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Understanding the Role of Haptic based Assistive Technologies for Rehabilitation of Divyangjan: A Review Study

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Abstract—
Purpose: *The aim of the present study was to understand the usage of tactile sense for rehabilitation purposes. The term 'Haptics' used in the field of medical rehabilitative technology traces its roots to the Greek word Hapticos meaning 'to touch'. Haptics involves a bi-directional sensory pathway involving the flow of sensory data between a human and the environment in which he is acting. It allows recognition of objects through the sense of touch based manipulation and exploration often employed by persons with visual impairment which allows them to recognize objects without the use of sight. Children with disabilities show developmental delays which often interferes with the development of fine and gross motor skills thereby adversely impacting haptic development. Method: The present study utilizes content analysis for performing in-depth and extensive review of literature related to Haptics and its role in rehabilitative sciences. Results: The systematic review reveals extensive use of 'haptic based rehabilitation devices and assistive technologies' in disabilities such as 1) use of haptic sensors in joysticks for controlling wheelchair movement among persons with loco motor impairment, 2) use of haptic technologies in rehabilitation of hand impairments for stroke patients, 3) use of haptic interface in computer applications for persons with visual impairment, 4) use of haptic sensors in robots, 5) use of haptics for communication among individuals with sensory impairments especially deaf-blind. The findings further reveal the potential of haptic based assistive and rehabilitative technologies towards improvement in tactile perception and sensations among children with disabilities (Divyangjan) thereby helping in development of their sensory and cognitive functioning. Such technologies also have great potential to act as need based therapeutic approaches for such children in future.*

Keywords: *Haptics, Rehabilitative Technologies, Assistive Technologies, Persons with disabilities.*

1. INTRODUCTION

According to Jafari et al. (2016) the word 'Haptics' traces its origin from the Greek words *Hapteshai* and *Haptikos* meaning 'to touch' [8]. Haptic based exploration involves both kinesthetic and direct tactile feedback. Through such a bidirectional sensory feedback mechanism the individual gains a lot of information about the environment in which he is acting without the use of sight.

According to Abdelkader (n.d.) 'haptic' is a broad term which refers to a combination of three senses-tactile, proprio-receptive and kinesthetic. Haptic feedback can play a potential role in rehabilitation of persons with disabilities [1]. The development of this sensory mechanism occurs in early childhood stage, however in children with special needs, it may be delayed. Manipulative and cognitive play can contribute to haptic based perceptual development as shown in previous research studies. Direct handling and manipulation of an object makes use of the sense of 'touch' which reveals certain characteristics of the object as mentioned below:

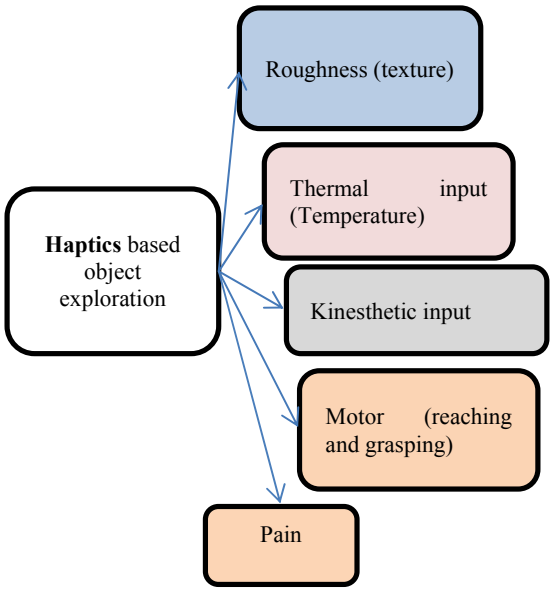

Figure 1: Object exploration – Haptic based features

The sense of touch helps us to communicate closely with our surroundings. According to Maria Montessori, senses are our gateways of knowledge; the sense of touch allows us to feel, identify and relate with the objects in our immediate

environment. According to scientific studies, skin is the largest organ and we receive various sensory inputs through our skin-pressure, thermal, texture and pain. According to Study-Body-Language.com, touch is a human mechanism to feel reality, feel comforted and to be close to our surroundings [5].

Touch varies according to the level of physical intimacy such as social/professional touch which is polite such as light handshake, light kiss; friendship based touch which is filled with warmth such as hugging etc. The type and nature of touch can reveal the nature of relationship and human bonding such as sympathy, empathy, care, concern and love for fellow beings [4]. Hence 'haptics' plays an important role in human communication and rehabilitative engineering.

