Engaging Children with Autism in Interaction using Haptic and Tactile Interfaces

A.Pérusseau-Lambert[1], M. Anastassova[1], M. Boukallel[1], M. Chetouani[2], O.Grynzspan[2]
1 : CEA, LIST, Sensorial and Ambient Interfaces Laboratory, 91191 – Gif-sur-Yvette CEDEX, France/ 2 : Sorbonne Universités, UPMC Univ Paris 06, IFD, 4 place Jussieu, 75252 PARIS cedex 05, France

ABSTRACT

Atypical sensori-motor reactions and social interaction difficulties are commonly reported in Autism Spectrum Disorders (ASD). In our work, we consider the possible relationship between using our sense of touch to discover our environment and the development of interaction competencies, in the particular case of ASD. For this purpose we will use two tasks: shape perception and stimming with a haptic feedback device and a tactile wearable device. The designed devices will be based on the State of the Art and advices from experts in ASD. We plan to work on the needs and skills of children on the spectrum in the lower range of intelligence scores. This article details the development of our PhD project, which aims at designing efficient and reliable haptic force feedback/tactile proprioceptive interfaces and interactions for ASD user. Preliminary results on the development of our interfaces and the design of the interaction tasks are presented as well as our specific contributions.

Keywords: Human Computer Interaction, Autism Spectrum disorders, haptic force feedback interface, tactile interface, Shape perception task, Stimming task, Social interaction, Motor skills

Index Terms: H.5 [Information interfaces and presentation]: User Interfaces – Haptic I/O -- K.4 [Computers and society]: Social Issues – Special needs

1 INTRODUCTION

Autism Spectrum Disorders (ASD) is a neurodevelopmental disorders that is present in one new-born over 160 in the World [2] This disorder is characterized by impairments in social interaction (e.g. social awareness, verbal and nonverbal communication) and repetitive, restricted behavior, interest or activities (e.g. atypical movement, play, and preoccupations with objects or topics, atypical sensory behavior) [3].Our key research question is the study of ASD individuals' motor skills when exploring a shape, in both individual and collaborative tasks. We specifically have chosen a shape recognition task involving haptic perception, because these skills may an issues for ASD low-functioning individuals'. For example, people with ASD may have difficulties with fine and gross motor skills [4], visual-motor coordination [5], motor planning [6], precision grip [7] object manipulation and visual-motor integration [8].

Moreover, sitting, rolling, crawling, prone and supine are gross motors skills often involved in imitation tasks, which may be impaired in individuals with ASD. Imitation is pivotal to human social development and altered imitation skills can compromise social competencies [9].Other skills used during social interaction may be impacted by motor issues faced by individuals with ASD (e.g. joint action[3], play activities) thus can lead to delays in social learning [10]. Our project focuses on the development of a suitable haptic interface to engage interaction between users and devices, and carry out the development with a user-centric approach.

* alix.perusseau-lambert@cea.fr

In this article, we will present our project which consist of developing haptic and tactile interfaces for a task of shape perception and a task of Stimming with the purpose of engaging children with low-functioning autism to interaction. In the section Theory we will present a scope of the related work, then we will discuss our research approach and methodology. Finally, we will give the first results of our work and the expected contributions of our project.

2 THEORY

2.1 Motors impairments and socials interaction issues

As described in the Diagnosis criteria [3], ASD individuals may present atypical sensory behavior. Studies have been mainly done in vison and auditory modalities [11]. Nevertheless, one of the primary human sense used to explore and interact with our environment is the sense of touch [12]. It gives us special information about object as texture, weight, temperature or shape [13], [14]. To reach an object, to grasp it, hold it, to feel contact pressure over our skin, displace it, we need motor skills to make our body move as we desire to. Haptic exploration involves the use of motor skills [15] to displace our body parts, reach objects, grasp them etc. For those reasons we seek to involve motors skills and haptic abilities by providing force feedback stimulation to the mechanoreceptors of the user's body joints.

