and two fingers or, eventually, the pressure that child must exercise to put a cube over another may be excessive causing the tower to fall.

Methods

One key point to guarantee the success of the ST construction is the selection of a suitable and trans-disciplinary team of experts in the field of: engineering, education, psychology, physiotherapy and occupational therapists. This team of professionals work under EDUCERE Research Project during three years. EDUCERE goes one-step forward on existing Ambient Intelligence (AmI) as it takes into account the development skills of children with motor impairments to create daily life based markers that push home health services by acquiring data from the so-called Smart Toys as: rattles, balls and cube towers.

The acquisition and systematization of needed knowledge required for the development of ST proposed in this paper is a critical aspect that determines its effective use at home and/or with educators at nursery school. The Knowledge Acquisition (KA) process is the first step for creating some Smart Toys and it strongly influences the conditions for correct operation. This process covers up to the final stage of ST development. These ST are key tools that contribute to motivate learning and generate emotions in children between

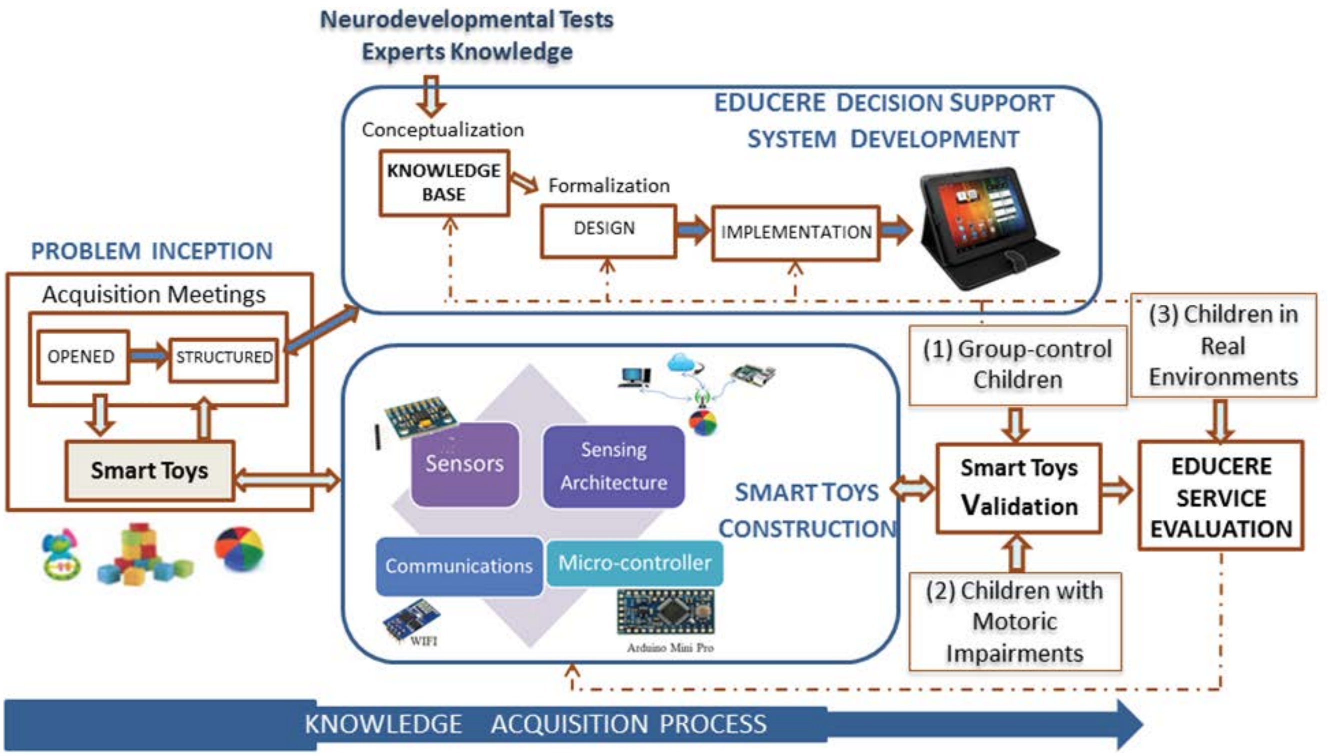

Figure 1: Methodology for Smart Toys and Decision Support System Development.

