DESIGN APPROACH TO REHABILITATION: DEVELOPING THERAPY ASSISTIVE PRODUCTS FOR CHILDREN WITH HEMIPLEGIC CEREBRAL PALSY
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Cerebral Palsy; rehabilitation; design intervention; co-design; multidisciplinary; product design.

Abstract
Therapy plays an important role in rehabilitation of children suffering from physical disabilities. Disability conditions like Hemiplegic Cerebral Palsy require vigorous therapy measures, which could be unappealing to children. Using therapy assistive products for rehabilitation can make therapy activities engaging and appealing to children and yield effective outcomes. However, there is limited availability of context based therapy assistive products, which are engaging, and appealing to children suffering from Hemiplegic Cerebral Palsy. This study explores how design methodology can be used to develop therapy assistive products for rehabilitation of children with disability. The study is based on developing a set of therapy assistive products to improve the hand-skills of children with Hemiplegic Cerebral Palsy. Developing therapy assistive products require comprehensive understanding of therapeutic aspects, design aspects and careful integration of the two disciplines. Hence, practicing multidisciplinary and participatory design approaches in the design process is imperative. Usability of therapy assistive products are highly impactful in nature, and therefore an iterative process of prototyping, testing, receiving constructive feedback and developing the products based on feedback should be adopted to achieve feasible and functional outcomes.

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INTRODUCTION

Globally, the prevalence of disability among children aged 0–14 years is 93 million (5.1%) with 13 million (0.7%) children experiencing severe difficulty disabilities (World Health Organization, 2011). Among various conditions that lead to disability, Cerebral Palsy is one of the most common impairments that cause disability in children. Estimated figures indicate that 1.5 to 2.5 children per 1000 live births suffer from Cerebral Palsy (Gupta & Appleton, 2001). Cerebral Palsy is a group of motor-neuron diseases that occur pre-natal, during birth or early stages of development of infants. According to the topographical classification, there are three main forms of Cerebral Palsy as quadriplegia, diplegia and hemiplegia. In quadriplegia, both upper extremity and lower extremity are impaired, while in diplegia only the lower extremity is affected. In Hemiplegic Cerebral Palsy, half of the body, that is one upper limb and lower limb of the same half, is impaired. The main cause of Hemiplegic Cerebral Palsy is damage to one hemisphere of the brain. If the left hemisphere of the brain is affected, the right side of the body is impaired and vice versa. The impairment to the upper limb is more severe in Hemiplegic Cerebral Palsy (Sankar & Mundkur, 2005) and is a disability that needs therapy intervention for rehabilitation. This study only focused on improving the hand-skills of children with Hemiplegic Cerebral Palsy, as different conditions of Cerebral Palsy require different therapy interventions.

World Health Organization (World Health Organization, 2011) views disability as the interaction between the impairments of body functions and structures, activity limitations, participation restrictions, personal factors and contextual factors, rather than just impairments to the body functions and structures (Figure 1). It is vital to understand the dynamic interactions among these five elements when planning interventions to rehabilitation as changes to each element influence the others.

World Health Organization (2011) suggests that ‘rehabilitation targets improvements in individual functioning’. Hence, it is important to understand each component of disability - body functions and structures, activity limitations and participation restrictions (see Figure 1). International Classification of Functioning, Disability and Health (ICF) (World Health Organization, 2001) provides guide to framework and document the functioning, disability
and health for rehabilitation. According to the ICF, rehabilitation of hand-skills of children with Hemiplegic Cerebral Palsy should focus on muscle and movement functions of upper extremity for changing and maintaining body position/moving and handling objects (World Health Organization, 2001).

Hemiplegic Cerebral Palsy impairs both posture and motor functions of the upper limb. Typical posture (see Figure 2) of the impairment include ‘pincer grasp of the thumb, extension of the wrist and supination of the forearm… increased flexor tone with hemi paretic posture, flexion at the elbow and wrist…[and] palmer grasp persisting for years’ (Sankar & Mundkur, 2005). Degree of deformity of the posture may differ from child to child according to the nature of damage to the brain. When it comes to motor functions of the upper limb, muscle spasticity that occur in children with Hemiplegic Cerebral Palsy cause impairment to both gross motor functions and fine motor functions.