2.2 Shape perception

We decided to use a haptic force feedback interface to engage children with ASD in a shape recognition task using their motors skills. Thanks to this interface we will be able to control the haptic force, as well as to reconfigure the environment according to the specificity of the task and the user. We defined our task, by searching which kind of activities could involve haptic exploration and relate to different motor deficits faced by ASD individuals. A State of the art review and several discussions with two experts in autism made us focus on a shape perception task, which requires various motor skills such as reaching an object, grasping it, and following a contour. The user will hold an end-effector mounted over our interface and; will have to explore freely the workspace. In some particular positions the interface will apply a force feedback to the user hand, blocking his movement, and thus simulating a virtual wall. We will configure the blocked position to represent the contours of a shape. When the user finishes his/her exploration, he/she will pick a figure, among a certain number of shapes displayed on a screen. The objective will be to pick a shape that matches with the haptically explored one. The workspace exploration involves user's motors skills to move the end-effector, while the application of virtual walls calls on to the use of haptic exploration skills.

2.3 Stimming

Stimming is a natural human behavior consisting on self-stimulation in order to understand one' environment and acquire self-consciousness. Nevertheless, it is associated with intellectual disabilities, and in particular with Autism Spectrum Disorder. The DSM-5 [3] includes stereotyped behavior as part of the diagnostic criteria for Autism Spectrum Disorder: "Stereotyped or repetitive speech, motor movements, or use of objects…symptoms together limit and impair everyday functioning." The fact that stimming interferes with every day activities, prevents efficient learning. In this sense, stimming in ASD differs from stimming that is observed in typical individuals. Moreover, individuals with autism may be submerge by sensorial stimulus during stimming; this is called meltdown and it can lead to self-injury [17]. Autistic stimming can have various form: sniffing or smelling people, rocking front to balk, scratching or rubbing the skin with one's hand or with another object, opening closing fists, vocalizing in the form of humming, grunting etc.….

In our work we will focus on tactile stereotypical stimming behaviors. Our approach is to develop a tactile interface helping Individuals with ASD to learn how to manage their tactile stimulation, we will details the interface and the task of Self-Stimulation later in the article the details.

2.4 Haptic/ Tactile Interfaces

Haptic force feedback devices are numerous and diverse. Sigrist & all [18] presented a review of the interfaces using augmented visual, auditory, haptic and multimodal feedback in the case of motor learning. They were investigated in the way in which haptic interactions enhance learning in different types of motor task (e.g., simple vs. complex or cyclic vs. acyclic) and for what type of population (e.g., beginner, expert; or child, adult, elderly). They mostly presented the experimental protocols and to a lesser extent the technologies used in each case. By contrast, Hayward and all's [19], reviewed a number of haptic interfaces and their properties. Hayward and all's review shows that technologies such as the Phantom Omni or the Pantograph may be suitable for the interaction task we would like to support and investigate. The Phantom Omni is a pen- or stylus-type haptic interface, for haptic exploration. There are different versions of the device, presenting various workspace and forces output specifications. These are point contact devices, and in this sense, the endpoint of the robot can be mapped to a position in the virtual environment and force feedback can be sent to the user. This technology might be suitable for our shape recognition task, by allowing movement in 2D or 3D space. However, the Phantom requires good 3D representation skills. Also, as the Phantom is based on a serial mechanism, the device elements can physically interfere [20].

The 3 degree-of-freedom (DOF) Pantograph, which is also a point contact device, is restricted to moving in a plane. It can however apply forces to the user's hand in the two planar directions [21]. Some development have been done to improve this device by adding magneto-rheological (MR) brakes and direct courant (DC) motors, transforming it into a hybrid device and strengthening its stability when displaying forces with less friction and backlash [22].Nevertheless, this device design may result in a bulky system with a limited workspace.

We would like our interface to display a programmable and tunable haptic feedback over the user hand, over a large workspace. As we would like to stimulate motor skills of the upper part of the body, the limitation of the maximum workspace must be the length of the maximum user's arm extension. Since the length can vary, we need a customizable workspace. Moreover, individuals with ASD may present atypical haptic perception. Therefore we will need an adaptable enough technology to satisfy different user needs. [23] Furthermore, individuals with ASD may also present stereotyped behaviors. Based on interviews with ASD experts, we inferred that our device has to be rigid and not easily deformable. Among the haptic interfaces presented in the literature to provide a force feedback, the magneto-rheological fluids [24] based technologies are often employed, especially in virtual reality [25]. For instance, they have been used in glove for virtual reality [26], [27] in other wearable device [28], musical keyboard [29], or with DC motor for a hybrid 1 DOF force feedback interface [30]. The Magneto-rheological fluids technology allows displaying different types of force feedback. Moreover, MR actuators have a small size. In this sense, they are easy-to-integrate.

