Hoyo – Shape Memory Alloys enable a new way to approach the treatment of the Autism Spectrum Disorder

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ABSTRACT

Sensory disorders characterise 90% of individuals with an autistic spectrum disorder (ASD); however, each individual is unique. Hoyo is an innovative product that fits the single sensory profile of the child. The device provides complex sensorial stimulation to the trunk of the user's body thanks to a series of inflatable bladders. To do so, Hoyo features shape memory alloys (SMAs), which provide a compact, lightweight, and silent system. Indeed, such properties are all essential characteristics for a product dedicated to ASD. Therapists can program the system to adapt Hoyo to the child's needs rather than asking the child to accommodate an existing product. Being able to release the tension caused by an over-

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stimulating environment is the first step towards achieving a higher level of inclusion in the educational system.

Keywords: Industrial Design, Shape Memory Alloys, Human-centred Design, Human-systems Integration, Autistic Spectrum Disorder

INTRODUCTION

The Autistic Spectrum Disorder (ASD)

In 1943, while describing eleven cases of infantile psychosis, the pediatrician Leo Kanner underlined how the subjects had some atypical behaviours, such as the tendency to isolate and ignore the signals from the surrounding environment. It was in this occasion that the concept of autism was introduced for the first time (Cottini, 2013).

Definition. The tenth review of the International statistical Classification of Diseases and related health problems (ICD) identifies the ASD as a syndrome characterised by two main factors: the disorder – occurring within the first three years of a child's life – and the manifestation of atypical social interaction, communication and behaviour, which is generally characterised by stereotypes and repetitive actions (Gison et al., 2012). Despite the official definition, cases extremely vary from one another, defining autism as a spectrum disorder. Indeed, every single patient has its own history and peculiarity and even if it is important to identify some standard symptoms for a correct diagnosis, an effective treatment should consider the child as a unique case. Moreover, the ASD changes throughout the individual's life (Riesgo et al., 2013); nevertheless, some general guidelines can be identified. Indeed, the 90% of the autistic population has a sensory disorder, the 33% is non-verbal, the 11-40% has anxiety-related problems and the 30% suffers from epilepsy (Autism Speaks, n.d.; Orphanet, n.d.).

Recently, the number of people with autistic spectrum disorders grew. This was caused increasing autism awareness and research advance that allowed early-stage autism identification, consequently leading to a significant increase in registered cases (Disease, 2017). This work considered the generic ASD and stressed perception and sensory aspect, since characterising most of ASD individuals.

Sensory Disorders. Children with autism process sensory stimuli differently compared to their neurotypical peers (Kern et al., 2007; Marco et al., 2011). In fact, they may show hypersensitivity, hyposensitivity or a combination of the two. While hypersensitivity causes discomfort feelings related to sensory inputs, hyposensitivity may head towards stereotyped behaviours. When both hypersensitivity and hyposensitivity occur, the child may need specific sensory inputs while being reactive to others (DeGangi, 2017; Kern et al., 2007).

Therapies and available tools

Today the ASD is mainly treated in two parallel ways, i.e. pharmaceutical therapies, and the so called non-pharmaceutical therapies (consisting in the use of exercises and tools to achieve results). This study focused only on non-pharmaceutical treatments since it did not aim to develop a medical device.

Therapies. Non-pharmacological treatments avoid biological support; instead, they involve psychological support on e.g. behavioural, developmental and educational levels (Narzisi et al., 2014). Even though there's no single therapy that works for every child, behavioural therapy is widely supported by previous research (Bertin, 2016). The idea at the base of this type of therapy, more specifically of the Applied Behaviour Analysis (ABA) treatment, is that every behaviour can be modified and regulated by actions of reinforcement or discouragement, so what happens because of the children's action will condition their future behaviour (Granpeesheh et al., 2009).

Another key aspect in children therapy is the capability to self-regulate, i.e. the ability of managing their own emotions and behaviours. Having self-regulation problems impacts several aspects of everyday life, including learning activities, social relationships and well-being feeling (Ray, 2017). The activities proposed to help the sensory regulation process are grouped as Sensory Integration Therapy (SIT). Deep pression is among SIT activities, providing a calming effect that decreases sympathetic arousal and parasympathetic responses, while improving heart rate and respiration (Anderson, 2016).

Available Tools. Several products addressing non-pharmacological ASD therapies already exist. For instance, vibrating cushions, suspended swings and weighted vests are widely available and commonly applied in therapies. All the previous focus on providing a specific sensory stimulation, letting the therapist understand if and how it would then interact with the child's profile. An interesting and innovative device is Tjacket, consisting in a wearable device that can provide deep pressure through the inflation of air bags. The deep pressure acted by the jacket is a way to release stress and anxiety, reduce sleeping problems and depression as well (Tjacket, n.d.).

