The Role of Haptics in Pediatric Rehabilitation

Ellyana Sungkar
Department of Physical Medicine and Rehabilitation, Dr. Hasan Sadikin General Hospital,
Faculty of Medicine, University of Padjadjaran, Bandung, Indonesia.

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Abstract: Haptic is derived to the Greek word that means the sense of touch. Haptic is consisted of kinesthetic and tactile. Areas of Haptics are divided into machine, computer and human haptics. In haptic technology, human sense of touch have coupled with computer and used mainly in creating and controlling virtual objects. Haptics technology can be used to train people for task requiring hand-eye coordination. Haptic interface is included as haptics technology, it is a system that allows a human to interact with a computer through bodily sensations and movements. Haptics in medical rehabilitation has a primary purpose to recover or improve the impairments. Haptics is proven to be beneficial in medical rehabilitation for disability children to improve their haptic perception development, overall cognitive and social interaction in the long term. In conclusion, Movement disorders in children are causally and clinically heterogeneous and present in a challenging developmental contexts. The haptics technology should be categorized as the complement of conventional therapy in pediatric rehabilitation that motivating, allows for high repetition therapy, and improves outcomes recording and feedback.

1 INTRODUCTION

Rehabilitation science has recently shown that intense and longer physical rehabilitation trough repeating movement will benefit even chronic patients. Robots are ideal in this kind of situation, because they are not only can train patients for the required long duration without tiring (unlike human therapists), but also lead to a reduction in labor costs (Burdea,2010). Basic development theory of robotic rehabilitation is the Haptic Technology.

The meaning of Haptic Technology is the technology of virtually touching and feeling the objects and forces. It is a new emerging technology from the area of virtual reality that allows computer users to use their sense of touch to feel three-dimensional virtual objects using haptic devices (D. Naga, 2013).

Haptic is derived to the Greek word that means the sense of touch. The word entered English in the late 19th century as medical synonym of tactile (ISO, 2011). The development of haptic in human has been started since an early age and it is important because it enables humans to perform a wide variety of exploration and manipulation task. Haptic is consisted of kinesthetics and tactile receptors (Vera, 2016). The tactile aspect refers to the static and information received from the nerve terminals of the skin. Kinesthetic refers to the dynamic aspects of interaction with the object (Carter J).

There is also an idea which is developed by the use of kinesthetic sense through receptors located in the muscles, joints and tendons. These receptors also allow the person to feel the force/torques exercised upon contact with a body and to know where this person's hand within the space, even with his eyes closed.(Coles, 2011) Tactile receptors such as pressure, shear, and vibration, are sensed by specialized sensory end organs known as mechanoreceptors that are embedded in the skin.

The Cutaneous mechanoreceptors are localized in the various layers of the skin where they can detect a wide range of mechanical stimuli, including light brush, stretch, vibration and noxious pressure by touch.(Roudaut Y, 2012)

Touch itself is the detection of mechanical stimulus impacting the skin, including innocuous and noxious mechanical stimuli. It is a necessary sense for the survival and the development of mam-

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mals and human.(Roudaut Y, 2012) Touch is a compound sense because it represents different tactile qualities, namely, vibration, shape, texture, pleasure and pain, with different discriminative performances.

Haptic also affected by mechanoreceptors. The aptitude of mechanoreceptors is to detect mechanical cues relies on the presence of mechano-transducer ion channels that swiftly transform mechanical forces into electrical signals and depolarize the receptive field. This local depolarization, called receptor potential, can generate action potentials that promulgate toward the central nervous system.

There are four main functions that contributing in human haptic perception: somatosensory sensation, manual and in-hand manipulation, cognition and vision (ISO, 2011).

The role of somatosensory sensation in haptic reaction is to developed a body scheme to help the interpretation of object's spatial properties, then to manage manual and in hand manipulation during active touch. The role of Manual and in hand manipulation is to generate exploratory actions from the information from motor command, produces tactile feedback needed for object acknowledgment. The role of cognition is to understand and acknowledge the world to develop the inquiry of environment. The Role of vision is to help learning and recognize object characteristics (ISO, 2011). All of them above are use in haptic extrimity rehabilitation device.