Considering the cutaneous part of the sense of Touch [31], vibration are present everywhere in daily life: smartphone, computer, mouse, watch, subway, music, car, cats.... In our project we want to use a programmable vibro tactile actuators to help the user to tame his owns perception of vibration, his tactile perception, in a task of self-stimulation leading to interaction.

Vaucelle and all [32] have presented a multi position scarf with vibrations motors and Peltiers junctions at the extremities of the device. Nevertheless, the device was not used in a stimming task and no results with a user study were presented. It was used for asynchronized and personalized affective touch [33]

Tang and all [34] proposed a low cost tactile sleeve to potentially help individuals with autism to manage their hyper sensibility to simple contact and dynamic human touch. They based their approach on ASD interventions. No user study with individuals with ASD were presented.

3 RESEARCH APPROACH AND METHODOLOGY

3.1 Haptic Exploration Table

To implement our task of perceiving virtual walls forming the boundaries of an object, we would like to explore a new path by developing a mobile XY haptic exploration table using the magneto-rheological (MR) fluids as passive devices. In this configuration, our device may provide tunable force feedback and a customizable workspace. The use of passive actuators has often been discussed during the design phase. MR brakes are presented as more stable [35] than active actuators such as DC motor. However, they have limitations as far as transparency is concerned. To alleviate this hybrid devices, using active and passive actuators, have been developed [36]–[38] presenting stability and transparency that we would like to expect from our device. Nevertheless, they are limited in performance, workspace and application potential. [36] An and all have developed a stable 1 DOF hybrid force feedback device. However, they showed limited performances during the hybrid mode. Kwon and all [37] device is stable during the hybrid mode but they have a number of transparency issues and the working space is limited by the design of the interface.

We decided to develop the first prototype of our interface with the MR brakes and test its transparency before deciding whether we will add DC motors. DC motors can be dangerous for people with motor difficulties given that the motor can drag the user's arm or hand against her/his will, and can cause injuries. We have chosen to stimulate an exploration in the horizontal plan, to stay close to the natural position of drawing, writing or eating. This configuration also allows the users to sit and employ only the upper part of their body. The XY exploration table allows us to create a shape in 2D space, with a customizable workspace. To carry out this project, we will work with the MR-brakes developed by the Laboratory of Sensorial and Ambient Interfaces of the CEA [39].From a rehabilitation point of the view, it is important for the user to do the movement himself. Otherwise the user could lose interest in the device and; the interface would end up doing all the physical work for him. We have conceived this interface to take into account the skills and competences of each ASD user. The handle can be 3D printed and replaced to be suitable for any grip the user need to learn. Fine motor skills and grip are often deficient in user with low-functioning autism. We also have thought about adding a screen display to keep track of real time user movements, and display a game that keeps the user interest. The screen display have audio output that allow the stimulation of hearing, if needed. According to ASD expert, it is really important that the interface is adaptable to each ASD user characteristic, and that the various stimulation modalities can be used separately or together.

Another aspect of our interface, is its innovative aspect. To our knowledge, we have not find in the literature any similar interface. We have found mostly robot companion to enhance social interaction with ASD children, tablet games, smarts toys, and sensory environment.