Figure 2: Typical hand posture of Hemiplegic Cerebral Palsy (Source: Authors, 2017).

According to the World Health Organization (2001), ‘[Rehabilitation] contribute to a person achieving and maintaining optimal functioning in interaction with their environment, using the following broad outcomes:

- prevention of the loss of function
- slowing the rate of loss of function
- improvement or restoration of function
- compensation for lost function
- maintenance of current function’

Rehabilitative medicine and therapy are main methods of rehabilitating disability. For the treatment of Hemiplegic Cerebral Palsy, physiotherapy and occupational therapy, occasionally accompanied with speech therapy, play a major role than rehabilitative
medicine. Kluzik, Fetters, & Coryell (1990) note that neuro-developmental therapy on hand exercises can produce immediate improvements in motor functions of hands. Physiotherapy and occupational therapy are vital in developing postural and motor skills of the children and therapists can use assistive products to engage children in therapy effectively.

METHODOLOGY

This study is based on a case study of developing a set of therapy assistive products to improve hand-skills of children with Hemiplegic Cerebral Palsy, focusing on improvement of motor skills of the hand through physiotherapy. The study was conducted at Lady Ridgeway Hospital for Children (LRH), Colombo, Sri Lanka, which is the only government-operated children's hospital in Sri Lanka. The study focused on children aged 4 years to 12 years and the study was conducted with the participation of 10 children suffering from Hemiplegic Cerebral Palsy, who were identified through health professionals. A group of five health professionals, consisting of neurologists, physiotherapists and occupational therapists and a group of 15 parents and caregivers also participated in this study. This study employed both quantitative and qualitative research methods. Primary data for the study were collected through questionnaire surveys, focus group interviews, observations and interactive therapy sessions. Secondary data were collected through literature survey and precedent studies. Gross Motor Function Classification System (GMFCS) was used to understand the degree of severity of gross motor abilities of the children with Hemiplegic Cerebral Palsy and the Manual Ability Classification System (MACS) was used to understand how they handle objects with hands. Modified Ashworth Scale (MAS) was employed to evaluate the effects of the therapy assistive products on motor skills of the hand.

The study adopted a questionnaire survey at the initial stage of the study. Questionnaire survey was conducted with the participation of parents, caregivers and health professional with a sample size of 20. Objectives of the survey were identifying the nature of the therapy assistive products that are already in use and identifying improvements required regarding the therapy assistive products for children with Hemiplegic Cerebral Palsy. To gain further insight on the medical condition, children, therapy methods, therapy assistive products and nature of interactions, focus group interviews and interactive therapy sessions were conducted with the participation of children, therapists, parents and caregivers. Based on the observations and findings of questionnaire survey, focus group interviews and interactive therapy sessions, a set of therapy assistive product designs were developed.

The process of designing therapy assistive products included continuous prototyping, testing, and developing designs through observations and feedbacks received through testing. Therapy review sessions were conducted every two weeks for three months and Modified Ashworth Scale, which measures muscle tone and quality of movements through a grading system, was adopted to assess the effects of the use of therapy assistive products that were developed.

NEED OF DESIGN INTERVENTION FOR REHABILITATION

Results of the questionnaire survey reflected that 20% of the therapy assistive products at LRH were imported products and did not conform to the local system of therapy practice as they aimed to improve individual therapy functions rather than a set of functions in a gradual flow. Thirty percent of the therapy assistive products were locally manufactured and other
50% comprised of adapted products. Although they conformed to the local context therapy practice in the sense of medical functionality, they lacked in areas of conforming to user preferences, appeal, usability, aesthetics and creating product series with a suitable product language. Eighty five percent of parents and medical professionals complained on lack of availability of therapy assistive products in the local market that are affordable and user-friendly. In the questionnaire survey, parents and therapists observed that the children were willing to engage in therapy with the use of therapy assistive products than engaging in therapy without assistive products. Moreover, the time period children voluntarily participating in therapy activities was comparatively higher when therapy assistive products were used, especially where repetitive hand movements involved.

