Smart Objects for Autism: A Proposal of Classification of the Objects Based on the Autism Symptoms

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Abstract. The Technology could have a greater impact on the life of people, especially for disabled people. In this paper we focus on smart objects designed for the autistic people. In fact the IoT technologies are proving their suitability for these users. So we made a review and a qualitative analysis of the actual offer of these objects, adding also items for disabled people and not specifically designed for autistic people. Its general aim is try to understand if the smart objects could be useful for the autistic people and how they do this. As result, we present a proposal of classification of the smart objects for the autistic people, based on the symptoms of the Autism on which the object could have an effect.

Keywords: Smart object · Autism · Assistive technology · IoT · Interaction design · Tangible interaction

1 Introduction

Technology allows us to do things until now unimaginable and sometimes *magic*. But the technology with the greater impact on our life are the technologies with a real and concrete impact, which improve our daily activity. Every improvement achieved in the life of able people assumes a greater value in the life of people with any type of disability. In this paper we focus on technologies designed for the autistic people. Children with Autism have been noted to be skilled at using computers [1]. In this field, many project of innovative technologies have been carried out. On the base of the actor which the technology is made for, we can organize them on three different levels. For the autism researcher, technologies application can allow to collect large scale data for the deepest study and earlier diagnostic of this little-know disease. For the operators, psychologists and families, the potentialities are the monitoring of the users for a more personalized treatment [2]. For the end users, the technologies can be a support for the therapies, a tool for trainings of some skills, an appliance to communicate. Among others, some research of the Assistive Technology field have focused on the technologies designed for the autistic people, such as the development of a type of Ambient Assisted Living based on the Internet of Things infrastructure and device [3]. Just the

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IoT devices, based on Ubiquitous Computing paradigm [4], are proving their suitability for these users, in a way that their characteristics of pervasiveness and ubiquity, invisibility and integration in the every-day object, network connection make them versatile across the various fronts of the complex world of the Autism. This type of devices is called 'Smart Object' and consist of physical object in which is integrated: computational power, sensors, actuators, and possibly memory and connectivity [5, 6]. Our focus on the use of the smart objects for the autistic people is made also in a viewpoint of the potentialities of tangible interaction. In this paper we made a review and a qualitative analysis of the smart objects designed and objects for the autistic and disabled people. Its general aim is try to understand if the smart objects could be useful for the autistic people and how they do this. As result, we present a proposal of classification of the smart objects for the autistic people, based on the symptoms on which the object could have an effect. Its aim is to give a general direction to the future design of these devices, through some recurring design characteristics, and to be a tool for the designer to better understand this world of devices.

In the following section we describe the Autistic Spectrum Disorder. Then we make an overview of the several application of the technology for this disorder. The fourth section illustrate, firstly, the method of the smart object review. In the second part of this section a table with the characterization results is provided, and some qualitative analysis are reported. In the fifth section we describe the proposal of classification of the smart object for the autistic people and we identify some recurring design elements for each group of objects. In the last section we illustrate the conclusion.

2 The Autism Disorder

Autism (from the greekαὐτός [aw'tos], it means *self*: himself, herself, itself) is a neurodevelopmental disorder that affects the way a person experiences and interacts with the world. It was identified by psychiatrist Leo Kanner and, more than 60 years after its definition, its classification is still uncertain as well as its causes. In the fifth edition of the Diagnostic and Statistical Manual of Mental Disorders (DSM-V), Autism was defined as a spectrum of conditions, also more different between them, which regards the right development of social, cognitive, emotional, communicational skills. Indeed it was included in the Autistic Spectrum Disorder (ASD) with Asperger's disorder and childhood disintegrative disorder and pervasive developmental disorder not otherwise specified (PDD-NOS).