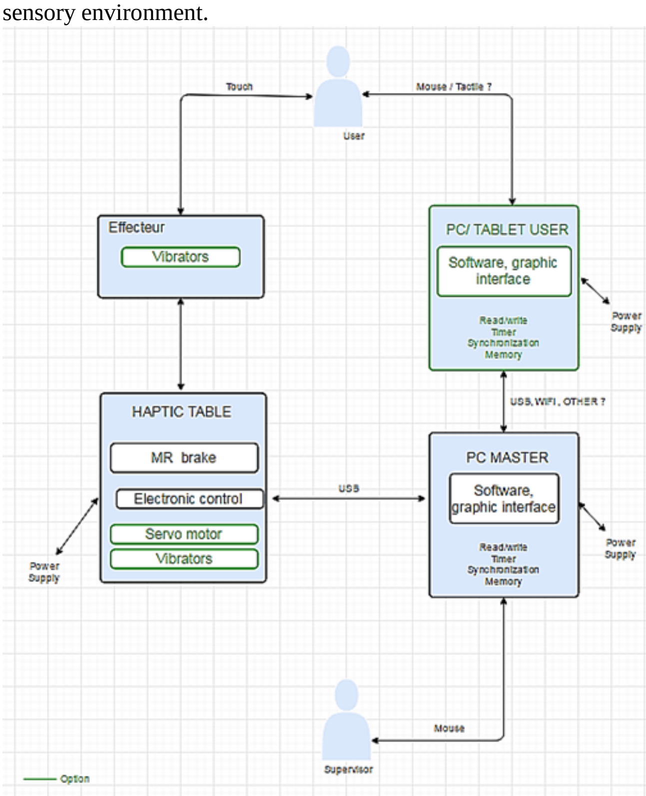

Figure 1Exploration Table overview

3.2 Tactile wearable display

Tactile mechanoreceptor for vibration, Pacini Corpuscle, are more present in the human skin, at the finger's pulp, palm, tong, face or belly[40]. Psychophysical experiment found that the Pacini Corpuscle frequencies answer range's is between 70 and 1000Hz.

Nevertheless, each individuals with ASD have a different sensibilities, for example one will like the wind caressing his forearm skin and other one will react badly. Considering those reasons we have decided to create a multi position wearable interface using tunable vibration actuators.

Our interface is made of soft synthetic tissues as Lycra, with band of scratch scotch over one face. Our vibration actuators are isolated by Silicon cover and can be fixed by scratch scotch over the interface. We have chosen two kind of LRA actuators, one with 235Hz of frequencies resonant and one with 200 Hz frequencies resonant. The particularity of those actuators is the decoupling between the frequency and the amplitude, allowing complex vibration.

4 Results

Our first result is the computer aided design of our exploration table device (Figure2), which helped us during the conception phase. The development of the device will be finished at the end of the year. The experimental situation (i.e. individual or collaborative, one or two devices) is still to be defined. However, our ultimate goal is to enhance interaction between two users (with at least one with ASD) using two communicating interfaces. Nevertheless we are also exploring the possibility of using an interface and a tablet. Considering multimodal interaction, we are aware that this may be a problem with autistic individuals. Nevertheless, we will need a screen to display the response figure, and perhaps the real-time track of the end effector displacement over the workspace.

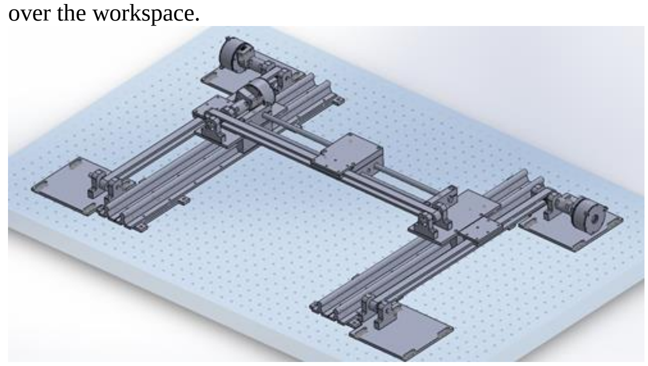

Figure 2 Haptic Exploration Table CAD's

Regarding our vibration interface, the conception phase is in progress. We have to define the experimentation protocol and the interaction tasks. We plan to use one device per user and pursue the development with advices from user family and caregivers.

We have already contacted medical professionals in the Pitiée Salpêtrière Hospital in Paris and an association. They have already expressed their interest in participating in the project. We would like to involve them in the project using a participative design approach. We are also working on a State of the Art review on tactile interfaces for Autism. Moreover our scientific contribution is the use of the MR brakes in an innovative design and the development of an interface assisting shape perception for Autism Spectrum individuals.