The extrimity rehabilitation are devided in two two groups the upper one and the lower one. The upper extremity rehabilitation focus to improving the patient's shoulder, elbow, wrist, and fingers and the patient's activities of daily living. Lower extremity training focus to exercising the patient's knee, ankle, foot, or the whole leg in walking. Robots have been used in physical rehabilitation for more than a decade, and they focused all of the above areas of therapy. A Major goal in point of view of rehabilitation is to help children with movement disorders in understanding the limits of the human body and help them interact in the physical environment. (B. Smits-Engelsman, 2013)

2 DISCUSSION

2.1 Human Haptic System

Human Haptic system is consist of the human sense of touch include a closed loop system of receptors sensing, transmitting messages to and from the brain, thinking, and manipulating. Haptic interfaces needs electromechanical and computer-based system. (SPIE)

2.1.1 Areas Of Haptic

Basically, a haptic system formed of two parts, namely, the human part and the machine part. Both the systems include Sensor, processors, and Actuator control circuitry. A sensor is accountable for sensing the haptic information exerted by the user on a certain object and sending it to haptic rendering module. The actuator will read the haptics data sent by the rendering module and transform this information into a form of perceivable by human beings.(Moradabad, 2014)

2.1.2 Haptics Interfaces

Haptics interface system will allow human to interact with a computer trough bodily sensation and movements. Haptic Interface uses fully duplex channel, you can both transmit and receive information simultaneously.(Technopedia) There are two types of haptic interfaces the first one is tactile and the second one is force feedback technology Haptic Interfaces.(Cohen YB)

Haptic Interface Scan is divided into two main groups from the point of view of the sensation they can create at the moment of contact with the part of the body, those which create kinesthetic stimuli and those which create tactile stimuli.(Bilgincan, 2010)

2.2 Tactile Technology

Tactile Technology known as touch screen, is a device that is responsible of stimulating the nerve receptors of touch to display, in the interaction with human skin. Tactile will feel vibration and pressure.

Vibration and pressure are the familiar mechanical receptors stimulated in Tactile Technology.(Garcia Hernandez N, 2014)

There are some parameters used in tactile technology and contribute in tactile feedback such as temperature, coarseness, shape, and texture.(Sato K, 2010)

Tactile feedback in the tips of fingers can help in increasing the degree of immersion of the user in virtual environment.(Zasulich, 2016)

There have also been a progress using tactile technology called by electro cutaneous interfaces. It uses the principle of electrostimulation of the nerve endings on the surface of the skin. These interfaces tend to be small, substantial, efficient and there are free of mechanic resonance.

2.3 Force Feedback Technology

The kinesthetic or force feedback Haptic Interfaces (HIs) demonstrates behaviors indistinguishable to robot mechanisms with which the user interacts and exchanges mechanical energy.

The way of the kinesthetic HIs are mechanically built under two great categories related to the way the force feedback applied (via links and tension elements). The first are compact in size and portable, while the other one are large. The most commonly used interface is the linked element one, where the rigid elements are linked to each other until the final effector are activated by electric engines located at the base of the device.(Jose-LuisRodriguez, 2012) The second interface group has the transference of force through tension cables, given the exerted force via motors in continuous and its movement is graduated by movement via digital decoders connected to them.(Sato K, 2010)

Tabel 1: Summary of Technologies Applied in Kinesthetic Haptic Interfaces(Zasulich, 2016)

Technology	Actuator Mechanism	Contact Zone
Pneumatic	Piston	Direct support to extremities
Hydratic	Piston	Direct support to extremities
Electric	DC motor directly connected or by cables and pulleys	Arm, hand wrist or fingers
Magnetic	Lorentz principle levitation mechanism	Hand, fingers

In this second group, a haptic exoskeleton is also established. This is another type of interface for the transference of force that was developed some time back and is based on tension cables by motors and position decoders. The support for these devices can be on the floor, wall, desk or on the user's body and can attain more than six degrees of freedom in the workspace.(Sabater J.M, 2010)

2.4 Haptic Manipulation Strategies In Infants

There are several development in infant haptic and motoric reflex. We all know that baby from 2 – 3 months will experiencing oral exploration, grasping, hand mouth coordination. Arm and hand movement develops fast during this stage. What was once a tight, clenched fist is now an open hand grabbing and batting object. Babies explore their hands by bringing them in front of their face and putting them in their mouths.(John M)

Baby from 4 to 6 months old will have a vision reflex as the initial exploration modality, and fingering behaviour.