The Autism disorder symptoms and their severity level vary widely depending on the level of development of the disorder and chronological age of the subject. But all autistic people are characterized by a so-called autistic triad: impaired social interaction, delay and disorder in the communication and restricted interest and repetitive behavior. The social interaction impairments regard deficits in understanding how to behave and interact with other people: lack or absence of social interaction initiative; difficulty understanding and using nonverbal behavior (e.g. eye contact, facial expression); unaware of the different ways to interact with the others (e.g. difficulty in adapting behaviors according to social contexts; difficulty understanding other people's points of view or feelings). Impairments in the communication concern deficits in

ability to communicate effectively with other people as: unusual or repetitive language; absence of desire to communicate; total lack of language or delayed or impoverished language development; talking about own interests regardless of the listener's response; comments inappropriate to the context. The impairments in the activities and interests consist in deficits in flexible thinking regarding interests, routines as: incapacity of generalize information; fixation in some interests; stereotypic patterns of behavior (unusual or repetitive gestures or actions); rigid routines and resistance to the change; fascination with object parts.

Autism has been documented in all the world's peoples, of every race or social environment. Its estimated prevalence, considering the Autism Spectrum Disorders, it's 1 in 68[1]. About the causes of autism, as said previously, there are no certainties. More and more scientific evidence points to genetics, though scientists note that it's likely there is no single cause. Among the other popular theories, in the public mindset, there are factors such as parental age, poisoning from heavy metals, vaccines and so on. The scientific evidence continues to refute these hypotheses, and also to suggest that different combinations of factors can be linked to different manifestations of Autism spectrum disorders. For our competence, whatever are the causes, it is vital to focus on issues of pressing concern to actual autistic persons and their families today, such as serene growth, enhancement of their ability, housing, employment and long-term supports.

3 An Overview of the Innovative Technology for Autistic People

Goodwin [7] provide a complete overview of the innovative technology developed for the Autism disorder: from the use of Internet as a support for the long-distance clinical health care and communications; to the use of Virtual Reality technology to practice rule learning in social skills or as teaching aid; to the wearable sensors to record physiological reaction, helping the autistics, and the people who interact with, to understand their physical state, so their emotions. The latter application was a part of the Affective Computing field, which focus on the potentials of the physiological communication and social-emotional skill development technologies. Autistic people, especially nonverbal, have trouble to communicate their emotions and to communicate on the outside what they experience on the inside (e.g. pain for headache). This gap can be fill up tracking of the physiological state (e.g. electrodermal activity) through the wearable device, as a small wristband. This type of device can have several aims: to make adjustments to the treatment plan; to identify the elements that enable a better focusing on some tasks or cause "meltdowns"; to collect long-term data for the research community to produce new insights for the Autism disorder; and to bring to the Autism people tools to recognize their emotions, self-regulate and calm themselves [2, 8]. For the education and

[1] Data referred to the prevalence of Autism in the United States released by the Centers for Disease Control and Prevention (CDC). In Europe many countries - including Denmark, Sweden, Portugal and the United Kingdom - lack of updated data on the prevalence of these disorders.

the therapy application, among others, an interesting and innovative trend explores the use of different kinds of robots with the aim to develop social and behavioral skills in a safe and controlled environment. Robota, a humanoid robotic doll, engages child with autism, through a bodily interaction, in an imitative interaction games [9]. ShyBot is a personal mobile robot designed to embody shyness behaviors, and through a Replay technique, to elicit reflection in the child on this type of behaviors via associating their outward observations with their inward feelings [10].

Nowadays, thanks to the IoT developments more researchers and developers are focused on developing various smart devices that can support autistic users in their daily routine, improving their quality of life. The smart objects, with their capability of identifying, locating, sensing and connecting, lead to new forms of communication between people and things and things themselves. Furthermore, they enable a tangible interaction that may be well suited for the autistic people providing a tangible focus for activities and taking advantages from an active learning, experienced through body and sensory awareness [11]. In addition, the interaction enabled through these objects puts the child in control, under possible guidance of and feedback from the teacher, but with the child learning at his/her own peace [9]. This advantage, although valid for the technology in general, is especially true in the case of the smart objects, that are based on a much focused and closer end-user interaction.