5 Conclusion

In this extended abstract, we have described some of the motor and social interaction difficulties faced by Individuals with ASD but also their behavioral issues. We presented a number of existing haptic and tactile interfaces potentially useful for our research. We have also identified a research goal: engaging children with low functioning autism in an interactive activity based on shape recognition task using a haptic feedback device, and/or based on a stimming task using a vibrotactile wearable interface.

References

[1] 'L'autisme en chiffres clés', *Vaincre l'autisme*.
[2] World Health Organization, 'Troubles du spectre autistique'. Centre des médias, Février-2016.
[3] A. Speaks, 'DSM-5 diagnostic criteria', *Retrieved Sept.*, vol. 15, p. 2013, 2013.
[4] K. Caro, M. Tentori, A. I. Martinez-Garcia, and I. Zavala-Ibarra, 'FroggyBobby: An exergame to support children with motor

problems practicing motor coordination exercises during therapeutic interventions', *Comput. Hum. Behav.*, Jun. 2015.

[5] D. Dewey, M. Cantell, and S. G. Crawford, 'Motor and gestural performance in children with autism spectrum disorders, developmental coordination disorder, and/or attention deficit hyperactivity disorder', *J. Int. Neuropsychol. Soc.*, vol. 13, no. 2, Mar. 2007.

[6] C. Hughes, 'Brief report: Planning problems in autism at the level of motor control', *J. Autism Dev. Disord.*, vol. 26, no. 1, pp. 99–107, 1996.

[7] F. J. David, G. T. Baranek, C. A. Giuliani, V. S. Mercer, M. D. Poe, and D. E. Thorpe, 'A Pilot Study: Coordination of Precision Grip in Children and Adolescents with High Functioning Autism':, *Pediatr. Phys. Ther.*, vol. 21, no. 2, pp. 205–211, 2009.

[8] B. Provost, S. Heimerl, and B. R. Lopez, 'Levels of Gross and Fine Motor Development in Young Children with Autism Spectrum Disorder', *Phys. Occup. Ther. Pediatr.*, vol. 27, no. 3, pp. 21–36, Jan. 2007.

[9] H. D. Pusponegoro, P. Efar, Soedjatmiko, A. Soebadi, A. Firmansyah, H.-J. Chen, and K.-L. Hung, 'Gross Motor Profile and Its Association with Socialization Skills in Children with Autism Spectrum Disorders', *Pediatr. Neonatol.*, Apr. 2016.

[10] M. Lloyd, M. MacDonald, and C. Lord, 'Motor skills of toddlers with autism spectrum disorders', *Autism*, vol. 17, no. 2, pp. 133–146, Mar. 2013.

[11] J. Case-Smith, L. L. Weaver, and M. A. Fristad, 'A systematic review of sensory processing interventions for children with autism spectrum disorders', *Autism*, p. 1362361313517762, 2014.

[12] R. Jacobson D., 'Haptic or Touch-based Knowledge', *Int. Encycl. Hum. Geogr.*, pp. 13–18, 2009.

[13] C. Sann and A. Streri, 'Perception of object shape and texture in human newborns: evidence from cross-modal transfer tasks', *Dev. Sci.*, vol. 10, no. 3, pp. 399–410, May 2007.

[14] Morton A. Heller and W. Schiff, *The Psychology of Touch*. Lawrence Erlbaum Associates, 1991.

[15] M. Gori, V. Squeri, A. Sciutti, L. Masia, G. Sandini, and J. Konczak, 'Motor commands in children interfere with their haptic perception of objects', *Exp. Brain Res.*, vol. 223, no. 1, pp. 149–157, Nov. 2012.

[16] S. Edelson, 'Self-stimularoy Behavior', *Autism Research Institut*. .

[17] S. Edelson, 'Self-injury', *Autism Research Institut*. .

[18] R. Sigrist, G. Rauter, R. Riener, and P. Wolf, 'Augmented visual, auditory, haptic, and multimodal feedback in motor learning: A review', *Psychon. Bull. Rev.*, vol. 20, no. 1, pp. 21–53, Feb. 2013.

[19] V. Hayward, O. R. Astley, M. Cruz-Hernandez, D. Grant, and G. Robles-De-La-Torre, 'Haptic interfaces and devices', *Sens. Rev.*, vol. 24, no. 1, pp. 16–29, Mar. 2004.