RESEARCH METHODOLOGY

Research Objectives: The following objectives have been framed for the study:

- To understand the nature, concept and meaning of 'haptics'.
- To find out the up-to-date application of haptics in rehabilitation of *Divyangjan.*

The present study utilizes content analysis method to review the unique applications of haptic based assistive technology for Divyangjan. The in-depth and extensive review of literature is directed for evidences of haptic based applications in the last three decades (1990-2019) have been done by analyzing secondary sources of data which includes books, printed articles (both online and offline). The key words used for the search includes: haptics, Divyangjan, tactile exploration, rehabilitation, haptics based assistive devices.

The secondary sources of data/repositories considered for the search includes both national and international sources as seen in Table 1.

Table 1: Secondary sources of Data

National	National Digital Library (NDL)
	Shodhganga
	Shodhgangotri
International	SAGE
	ERIC
	IEEE Explorer
	NCBI

FINDINGS

Applications of Haptic Technology in assistive and rehabilitative technology

(1) Use of haptics for persons with Visual Impairment

The first use of haptics in rehabilitation of PwDs was reported in the 19th century for persons with visual impairment in the form of Braille reading and writing. Persons with blindness rely on tactile feedback in absence of visual sense. The refreshable braille displays are modern adaptations of haptics based software [1].

Meers et al. (2005) reported the development of wearable electro-stimulation gloves for users with visual impairment which help in navigation and obstacle avoidance in crowded places such as car parks, campus etc [9].

Tang & Beebe (2006) developed a haptic based oral tactile mouthpiece which acts as an electro-tactile display for delivering basic navigation directional cues to the visually challenged [11].

(2) Use of haptic interfaces for children with disabilities

'Haptic interfaces' are promoting rehabilitation of children with disabilities by providing the missing haptic feedback through assistive robotic and other exploration based devices thereby providing the stimulation of sense of touch. It allows persons with special needs (Divyangjan) to receive the same sensory stimulations of the object which unimpaired kinesthetic and tactile manipulation provides such as object texture, thermal properties etc. [8].

Holloway et. al. (2019) reports the underutilization of haptic feedback in mobile usage among persons with special needs. Advanced hapticsutilizing a variety of vibrations (electro-vibrations, ultra-sonic vibrations, crystal elastomers etc.) can complement the graphical user interface allowing dynamic human machine interaction [7].

(3) Use of haptics for persons with Motor Disability

Haptics based interface can be used in joysticks (called *force feedback joysticks*) to promote better wheelchair control for persons with motor impairments and stroke patients who often lose haptic feedback. It can also be used in operating mobile phones and other such telecommunication devices which rely on the sense of touch [1].

Haptic based prosthesis can also be used to aid persons who have lost the use of fingers which have lots of mechanoreceptors. Such upper limb haptic based prosthesis allow greater grasp, restoration of pressure, grip and higher manipulative ability. Lower limb prosthetics based on haptics provide vibratory feedback which lead to improvement in gait, balance and posture.

Rivera & DeSouza (2013) mention the use of electromyographic (EMG)- haptic and gesture-based based assistive devices for people with motor disabilities allowing them the usage of ICT devices and wheelchairs.

(4) Use of haptic feedback mechanisms for neurological patients

Haptic feedback is often lost or distorted in patients with neurological diseases (stroke, Parkinson's disease, spinal cord injury, and peripheral neuropathy) leading to limitations in routine functioning and uncontrolled motor actions. Artificial haptic feedback through vibro-tactile feedback mechanisms can play an important role in regaining lost motor control and guide limb movements [6].

(5) Use of haptics for persons with Hearing Impairment

Tactile vocoders are haptic based solution for those with hearing impairment and are based on the fundamental s of tactile cues used by the hearing impaired (fingerspelling, lip reading, or Tadoma). This device analyzes the frequency of incoming auditory signals and displays spectral information as stimulation on the skin [2].

Table 2: Haptic based rehabilitation solutions for Divyangjan

Nature of Disability	Haptic based rehabilitative technology	Reviewed literature
Persons with Visual Impairment	Braille,	Abdelkader, n.d.).
	Wearable haptics-electro-stimulation gloves	Meers et al. (2005)
	oral tactile mouthpiece	Tang & Beebe (2006)
Persons with Hearing Impairment	Tactile vocoders	Bernstein et. al., 1991
Persons with Motor Impairments	force feedback joysticks	Abdelkader (n.d.).
	Haptic based prosthesis	
	EMG based haptic devices	Rivera & DeSouza (2013)
Persons with Neurological disorders	vibro-tactile feedback	Hewer, 1990
Haptic based interfaces for children	assistive robotic and other exploration based devices	Jafari et. al., 2016
	Advanced haptic based Mobile interface	Holloway, 2019

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