0 months and 5 years of age. The process to get evidence about a developmental difficulty or to diagnose is often a hard task. The reasons of this complexity are the variability in the ranges of standard development and the improvable accuracy of the assessment tools [8].

The methodology for KA requires consideration of both the definition of the knowledge to be systematized and the conceptualization and formal design of the information compiled from human and materials sources in order to model the functioning of the Smart Toys and the DSS. Besides, the relation between the KA collected from humans' expertise and its translation into a formal knowledge representation is successfully achieved in a cyclic way [3].

Common KADS (CK) is a knowledge engineering methodology for the design and development of DSS based on knowledge extracted from human experts and its codification to allow for its processing by a system [11]. Ontology is a formal model for representing information that can characterize, classify and categorize expert knowledge [12]. The use of ontologies is intended to facilitate communication and the exchange of information between different systems and institutions. It also allows processes scalability and reuse of knowledge between different versions of the same system, or between related systems.

Results

During the first years, a child spends a large part of his/her time playing. It is the means and the end through which children receive the challenges that will enable them to reach the different developmental milestones, thanks to what they can learn through play. A child that does not play enough may have a series of impairments that will make it hard or even impossible, to face the challenges presented by the society to which he or she belongs.

The incorporation of different kinds of sensors to everyday toys of children will allow collecting systematic information processes and actions in order to make an early detection of potential problems that may affect development in the field of mobility. Furthermore, when a motoric problem is detected, it will also be possible to use this technology for early attention in children through educational activities that can mitigate effects it may have in the future.

This research aim is design, develop and validate simple Smart Toys to home and school that can register children's behaviour and skills in order to detect problems of development and promote activities of stimulation. A systematic analysis of the interaction milestones and key stages of the child's development led to decide the use of rattles, balls and cube towers to monitor the skills and behaviour of children aged between 0 and 5 years [8,13-17]. Next, professionals subject to study Smart Toys developed in order to ensure their reliability and validity for the early detection of developmental difficulties. Furthermore, it is necessary design and develops a model guide for professionals and families which ensure an adequate use and interpretation of results obtained after the use of the developed ST. The team of health area experts analyzed different batteries assessment of child development. After that, they concluded that level motor parameters that are essential measure to detect any engine problem in children are: pressure contact surface (type of clamp ago), handling time, body posture (distribution of supports, load weight and amount of load), movement in space (related to body posture and movement), launch (distance, speed and direction).

The focus of this study is on the methodology description to carry out the stages of ST design, development and validation. Once the objectives, methods, and experts have been identified a strategy for ST development is needed. Figure 1 shows the whole process for the construction and validation stages necessary for the ST construction and the EDUCERE DSS development.

The embedded intelligence sensor systemstoys construction and the DSS Development have been carried out in the following steps:

Knowledge acquisition

Acquisition and formalization processes were developed on the basis of information gathered in open meetings and then structured with the team of experts. The process of acquisition of expert knowledge relied on the use of additional techniques such as questionnaires, surveys and interviews designed in accordance with the objectives to be met by the ST construction and DSS development.

Problem inception

Its target was to define the problem to be solved for early intervention. The group of trans-disciplinary experts involved in this phase were: psychologists, educators, physiotherapists, engineers, and occupationaltherapists. The team had several open meetings in order to support the problem definition and lead to specifically work with early screening of motoric disorders, by the construction of some ST like: rattle, cube towers and balls.

Educere system development

It covers the analysis, design and implementation phase of the DSS. This smart system has as input the information obtained by the ST and returns as output reliable information about the child interaction with the ST.

ST will facilitate effective decision making since simplify the more routine aspect of child care such as recording the same information many times for different professionals (paediatrician, psychologist, and physiotherapist) in diagnosis. In the decision, the EDUCERE DSS will drop children who show a “normal” psychomotor behaviour while they are playing, allowing professionals to focus on children who show anomalous performances. Our definition of “normal” is built, on the one hand, from the vast amount of data recorded and statistically analysed, and on the other hand, from the judgments of professional about psychomotor development level of children.

The core of the DSS is a Knowledge Base (KB) which collects different items and decisions based on the sensors embedded in the different Smart Toys.