Usability of therapy assistive devices is more effective if they conform well to the context they are being used. Couvreur & Goossens (2011) elaborate that ‘within healthcare contexts, local solutions are frequently more effective as they reflect the physical, emotional and cognitive needs of specific patients and engage all stakeholders in a specific local context’. Furthermore, Nimunkar, Baran, Van Sickle, Pagidimarry, & Webster (2009) note that ‘many of the medical devices built for developed countries may not be compatible with the environment in developing countries’. Studies conducted at local government funded hospitals regarding therapy assistive products revealed that most of the products in use are either adaptations of products available in the market or custom-made products from the workshops of hospital itself. While products from the hospital workshops were appropriate for therapeutic functions, they lacked in appeal and areas of usability. Thus, there is a need of product design intervention to develop therapy assistive products that specifically conform to local contexts.

Gunetillaka (2009) in his study of understanding Cerebral Palsy and planning intervention, identifies hand functions as one of the priorities that require multidisciplinary intervention. Gunetillaka (2009) further suggests incorporation of concepts of play and toys in planning therapy activities. Compared to the functions of the lower limbs, upper limb functions demand more control and discretion. During therapy sessions, which demand exercises and activities to be done for a prolonged period, ‘motivating a child to perform uninteresting, frustrating and repetitive movements by themselves is challenging’ (Weightman et al., 2010). Hence, developing therapy assistive products that are engaging and appealing to the children for rehabilitation is one of the practical and effective solutions.

When concerning design methodologies in developing medical devices, there is very little literature on how to apply them in practice. Although there are adequate literature on explanations and advantages of user involvement in the developing medical devices, ‘research concerning the process of involving users in medical device development remains relatively under-developed and poorly defined’ (Bridgelal Ram, Grocott, & Weir, 2008). Thus, there is a need to explore how design methodology should be applied in the practice of developing medical devices, especially in assistive products.

**CO-DESIGN APPROACH**

Developing therapy assistive products involve integration of two main disciplines, medicine and design. Thus, adoption of multidisciplinary and participatory design approach throughout the design process is inevitable in developing therapy assistive products. Co-design approach to design development considers the user as a partner in the process rather than viewing the user as a subject of the study. ‘User involvement through the cycle of device
development (concept, design, manufacture, testing and trials and production) increases the likelihood of producing devices that are safe, usable, clinically effective and appropriate to cultural context” (Bridgelal Ram et al., 2008). Allsop, Holt, Levesley, & Bhakta, (2010) highlight that when designing healthcare technologies for children with disabilities, ‘greater levels of participation’ of the end-user is vital. Users of the products can be identified as active and passive users. While the active users of the therapy assistive products are children with Cerebral Palsy - as they directly interact with the products, physiotherapists, occupational therapists, parents and caregivers are the passive users with indirect interaction with the therapy assistive products. Participation of patients, parents and healthcare professional in the design process from the beginning, rather than in latter phases of usability testing, help resolve conflicts at early stages of design development. Thus, identifying the key stakeholders at the very beginning of the study and engaging them in the design development process is an effective approach to developing therapy assistive product.

**EMPATHY**

Developing therapy assistive devices for children suffering from physical impairment is a difficult task, as it requires a comprehensive insight to the situation. However, being empathetic to the situation could provide insights that cannot be achieved through any other way. Free (2004) elaborates that ‘the ultimate users of the product may have very different priorities for a device than providers or purchasers of the product do’. Furthermore, Mcdonagh & Thomas (2010) emphasize that ‘gaining insight into a user’s emotions, aspirations, and fears can provide the designer with critical cues and inspiration to create more balanced functional and supra-functional products’. Active participation of children in a design development process is challenging, as there are difficulties in communicating and collecting constructive responses. It is also challenging to keep the children engaged and focused, as they are easily distracted. Therefore, rather than practicing traditional approach of researcher questioning the user for answers, more empathetic approaches to receiving feedback must be practiced. Interactive therapy sessions with children revealed that they were more likely to communicate their thoughts with other children, parents, caregivers and therapists in familiar group settings. They were also more communicative when the person receiving feedback also actively took part in the activities they were engaged in, as it creates a situation of peer exchange rather than a situation of hierarchy. Hence, it is critical that the design process of developing therapy assistive device has an empathetic approach.