4 Smart Object Review

4.1 The Review Method

Until now, more attention is given on the objects itself without a general thinking system and trans-disciplinary approach. Stated this, we made a review and a qualitative analysis of this type of smart objects which general aim is try to understand if the smart objects could be useful for the autistic people and how they do this, through the various interaction ways and patterns. This type of objects can be applied in three scenarios, which illustrate the use of smart devices on different scales: small, medium and large scale [12]. For our aim, the impact on autistic people and their life, we focus on the smart objects of the small scale operating within buildings. Furthermore, we clarify that our focus were physical objects that enable a kind of purely physical and sensorial interaction. Therefore, we have excluded the numerous projects consisting of apps and platforms. We have decided also to rule out the humanoid robots that currently represent a growing trend in the treatment of the Autism. In this case, we consider they refer to a different field of study.

For the review, we have conducted an Internet search and the results have showed there are many projects of smart objects designed for the people with Autism. Many of them were proof of concepts, others were the results of research application for the Academy and many others were real products on the market. So we have decided to include objects at any state of the development of the product. Then, to have the most complete overview of the field, we have included the smart objects designed for other types of disabilities, which functionalities could be useful for the autistic person. The selection has then been extended to those smart objects whose design and

functionalities are strongly related to the key concepts of Autism: from development of the social interaction skills, to expression of the emotions. In fact, this type of smart objects, although they are not specifically created for these users, is made for the development of some necessary abilities and skills, lacking in the autistic people. We have decided, lastly, to include also the *traditional* objects for people with special needs, that is objects without the 'augmented' part (e.g. computational power). In fact, it is important not to underestimate the world of knowledge grown before the development of the technologies, in a way that their interaction patterns can be still valid and applicable to the smart object field.

First of all, we have characterized the objects through a series of comparable and general elements referred to the Technological Features, the Objects Behavior and the Interaction Modes. The three macro aspect have been detailed in some elements that usually characterize a smart object. The Technological Features regard the hardware and software characteristics and the related functionalities. So we have examined if the object: (a) is equipped with an app, (b) connects and interacts with his peer, (c) conducts a monitoring activities via sensors, (d) and tracks the activities. The Object Behavior is referred to the behavior model of the object toward the user, to be understood as increasing in terms of responsiveness to the user. The behavior of the object could be (a) Passive, in a way that only reveal something (e.g. quality of the air). The following model (b) is based on a simply Input/Output relations, so the smart object that is manipulated through certain inputs produces certain outputs. The Proactive behavior (c) is characterized by a more advanced responsiveness for which the object is resourceful and solicits the user. The last pattern is the User Adaptive model (d) for which the objet uses every information learned in the interaction with the user to adapt dynamically its behavior. The Interaction Modes regard the interaction way through the object communicates and engages the users. The interaction could be mediated through (a) hands, through (b) the body (full body movements), through (c) senses (e.g. use of lights or scents), and through (d) body and senses.

After this first characterization, we have analyzed each object through a qualitative analysis of the interaction. The general aim of the qualitative analysis is to examine in depth every object, each one with own several features and interaction mode, to learn useful consideration for the design. The qualitative analysis of the interaction is based on the three implicated perspectives: the product design field, the interaction design field and the medicine field (neuropsychiatry). For the product design analysis level, we have identified the physical and digital aspects of the object: dimensions, shapes, colors, materials and characteristics, product type and any technological features. This physical characteristics, that give a certain affordances [13], are fundamental in a way that affecting how people use the object, what people think about it, how they hold it, and how they handle it. For the interaction design level of analysis, we have identified the interaction frameworks and patterns between the child and the object (e.g. the use of light or movements for feedback), and the use of certain organizational and interaction metaphors [14]. The metaphors form the conceptual infrastructure for the Ubiquitous Computing project, especially for the smart objects. For the neuropsychiatric analysis level, we have deduced a link between the symptoms disorder and the object features and its interaction. This last level of analysis allow us to suppose how these objects could intervene, in a positive way, in the course of the disease. The analysis is to be

intended in this order. So only after a clear understanding of the physical characteristics and the features of the object, that create and enable the interaction with the users, we can deduce the impact on the symptoms of the autism.