Limitations. Therapists do not necessarily know *a priori* if a device will work for the specific child. Therapists need to assess performance and change the device until they find what best suits the child's needs. Generally, regular tools require user adaptation to the tool itself, which is not desirable.

Shape Memory Alloys (SMAs)

Definition. Shape Memory Alloys are a group of intermetallic alloys, which, thanks to their unique microstructure, can memorize a shape and restore it after a deformation. There are some different alloys available on the market, like Cu-Zn-Al and Cu-Al-Ni, but NiTi alloys

are more suitable for many applications (Mohd Jani et al., 2014). SMAs, contrary to the other alloys, feature two stable crystalline structures, i.e. austenite and martensite. The austenitic structure is stable at high temperature and is responsible for the memorisation of the macroscopic shape through the so called "shape setting thermal treatment". Highly symmetrical and usually a body-centered cubic structure, the austenitic structure makes the material hard and difficult to be deformed. Instead, the martensitic structure is less symmetric, yet stable at low temperatures. This structure arranges in a self-accommodating way through twinning in case of no external force acting; otherwise, it detwins, leading to large macroscopic inelastic stress (Kumar & Lagoudas, 2008).

Properties. Austenite and martensite crystalline structures let SMAs feature shape memory and superelasticity properties.

The former occurs when the alloy is deformed in its martensitic phase and then unloaded while still in such phase. The material will recover its original shape only if heated above the characteristic austenite temperature(Chauhan et al., 2015). Instead, the superelastic behaviour occurs when the material is stressed in the austenitic phase, obtaining a detwinned martensite with considerable elongation values (up to 10%) (Mohd Jani et al., 2014).

Advantages. In 1971 researchers developed SMA-based braces, making the medical the first field of application (Mohd Jani et al., 2014). Recently, many other fields, such as the automotive, fashion, aerospace and sport, among others, were tested (Patoor et al., 2006). Still, many others could be experimented, introducing competitive features given by the unique SMAs properties. In some areas SMAs were used either as active or passive actuators. In this study, this material will be used as an active actuator placed inside specifically designed valves. This innovation allows to obtain a high-performance system, compared to electromagnetic valves. In fact, it is possible to gain a significant advantage in terms of reduction of energy consumption, noise, weight and space.

The opportunity

In the panorama of existing products for autism, there's a lack of customisable products and a surplus of static devices. By exploiting the properties of SMAs, this work addressed the development of a device able to follow the growth of the children and adapt to their needs. Silence, lightness, compactness and portability are key characteristics for a device intended to interact with children with ASD.

The device (Hoyo) referred to children aged 3 to 6 years, to provide early intervention. Due to extreme sensorial accumulation in schools, the device was meant to be used in such environments, to support the school program and routine. The goal of this device was to provide the users a moment of relaxation, to let them focus and accomplish their daily tasks.

MATERIALS AND METHODS

Fundamental partner of this project was SAES Group. SAES, through the subsidiary Actuator Solutions GmbH and the partner Alfmeier Präzision SE, provided an inflating massage kit, which is currently intended for the automotive sector. The kit core technology is a specifically engineered 76 µm SMA wire produced by SAES. Starting from the peculiarity of these wires, Actuator Solutions GmbH produces innovative actuators, integrating electronics and mechatronics to obtain systems with the previously-mentioned characteristics belonging to SMAs. These unique actuators let Alfmeier Präzision SE to produce the kit that, suitably modularised and configured, is currently integrated into the seats of medium-high range cars to enable the active massage function while driving. In this work, the kit was composed of a system of valves that manage the air flux and inflatable bladders, and a pump. The entire system was controlled by a proprietary software. Hoyo was developed by continuous collection of feedback – interviewing professors, teachers and therapists – and developed up to prototyping.

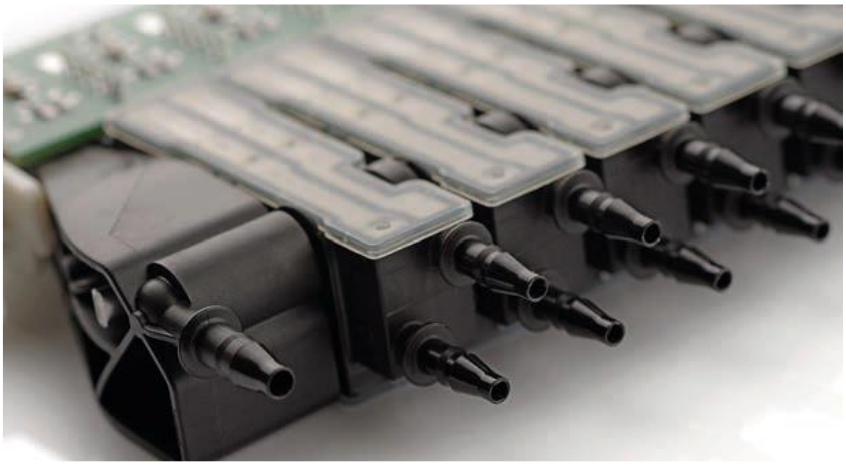

Figure 1. Set of 12 electronic valves produced by Actuator Solutions GmbH with a 76 µm SMA wire produced by SAES.