Baby from 7 to 9 months old will bang the hard objects, and can hold fingered textured object. Baby from 9 to 12 months old can turn and rotate the object using their both hands.(Mersch)

In the first months of baby life, they try to adjust manipulative behavior to objects characteristics (rigidity, texture, shape, weight, movable part, etc) and when they get older the haptic and motor skill will develop and help baby to explore a variety surface.(Ardiel EL, 2010)

2.5 Evaluation Of Haptic Perception In Infant

As children grow, they intuitively learn more sophisticated manual activities as a result of proceed hand functions.

In children with disabilities who cannot reach, grasp and directly manipulate objects due to their physical limitations, perceptual development can be delayed compared with typically developing children of the same age.(Nooshin J, 2016)

There is no standardized assessments to assess haptic perception in children with disabilities, that's why there are approach about the developmental assessment coupled with criteria of referenced procedures and process oriented to coup with that issue.

The standardized assessment only about to examine accuracy of haptic perception. The non-standardized assessment is to examine the way the child approaches a task, the effect of task on their nature haptic style / strategy.

2.6 The Use Of Haptic For Human

The results perceived a remarkably strong case for haptics' ability to influence appeal and interest for human use. Many of the study's subjects indicated content haptics were more approachable and persuasive. They also know that haptics is adding to their positive memory of the experience. Participants across a wide range of demographics, ages, and technology affinities rated their experience and the products they observed with haptics at 18% higher when it came to quality of experience. The study also showed that an 11% increase in brand value, and an average 40% increase of condition recall compared to non-haptic experiences. The diversification and depth of additional insights provided data points on how the human brain reacts to general and specific levels of tactile exposure. In The end, it proved that applying haptics is highly effective at transfer a user's attention from one experience to a more emotionally compelling environment. Haptics can make greater the visual and auditory user's experience by creating sensory immersion in rich and compelling tactile effects that are fully showed in video, virtual reality, augmented reality, and many other formats. Touch and sensory experiences are a major part of the human brain, and the sense of touch-enabled by haptic technology produces a meaningful and lasting sense of experiential emotional reality for the brain. The pragmatic and lasting effects of haptic design, confirm that it creates memorable and impression-based interactions that not only influence our reactions but also deeply connect us emotionally to the digital experience of the moment.(Immersion)

Table 2 : The benefit haptics for human

Haptics Influence recognition and perception	11% (Brand Recognition) + 18% (perception quality)
Haptics are an effective mode of persuasion	8% higher motivation and engagement responses
Haptics Intensity emotion	The frequency and density of haptics affect the level of emotional response. In a study, haptics impacted arousal but an average of 6% compared to standard condition
Haptics Improve Memory	High motivation and arousal both indicate an optimal level of mental effort, which facilitate memory encoding and overall desirability

2.7 Haptic In Medical Rehabilitation

The problem of rehabilitation is to motivate patients to exercise consistently, so as to achieve the goals of rehabilitation, haptic can be used when treating children with movement disorders.

Haptic feedback used in physical therapy is different from that provided to able-bodied users due to the force and motor coordination deficits of the disabled, because it's usually in the form of resistive forces which include graphics and other simulation modalities (Burdea,2010).

Haptic makes more movement therapy of body limbs by the use of control interfaces. It can provide a more intensive and effective therapy that need less mediation of a therapist compared with one-on to one therapies. (Gokeler A, 2014)

The primary motive of haptic use in medical rehabilitation is to have recovery or improvement of impairment. There are several haptic that is used in rehabilitation such as haptic exotendon for hand rehabilitation, customized haptic interfaces for blind people in computer interactions, customized haptic joystick for motor and cognitive impairment.Nooshin J, 2016)

Recent recommendations affirm that there are two aspects that play a central role in haptic feedback for physical rehabilitation, assistive haptics and disturbances(Burdea,2010).