4.2 Results of the Review

We have selected and analyzed 19 objects: 5 are smart objects designed specifically for autistic and ASD people, 2 is a smart object for disabled people, 8 are smart objects related to the key concepts of Autism, and 4 are traditional objects. This list is certainly nor exhaustive nor complete of the existing offer of this type of objects, probably we have not identified many projects and many other projects are launched while we are finalizing this paper. However, this activity of selection and review of these objects is to be intended as in progress. Following, we provide the table of the results of the characterization of the objects (Table 1).

Table 1. Results of the characterization of the objects analyzed

	Features				Object behavior				Interaction modes			
	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
The Boezels					•							•
Repeat				•		•			•		•	
T3 Objects		•	•	•		•					•	
Cradle					•					•		
Snug Vest						•				•		
Squeeze Chairs					•					•		
Auti						•		•				•
Ubooly	•		•	•				•	•	•		
Cubemate						•					•	
I Mirabilia			•	•			•					•
Sleep sheep			•			•						•
Topobo						•			•			
Paro								•				•
Soma mat						•						•
Rolling pins		•				•			•		•	
Moti	•			•			•				•	
Edwin the duck	•					•			•		•	
Keepon pro			•	•				•		•		
+ Me	•						•	•				•

As regards the qualitative analysis of the interaction, we provide a recap of two of the carried out analysis: Auti and Soma Mat.

Auti is an interactive toy designed for individuals with ASD, which aims to encourage positive social skills. These subjects have difficulties in acquiring useful skills to interact with other children. Their 'extreme' behavior, in the sense they do not always control their voice and body, or the behavior not appropriate to the context tend to scare other children. Auti takes a series of a typical aspects of social interactions and puts them in a safe environment, in which the child can experience them through play, without social risk. Auti is a spherical toy, whose body is made of soft fur of opossum and has 4 legs. It is equipped with a series of sensors, servo motor and accelerometer, which allow it to move, to detect sounds, talking, and, in general, to interact with the child. Its operation mode is based on positive and negative reinforcement that work to change challenging behavior. So when the child proves negative behaviors (e.g. yelling), Auti will pulls in and shut down. On the other hand, every time the child will behave in a socially positive way, stroking, or talking with a moderate tone of voice, Auti will respond with engaging behaviors, as various dances. The interaction metaphor used is the Animism, so the devices become our pets or peer and we are led to interact with them as if we were really interact with our friends and pets [14]. Furthermore, the interaction metaphor used lead child to grow fond of Auti. Its design and its affordances allow an interaction with close contacts, since its shape and its size allow child to pick it up easily. The Auti purpose to encourage the positive social behavior makes it a useful tool for the impairments related to the sphere of social interaction, considering that they could appear just as difficulties in the development and maintenance of social rapport and difficulties to accord behavior to social contexts.

Soma Mat [15] is a mat designed as a tool for the own body awareness exercises, according to the Somaesthetic philosophy. Somaesthetics is an interdisciplinary field which asserts the importance of the body and our body movements as part of our ways of being and thinking. Therefore, increasing the awareness of our body, engaging in various forms of training, we can become more perceptive and aware in the physical world in which we live and act. Soma Mat uses heat feedback in different parts of the mat corresponding to different part of the body to support the ability to direct user attention to that particular part of the body while he/she performs the exercises of the training lesson. The experience becomes both intensely pleasurable and help to follow directions and instructions for the exercises. Soma mat consists of a series of layers of foam in which are integrated a set of heat pads controlled by an Arduino micro controller, programmed to follow the audio script of the lesson. The interaction metaphor used is which ones of the Enchanted Objects. This metaphor implies adding something 'magical' to an existing object and it implies that the object is mostly like its earthly counterpart, but with significant behavioral differences given to it by the technology [14]. The use of the heat, helping to focus attention on the parts of the body in correspondence, makes the interaction with soma mat very intimate, infusing the subject with a sense of calm, relax and focus on him/herself. In fact, these mode of interaction enables in the subject a more general process of meditative bodily introspection through a full and total awareness of own body. So Soma Mat could be useful to the symptoms related to the stereotypic behaviors and movements and restricted interests. These symptoms, especially the meltdowns and the stereotypic movements, often occur in situations of high stress and anxiety.