The EDUCERE DSS KB evaluates motor skills such as speed and accuracy of movements, the pressure with which the child catches the object, the time that holds it and related cognitive skills such as the perception of space and objects, planning of movements, the intentionality of the actions, the detection and correction of errors, memory, imitation skills and creativity.The EDUCERE System relies on the KB to support early detection of motoric disorders.

The KB is developed using Protégé (ontology creation platform) [18] and Pellet (reasoning engine) [19]. The verification of the KB required a usable tool so that specialists might interact with the DSS in an efficient way.

Smart toys construction

The construction of Smart Toys are made taking into account the needs described by health professionals into the experts team.

One of the requirements to cover by these toys was that they encourage a fundamental integration and inclusion in order to improve an accessible child interaction.

Figure 2 shows the interior of the cube developed:

Figure 2: Inside of the developed Smart Cube.

The team of engineers who participated in the ST construction took into account key toys design requirements: (1) to get the child’s attention, which is similar to a traditional toy. For that, the Smart Cube has inside a *buzzer speaker* and several *LEDs (Light-Emitting Diode)* to facilitate the child stimulation process. As well as the size, weight, and number of sensors required for each toy. Accurately, the Smart Cube has: two *LDR (Light Dependant Resistor) sensors* by face, these sensors let you know whether or not the face is hidden by another cube. Furthermore, the Smart Cube has inside an accelerometer with gyroscope and a compass functionality; in order to measure the movement pattern made when placing the cube; to end with sensors details and to optimize the use of the Smart Cube battery, the engineers have placed a *tilt sensor* inside the cube for allowing to the ST to sleep when idle, and wake up when it detects movement, (2) the way to achieve greater autonomy during use. To that end, the Smart Cube battery has 7 hours of autonomy, enough time to carry out the experiment with several children in one session, (3) conclusions about sensing architecture that facilitate the toy communication with the DSS in order to allow the process of decision making.

Smart toys validation

Experts should be able to evaluate whether the Smart Toys contribute in a satisfactory way to improve early identification of possible motoric delays in children. The age of the child, in this first validation stage, is between 1 and 3 years old. This phase has two planned stages:

1. Evaluation of the ST - in this case, the Smart Cube - which involves recording and analyzing cube movements in a control group of children 1-3 year old with no developmental problems detected.

2. It will also carry out the recording and analysis of Smart Cube movements in a group of children 1-3 years old with developmental problems diagnosed. These data will be correlated with data collected with the same tools.

During the validation process, the child will be accompanied by a therapist who will guide her/him in the interaction with the ST. At first, the child may make a toy exploration, manipulating it as desired for a few minutes. After that, the therapist will tell her/him what kind of movement should be performed, in the case of cubes; the child must build blocks between 3-9 cubes, depending on the age of the child. While performing this cube block the involved sensors are collecting data about: acceleration, twist, time and jerk (number of stops and accelerations which are performed to move a cube from its initial position to the final). All this data will be gather at EDUCERE database. When the experiment will finish the information collected in the database will be processed by the EDUCERE DSS. Above, at EDUCERE System Development stage we have provided more details about this question.

Educere service evaluation

This controlled evaluation is scheduled for spring 2016 in cases considered of interest by the professionals already involved in the final stage. Thus, a web tool (EDUCERE DSS) is being built to facilitate the work of experts in the process of decision making. Several professionals: paediatricians, physiotherapists, occupational therapists, developmental physiologists and educators, will be involve in the verification stages both for usability and system performance tests along six months. End users pointed out that they could use the tool by themselves in clinical routine. They will be provided with a professional’s guide for an adequate use to assess the required items. Professionals may use the results obtained by recording the child’s relationship with the toy for a plan of follow-up or treatment of the aspects that show a deviation from normative values (validated with EDUCERE DSS). It is important to note that this interaction will provide very accurate quantitative information that will help professionals to guide the steps and should never replace, but supplement, the professional criteria to use it. In addition, they can check each of the aforementioned characteristics of motion (speed, interface, etc.) that the professional may be related to their clinical observations. These data, to be very precise, may be used, also, for the purpose of improving the quality of investigations.

Conclusion

This communication details an innovative procedure to create EDUCERE smart objects by embedding sensors on toys and pieces of furniture according to the Internet of Things (IoT) paradigm. In this way, it aims to smart cooperative prevention and early attention of motoric impairments by monitoring and stimulating children's activities.