RESULTS AND DISCUSSION

Hoyo is a stuffed toy for preschool-age children that can apply a pressure on the users' chest to help them relax and release the stress accumulated to live at best their time at the kindergarten (Figure 2). The device is meant to be hugged and touched because of its softness and interchangeable fabric texture; moreover, Hoyo is also meant to give a hug which feels

comfortable for the child. The uniqueness of this system is the total customization, which is allowed by the massage inflation kit provided by SAES (Figure 3). This kit allowed to propose a device that adapted to the child's needs instead of asking the child himself to adapt to the device. Interviews with a child neuropsychiatrist highlighted how the customization should refer not only to the intensity of the pressure, but also to the area and the frequency. Moreover, thanks to the use of the smart valves, Hoyo is extremely lightweight and silent. The therapist can regulate the sensory stimulation to fit the child and update the inflation routine whenever desired or required.

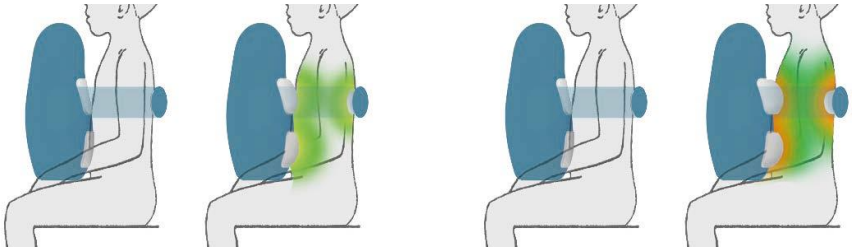

Figure 2. Visualization of the inflation possibilities and available positions.

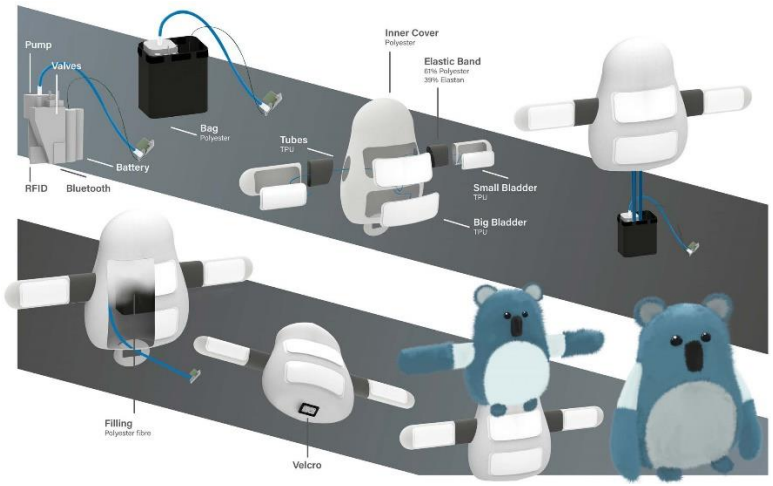

Figure 3. Components and assembly sequence.

Hoyo is also characterized by interchangeable covers. Different textures and colors were designed to suit each child's preference. Indeed, several covers help to meet the different sensory profiles of the children, who may prefer certain colors and textures over others, which may even be annoying.

Prototype design and programming (Figure 4) allowed to understand the actual interaction between the valve set and the device. Being an initial attempt, a generic routine was added. Future work may involve user testing and data validation of the design choices. An initial

examination showed the importance of fabric selection. It would be interesting to study and test fabrics with different elasticities and fillings of different density. A further step it would be to produce a more advanced prototype to be actually tested with experts in order to experimentally verify the possible benefits and any improvements to be made.

Figure 4. Hoyo

CONCLUSIONS

Hoyo is a device designed to support therapies for autism that is innovative in its technological transfer from the automotive sector. The use of SMA-based valves offered unique performances that matched the needs of a product dedicated to children with autism. In fact, SMAs properties allow to obtain an extremely silent, lightweight and reactive system, with performances that couldn't be obtained with regular materials. The result of this contamination of fields was a device meant to accompany the children as they grow, helping them to integrate into the school system and promoting a more inclusive environment. The limits of the project were in the missed opportunity of testing the device. The design of Hoyo could gain even more value through a testing phase, where feed-back from therapists, children and parents could be collected; therefore, data could confirm the actual design or highlight further improvements to be ad-dressed.

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