5 Proposal of Classification

The qualitative analysis of the interaction of the objects reveals a classification applicable to the objects and smart objects for people with Autism and based on the triad of symptoms of the disorder. From each qualitative analysis, we have observed how each object could match with only one of these symptoms. Furthermore, we have identified some recurring design elements in the objects belonging to the same group. The proposal of classification provides three type of objects: Enablers of Social Interaction, Supports for Learning and Inhibitors of Behavior.

The Enablers of Social Interaction are the objects designed for the issues related to the Social field, that regard social and emotional development, reciprocity, and interaction. These objects are characterized by features that, through their digital and physical design, enable, stimulate, and solicit in the children the relationship skills and their development. Included in this group are 9 objects: The Boezels, Auti, CubeMate, I Mirabilia, Topobo, Paro, Rolling Pins, Keepon Pro, and +Me. This type of objects often have in common a series of design elements: the product type, i.e. the toys; the interaction metaphors used, i.e. the Animism; and the Interaction Multimodal Mode based on sensory and bodily stimuli and feedback. With this type of objects the children can explore and discover the interaction skills rather than being taught explicitly, through objects designed as toys. Furthermore, the use of the metaphor of animism lead child to grow fond of the object, enabling the type of unconstrained and unstructured interaction, characterized by a multimodal interaction, that engage the attention of autistic children.

The second type of objects aims to be a tool for the issues of the Communication field, precisely for the symptoms of cognitive and communication impairments. These objects are the supports for the cognitive training and the language learning. Included in this group are 5 objects: Repeat, T3 objects and T3 board, Ubooly, Moti, and Edwin the Duck. This type of objects often have in common some technological features, that are the tracking functionalities and the app. For the interaction modes these objects are characterized by a hands-on or a multisensory interaction. Through these design elements this type of objects are a real learning tools that goes beyond the object itself and consist of a complete learning and training system that, through the app, provides the training exercises for the users and, through the tracking features, gives to the teachers or the parents (or to the users too) the possibility to collect and view the data. Furthermore we have noticed that the interaction enabled through these objects is more 'formal', as based on hands-on interaction and sensorial reinforcements. To reinforce this last consideration there is another recurring element in the design of these objects: the use of plastic materials, which perception to the tactile contact is much colder and pretended.

The Behavior Inhibitors pose themselves as a 'remedy' to the occurrences of symptoms of repetitive and stereotypic behaviors and movements. Indeed, these objects are characterized by features that allow children to calm, engaging their attention in other activity, or allow them to relax. Included in this group are 5 objects: Cradle, Snug Vest, Squeeze Chairs, Sleep Sheep, and Soma Mat. These objects have in common the product types, as furniture or wearable, and interaction modes focused on body or

multimodal stimuli and feedback. Furthermore, these objects often are not a smart object or they have very basic technological features, so their behavior are based on input/output relations and they are more focused on the physical and sensorial interaction through primordial stimuli (e.g. heat in Soma Mat or white noise in Sleep Sheep).

This proposal of classification aims to inform and give a general direction to the future design of these devices, not only through the identified recurring design characteristics but also providing a tool to better explore and understand the actual offer of these objects, facilitating the conceptualization of new smart objects for the Autism disorder.

6 Conclusion

In this paper, starting from an overview of the potentialities of the technologies for the Autism disorder, we focus on the smart object that, given their versatility and the technical features, are among the most important innovations for people with special needs, as the autistic people. To better understand this trend, we have explored and characterized the actual offer of these objects, adding also items for disabled people and not specifically designed for autistic people in a viewpoint of theoretical debate and pure inspiration. For each object we made also a qualitative analysis of the interaction on the base of the three implicated perspectives: the product design, the interaction design and the medicine field. Thanks to this qualitative analysis we could deduce the correlation between the smart object features and design characteristics and Autism symptoms. So we present a proposal of classification of the smart object for the autistic people, based on the symptoms on which the object could have an effect. The proposal of classification provides three type of objects: Enablers of Social Interaction, Supports for Learning and Inhibitors of Behavior. Its aim is to give a general direction to the future design of these devices, through some recurring design characteristics, and to be a tool for the designer to better understand these world of devices.