Assistive Haptics is used by the patient who had a neurological disorder (stroke, spinal injury, cerebral palsy). In rehabilitative assistive technologies, the primary purpose of intervention is recovery or improvement of impairment.

Haptic disturbances are effects overlaid in the simulation in order to increase therapy difficulty or induce desired after effects. For example in the Rutgers Ankle CP which is one of haptic devices from the Rutgers Physical Rehabilitation Institute, air turbulence was simulated when piloting the airplane during a storm by oscillating the Rutgers Ankle in the horizontal plane. Tests showed that patients gradually learned to cope with these haptic disturbances, eventually being able to clear 100% of the target hoops. This is indicative of improved ankle control (Burdea,2010).

2.8 Haptic Technology In Medical Setting

In multimodal haptic guidance systems in medical setting have been accompanied by visual and/or auditory sensory information to enhance the perception and task performance of people with disabilities. (Jafari N, 2016)

This haptic guidance system is used in several devices. For example that is use in Serious Games (SG) based therapies for Upper limb. The function of this device is to optimize neuro-rehabilitation in CP children. It increase engagement and provide rich, congruent multi-sensory feedback during virtual interaction.(Bortone, 2016)

Providing the haptic feedback in a virtual environment appears to be a feasible approach to improve cerebral palsy children's handwriting skills.(Choi KS, 2011)

The earliest applications of haptics in upper extremity rehabilitation is the MIT MANUS one of the commercial robotic for upper extremity that was released at the Burke Rehabilitation Hospital, NY 1994. The patient rests their forearm on a special support with safety coupling that detaches in case of excessive forces, then the patient is strapped in a chair in order to prevent compensatory torso leaning and faces a monoscopic display controlled by a PC (Burdea,2010).

After The MIT MANUS there is a development of prototype called The Rutgers Master II Glove only weighs about 100 grams. The Rutgers Master II has an exoskeleton that provides one degree of force feedback per finger. The glove uses a direct-drive configuration and compressed air, so that each fingertip is resisted in flexion with up to 16 N force. This Glove is faster and easier than the previous one(Burdea,2010).

While robots for upper extremity rehabilitation have existed, those used to train the patient's walking and ankle control are more infrequent. The robots for lower extremity uses the same treadmill and Body Weight Support approach, but adds a pair of leg exoskeleton robots, which assist the gait cycle with speeds up to about 3 km/h(Burdea,2010).

There is also a robotic ankle therapy for children with CP, that is proved to improve plantar flexor and dorsi flexor ROM, strength, spasticity, mobility, balance (Paediatric Balance Scale), and Selective Control Assessment of the Lower Extremity (SCALE).(Moulton S, 2014)

For children with Down syndrome and developmental disabilities, there is a commercial prototype of a multimodal guidance system called a PHANToM interface. It uses haptic guidance to assist the user's hand movements in sketching a template shape by tracing its contours in a virtual environment. Then, the sketched shape was printed on a piece of foam and haptic feedback assisted to cut it out using a hot wire tool connected to the PHANToM device. This device equipped with an audio feedback related to the hand's velocity and position. Participants' precision of operation was assessed before and after being guided by sound and haptic feedback.(Covarrubias M, 2011)

Using all of the robotic and haptic devices can make a possibility that children with disabilities may experience improving haptic perception development, potentially leading to improved overall cognitive and social interaction in the long term.(Atashzar SE, 2017)

2.9 The Downsides Of Haptics

There are some of the disadvantages of the haptic technology such as higher cost, complex in nature, large weight and size, crude experience, requires advance design.(Mathur P, 2014)

3 CONCLUSIONS

Movement disorders in children are causally and clinically heterogeneous and present in a challenging developmental context.

The patients were able to accomplish and motivated trough rehabilitation session with the support from haptic use. Haptic help increase the therapy dosage and reduce the supervision and lead us to improve cost benefit profiles.

The haptic technology should be categorized as the complement of conventional therapy in pediatric rehabilitation that motivating, allows for high repetition therapy, and improves outcomes recording and feedback. Intensive rehabilitation is necessary for improving motor function in children with movement disorders.

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