**ITERATIVE PROCESS**

Usability and outcomes of therapy assistive products are highly impactful in nature. Therefore, design development process need to be carefully planned to eliminate usability flaws and validate the products. Best way to achieve this is through an iterative process of usability testing and refining the product as much as possible. Martin, et al. (2008) elaborate that when developing medical devices, ‘although expensive and time consuming, the optimum method of applying usability tests is to perform a number of tests throughout an iterative design procedure’. This facilitates to gain a meticulous and comprehensive understanding of the user requirements. Hence, any further adjustments needed in the designs could be identified and amended at early stages of product development process.

Prototyping is a useful and essential tool in developing therapy assistive products. Adopting product visualization methods along with prototyping from the beginning of idea development
phase allows understanding the usability of the products and identifying feasible outcomes. Hence, this study adopted an iterative process of prototyping, testing the prototypes with users, receiving constructive feedback through testing and improving the prototypes according to the feedback to achieve effective outcomes in developing therapy assistive products.

**DESIGN DEVELOPMENT**

Motor skills of the hand can be identified as gross motor skills that involve large muscle movements and fine motor skills that involve small muscle movements with eye-hand coordination (see Figure 3). Due to muscle spasticity and postural deformities, children with Hemiplegic Cerebral Palsy have a limited range of motion and dexterity of hands (see Figure 2). Therapy assistive products that are presented in this research were developed to improve posture, gross motor skills, and fine motor skills, range of motion, dexterity and strength of the muscles of the hands.

![Motor Skills of Hand Diagram](image)

**Figure 3: Motor skills of the hand (Source: Authors, 2017).**

One of the main problems identified in the study regarding the therapy assistive products that were already in use at LRH was that most of the products focused on individual therapy functions and did not consist of product series or levels that facilitated different stages of therapy process. The set of therapy assistive products developed in this study consists of three designs, namely, Design A, B and C, whose degree of sophistication of the therapy function increased progressively from Design A to Design C (see Figure 7). Each of these three designs consists of inter-changeable parts to create different complexity levels within one design. Design A (see Figure 4) aimed to improve the large muscle movements of shoulder and elbow while at the same time improving the grip. Design B (see Figure 5) aimed to improve fine movements of the shoulder, elbow and wrist while improving the grip as well. Design C (see Figure 6) encourages the fine movements of the wrist and fingers. Design A and B involuntarily encourage correct posture of the hand when handling. Thus, the child maintains the correct posture for a considerable amount of time without any external force applied.
Figure 4: Design A (Source: Authors, 2017).

Figure 5: Design B (Source: Authors, 2017).

Figure 6: Design C (Source: Authors, 2017).
Developing therapy assistive products require careful brainstorming and planning. Weightman et al. (2010) discuss about five design requirements that should be considered when developing rehabilitation technology for children with Cerebral Palsy: therapeutic benefits, mechanical functionality, safety, social acceptability and motivational factors. Fulfilling these requirements ensures feasible outcomes of the products. Therapeutic benefits of the therapy assistive products developed to improve hand-skills of children with Hemiplegic Cerebral Palsy include posture correction, grip improvement, muscle strengthening and developing gross motor and fine motor skills. It is important that the above aspects be presented in several phases in therapy assistive products, according to complexity of the skill level needed to be achieved. This ensures that each skill level is achieved and any difficulties in achieving certain skills could be monitored during the therapy sessions. On the other hand, it ensures that realistic goals are set for the child, which contributes as a motivational factor for children to engage in therapy.

The therapeutic functions like movement types, patterns, postural capabilities and ergonomic factors of the children mainly influence the development of forms of therapy assistive products. When developing design A and B, special attention was paid to the typical hand posture of children with Hemiplegic Cerebral Palsy and their gripping abilities. It was observed that one of the main postural deformities in children with Hemiplegic Cerebral Palsy was thumb adduction. Children showed reluctance to typical therapy methods of using splints and continuous verbal encouragements of therapists to correct the thumb posture. However, with design intervention, solutions to these problems could be provided through form development to encourage correct postures without the child being consciously aware of it. In Design A and B, a spherical form was used in the gripping areas to keep the thumb away from palm and reduce finger flexion throughout the therapy activities, and to encourage the correct hand posture when in use by reducing wrist flexion, internal rotation of the forearm and shoulder adduction. Design A and B also consist of interchangeable three gripping ball sizes to improve grip patterns of gripping large objects to small objects.
Identifying different parameters of design requirement is essential in design development. Along with the therapeutic aspects of therapy assistive products, design elements like colour and texture should also be taken into consideration when developing therapy assistive products. Most of the children that suffer from Hemiplegic Cerebral Palsy have a slow rate of cognitive development. Most of them could only identify basic colours like red, blue, yellow and green. Children also respond positively to bright colours, compared to dull colours which evoke negative emotions (Boyatzis & Varghese, 1994). Hence, bright colours were used in therapy assistive products to enhance the appeal to children. Colours were also utilized in products to set boundaries and differentiate components.