Currently, we are just at the beginning of the development of the smart objects for the Autism but, from this study and the resulting classification, we can understand as all the implicated fields in the design of a smart object for the autistic people are fundamental in its final effectiveness. So, we aim to underline the necessity of a shared and trans-disciplinary approach of the design. Stated this, the classification here proposed is not to be understood as definitive, because on one hand the review will continue to include new objects and on the other hand the classification will be refined together with specialists, such as therapists, as well as together with autistic children's parents. Furthermore, given the complexity of this disorder and as in the development of all UbiComp devices [6], we believe it is necessary to find the ways to get involved the end users, and their care-givers, at different stages of the process (e.g. through test users with real prototypes).To conclude, the key result of this paper is there are not best solutions for each symptom of the Autism, but rather it is necessary to develop an ecosystem of devices, flexible and adaptable to match the unique needs of this kind of users and their personal severity level of the disorder symptoms.

References

1. Murray, D., Lesser, M.: Autism and computing. In: For Autism 1999 Online Conference Organised by the NAS with the Shirley Foundation (1999)
2. Picard, R.W., Goodwin, M.: Innovative technology. The future of personalized autism research and treatment. Autism Advocate **50**(1), 32–39 (2008)
3. Sula, A., Spaho, E., Matsuo, K., Barolli, L., Xhafa, F., Miho, R.: A new system for supporting children with autism spectrum disorder based on IoT and P2P technology. Int. J. Space-Based Situated Comput. **4**(1), 55–64 (2014)
4. Weiser, M.: The computer for the 21st century. Sci. Am. **265**(3), 94–104 (1991)
5. Kranz, M., Schmidt, A.: Prototyping smart objects for ubiquitous computing. In: Proceedings of the International Workshop on Smart Object Systems in Conjunction with the 7th International Conference on Ubiquitous Computing (Ubicomp) (2005)
6. Papetti, A., Iualé, M., Ceccacci, S., Bevilacqua, R., Germani, M., Mengoni, M.: Smart objects: an evaluation of the present state based on user needs. In: Streitz, N., Markopoulos, P. (eds.) DAPI 2014. LNCS, vol. 8530, pp. 359–368. Springer, Heidelberg (2014)
7. Goodwin, M.S.: Enhancing and accelerating the pace of autism research and treatment: the promise of developing innovative technology. Focus Autism other Dev. Disabil. **23**(2), 125–128 (2008)
8. Picard, R.W.: Future affective technology for autism and emotion communication. Philos. Trans. R. Soc. Lond. B Biol. Sci. **364**(1535), 3575–3584 (2009)
9. Dautenhahn, K., Billard, A.: Games children with autism can play with Robota, a humanoid robotic doll. In: Universal Access and Assistive Technology: Proceedings of the Cambridge Workshop on UA and AT 2002, pp. 179–190. Springer, London (2002)
10. Lee, C.H.J., Kim, K., Breazeal, C., Picard, R.: Shybot: friend-stranger interaction for children living with autism. In: CHI 2008 Extended Abstracts on Human Factors in Computing Systems, pp. 3375–3380. ACM (2008)
11. Farr, W., Yuill, N., Raffle, H.: Collaborative benefits of a tangible interface for autistic children. In: Proceedings of the Workshop on Tangibles for Children, CHI 2009, pp. 1–4. ACM (2009)
12. EURESCOM: Smart Devices 'When Things Start to Think?' Strategic Study - Project P946-GI (2000)
13. Gibson, J.: The theory of affordances. In: Shaw, R., Bransford, J. (eds.) Perceiving, Acting, and Knowing. Lawrence Erlbaum Associates, Hillsdale (1977)
14. Kuniavsky, M.: Smart Things: Ubiquitous Computing User Experience Design. Morgan Kaufmann, San Francisco (2010)
15. Höök, K., Ståhl, A., Jonsson, M., Mercurio, J., Karlsson, A., Banka Johnson, E.C.: COVER STORY: Somaesthetic design. Interactions **22**(4), 26–33 (2015)