The Smart Cube allows the recording and analysis of valuable of data related to the motoric development of a child. This solution provides professionals with the opportunity to obtain multiple patterns of motor behaviour, some of them from children diagnosed with motoric development problems and others for children who do not have any physical disorder. The added value of EDUCERE Smart Cube is to get ambiguous behaviour patterns that must necessarily coincide with the doubts that have experts have about the development of those children who show certain anomalies that must be monitored and corrected to avoid further problems. In this case, it is possible to notify family and professionals about the need to monitor the child's developmental level.

The core of the EDUCERE DSS is a rules based ontology that integrates mainly children's motoric items according to the age. The ontologies also support the communication between all professionals involved in the system construction allow reuse domain knowledge and facilitate recovery, integration and interoperability between heterogeneous sources of knowledge.

Hence, the earliest acquisition of development information from the natural interaction of the children with these Smart Toys, the most effective and reliable way to feed a DSS and experts with real time monitoring information.

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References

1. http://www.who.int/disabilities/world_report/2011/en/.
2. Paul R (2011) Language Disorders from Infancy through Adolescence: Listening, Speaking, Reading, Writing, and Communicating. (4th edn) Elsevier Health Sciences, Netherlands.
3. Martín Ruiz ML, Valero Duboy MÁ, Torcal Loriente C, Pau de la Cruz I (2014) Evaluating a web-based clinical decision support system for language disorders screening in a nursery school. J Med Internet Res 16: e139.
4. Department of Health. Information for a Healthy New York. The Early Intervention Program: A Parent's Guide.
5. Council on Children With Disabilities, Section on Developmental Behavioural Pediatrics, Bright Futures Steering Committee, Medical Home Initiatives for Children With Special Needs Project Advisory Committee (2006) Identifying infants and young children with developmental disorders in the medical home: an algorithm for developmental surveillance and screening. Pediatrics 118: 405-420.
6. Valero MA, Linden M, Velasco JR, Björkman M (2014) Personalisation of intelligent homecare services adapted to children with motor impairments. 8th International Conference on Ubiquitous Computing and Ambient Intelligence. Personalisation and User Adapted Services Lecture Notes in Computer Science 8867: 476-479.
7. De Rouck S, Jacobs A, Leys M (2008) A methodology for shifting the focus of e-health support design onto user needs: a case in the homecare field. Int J Med Inform 77: 589-601.
8. Nunez-Nagy S, AlarcosAlcázar B, Valero Duboy MA, GallegoIzquierdo T, Ramírez Romero RJ, et al. (2015) Smart toys for detecting children developmental delays. International Conference on Recent Advances in Neurorehabilitation.
9. Tolmie CJ, du Plessis JP (1997) The use of knowledge-based systems in medicine in developing countries: a luxury or a necessity? Methods Inf Med 36: 154-159.
10. Burstein F, Holsapple C (2008) Handbook on Decision Support Systems. Berlin Springer.
11. Alonso Betanzos A, Guijarro Berdiñas B, Lozano Tello A, Palma Méndez JT Taboada Iglesias MJ (2004) Ingeniería del conocimiento. Aspectos Metodológicos.
12. Corcho O, Fernández-López M, Gómez-Pérez A, López-Cima, A (2005) Building legal ontologieswith METHONTOLOGY and WebODE. Lect Notes Comp SC 3369: 142-157.
13. Bayley N (1977) Escala Bayley del desarrollo infantil. Madrid: Publicaciones de Psicología Aplicada.
14. Cools W, Martelaer K, Samaey C, Andries C (2008) Movement skill assessment of typically developing preschool children: A review of seven movement skill assessment tools. J Sports Sci Med 8: 154-168.
15. Chambers M, Sudgen D (2006) Early years movement skills. Description, diagnosis and intervention. Whurr Publishers, England.
16. Roid GH, Sampers JL (2011) Merrill-Palmer-R. Escalas de desarrollo. TEA Ediciones.
17. Jonson-Martin NM, Jens KG, Attermeier SM, Hacker BJ (2009) Currículo Carolina (CCITNS): Evaluación y ejercicios para bebés y niños pequeños con necesidades especiales. (3th edn) TEA Ediciones.
18. http://protege.stanford.edu/.
19. https://github.com/complexible/pellet.