Nature of surface textures of therapy assistive products can be utilized to enhance the therapeutic functions and appeal to children. Nature of the surface can be determined through tactile requirement set by the therapeutic aspects, tactile preferences of the children and the mechanical functioning of the products. Studies indicate that children with Cerebral Palsy chose hard objects over soft objects as they may have decreased tactile awareness and need greater proprioceptive input that hard objects provide. Studies further suggest wood and thermo-plastic as suitable materials to be used in product for children with cerebral palsy (Curry & Exner, 1988). When selecting suitable materials for product manufacturing, material availability, affordability and manufacturing technology were also taken into consideration. Wood is an abundantly available material in the local context and necessary manufacturing facilities are also readily available. Hence, wood was used as the main material used in the Designs A, B, and C, considering the above factors.

Availability of affordable therapy assistive products is one of the biggest issues in developing countries (World Health Organization, 2011). Hence, when developing therapy assistive products, availability and affordability of manufacturing technology were taken into consideration. LRH, and most of the other local government operated base hospitals, consists of workshops at hospital premises with basic wood manufacturing facilities. Thus, the products were developed to conform to the manufacturing facilities available at hospital workshop and, as a result the products are more affordable and readily available.

**CONCLUSION**

Although the degree of severity of the condition differed in each child who participated in this study and the progress was slow paced, 7 out of 10 children indicated improvement in the Modified Ashworth Scale, after the use of the products (Design A,B,C) for continuous three months. Therapy review sessions also indicated improvements in muscle strengthening, posture correction - especially in the case of thumb adduction, gripping and range of motion. Use of Design A indicated most impact in the improvement of range of motion while Design C indicated most impact in strengthening and reducing muscle tone of finger joints.

Developing products in the field of healthcare is challenging, as it demands comprehensive understanding of the therapeutic requirements and highly functional outcomes. Current practices of design methodology are more sensitive to the usability of products and provide ideal tools and techniques to develop products in the field of healthcare. Developing therapy assistive products require integration of both design aspects and medical aspects in the products. Therefore, adopting Co-design approach in developing products is vital as it ensures the active participation of key stakeholders in the design process. Practice of Co-design approach integrates the knowledge and experiences of professional in the fields of healthcare, design and technology to develop therapy assistive products. Active participation...
of key stakeholders throughout the product development process also ensures that the outcomes are more effective, user-friendly and feasible. Users of the therapy assistive products are not just the children who directly interact with them, but also include passive users such as therapists, parents and caregivers. When developing products, feedback on usability from both active and passive users must be taken into consideration and products must be improved iteratively based on the feedbacks and observations to provide better solutions. Therapy assistive products for rehabilitation of hand-skills of children with Hemiplegic Cerebral Palsy should present achievable goals to children with gradual improvement of skill levels from gross motor functions to fine motor functions. Physiotherapists and occupational therapists continuously evaluated the therapy assistive products during therapy sessions and observed improvements in motor functions of children. It was also observed that children were more engaging in therapy activities when using these therapy assistive products. However, these products could be further developed through testing and evaluation. While this study only focused on motor functions of the children, through further experiments of textures, forms, and materials, these products could be developed to assist rehabilitation of sensory functions as well. Design intervention for developing therapy assistive products is a sustainable approach to rehabilitation of disabilities. Design methodology can be adopted to develop therapy assistive products that are therapeutically effective, engaging, and cost effective. Although this study focused only on developing therapy assistive products for children with Hemiplegic Cerebral Palsy, this design approach can be adapted to develop rehabilitation solutions to various conditions of disabilities through design intervention.

REFERENCES