[20] S. D. Laycock and A. M. Day, 'Recent Developments and Applications of Haptic Devices', *Comput. Graph. Forum*, vol. 22, no. 2, pp. 117–132, Jun. 2003.

[21] 'The Pantograph Mk-II , a haptic instrument.pdf'. .

[22] Jinung An and D.-S. Kwon, 'Five-bar Linkage Haptic Device with DC Motors and MR Brakes', *J. Intell. Mater. Syst. Struct.*, vol. 20, no. 1, pp. 97–107, Jan. 2009.

[23] N. A. J. Puts, E. L. Wodka, M. Tommerdahl, S. H. Mostofsky, and R. A. E. Edden, 'Impaired tactile processing in children with autism spectrum disorder', *J. Neurophysiol.*, vol. 111, no. 9, pp. 1803–1811, May 2014.

[24] G. Bossis, S. Lacis, A. Meunier, and O. Volkova, 'Magnetorheological fluids', *J. Magn. Magn. Mater.*, vol. 252, pp. 224–228, Nov. 2002.

[25] E. Brau, 'Contribution à l'étude d'interfaces portables à retour d'efforts pour la réalité virtuelle', 2005.

[26] J. Blake and H. B. Gurocak, 'Haptic Glove With MR Brakes for Virtual Reality', *IEEEASME Trans. Mechatron.*, vol. 14, no. 5, pp. 606–615, Oct. 2009.

[27] S. H. Winter and M. Bouzit, 'Use of Magnetorheological Fluid in a Force Feedback Glove', *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 15, no. 1, pp. 2–8, Mar. 2007.

[28] I. Farkhatdinov, A. Garnier, and E. Burdet, 'Development and evaluation of a portable MR compatible haptic interface for human motor control', in *World Haptics Conference (WHC), 2015 IEEE*, 2015, pp. 196–201.

[29] J. Lozada, 'Modélisation, contrôle haptique et nouvelles réalisations de claviers musicaux', Automatique/Robotique, Ecole Polytechnique X, 2007.

[30] C. Rossa, J. Lozada, and A. Micaelli, 'A new hybrid actuator approach for force-feedback devices', 2012, pp. 4054–4059.

[31] I. Morrison, L. S. Löken, and H. Olausson, 'The skin as a social organ', *Exp. Brain Res.*, vol. 204, no. 3, pp. 305–314, Jul. 2010.

[32] C. Vaucelle, L. Bonanni, and H. Ishii, 'Design of haptic interfaces for therapy', in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, 2009, pp. 467–470.

[33] L. Bonanni, C. Vaucelle, J. Lieberman, and O. Zuckerman, 'TapTap: a haptic wearable for asynchronous distributed touch therapy', in *CHI'06 extended abstracts on Human factors in computing systems*, 2006, pp. 580–585.

[34] F. Tang, R. P. McMahan, and T. T. Allen, 'Development of a low-cost tactile sleeve for autism intervention', in *Haptic, Audio and Visual Environments and Games (HAVE), 2014 IEEE International Symposium on*, 2014, pp. 35–40.

[35] C. Rossa, J. Lozada, and A. Micaelli, 'Stable haptic interaction using passive and active actuators', 2013, pp. 2386–2392.

[36] Jinung An and Dong-soo Kwon, 'Haptic experimentation on a hybrid active/passive force feedback device', 2002, vol. 4, pp. 4217–4222.

[37] T.-B. Kwon and J.-B. Song, 'Force display using a hybrid haptic device composed of motors and brakes', *Mechatronics*, vol. 16, no. 5, pp. 249–257, Jun. 2006.

[38] Yun-Joo Nam and Myeong-Kwan Park, 'A hybrid haptic device for wide-ranged force reflection and improved transparency', 2007, pp. 1015–1020.

[39] C. ROSSA, 'L'UNIVERSITÉ PIERRE ET MARIE CURIE', Université Pierre et Marie Curie, 2013.

[40] M. Benali-Khoudja, 'Thèse sur le rendu tactile, Une étude physiologique et un etat de l'art technologique sur le rendu tactile', Fontenay-aux-roses, 2002.