Physical Therapy System for Children with Hemiplegia

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Abstract: - The paper describes a novel system and a physical therapy method for rehabilitating the affected limbs of infants and children diagnosed with hemiplegic cerebral palsy (CP). Currently, the most effective procedure for the treatment of cerebral palsy is constraint-induced movement therapy (CIMT), which includes limiting the movement of the unaffected arm to encourage the use of the affected arm. Children diagnosed with hemiplegic cerebral palsy may benefit from self-generated motor activity produced when using their affected limb by constraining their unaffected limb and applying a variety of standard reinforcement techniques. Such "Constraint-Induced Movement Therapy" has shown promise when applied to young children and infants diagnosed with hemiplegia. Behaviorally, these children hold their affected arms flexed at the elbow, and tend to clench the fist. Currently, effective procedures for training children to use their affected arm have relied only on behavioral reinforcement techniques. These techniques facilitate grasping skills only, which may lead to significant impairment of hand opening. This paper describes a novel biofeedback system (U.S. Patent Application No. 61/167/679, patent pending) that provides therapeutic treatment for young cerebral palsy sufferers 7–25 months old. The device comprises a position sensor system, transceivers, and signal processing system, and will interface with an audio/video output system to provide positive biofeedback in the form of pleasant sound (music) and images for psychological reinforcement of constructive, habitual muscle motions, such as fist opening, clapping, and arm rising.

Key-words: - Cerebral Palsy, constraint-induced movement therapy, biofeedback device.

1 Introduction

Cerebral Palsy (CP), defined broadly as “a non-progressive motor impairment syndrome caused by a problem in the developing brain,” affects at least 2 in 1000 children in the United States and more than 1 million children in the industrialized world [1]. Cerebral Palsy is a disorder in infants characterized by “spastic rigidity of limbs” [2] due to non-progressive brain damage early in life [3]. Behaviorally, children who are diagnosed with mild cerebral palsy (hemiplegia affecting one side), hold their affected arms flexed at the elbow, and tend to clench the fist. Such children can be helped using "constraint-induced movement therapy," in which the unaffected arm is put in a cast and the child is intensively encouraged to use the "bad" arm using a variety of reinforcement techniques.

Constraint-induced movement therapy (CIMT) has been found to be a promising treatment for substantially increasing the use of extremities affected by neurological injuries. The elements of CIMT therapy are: 1) constraint of the unaffected arm to encourage the use of the affected hand, 2) practice of the affected arm, and 3) use of intensive techniques to train the affected arm [4]. Earlier successful results from the use of CIMT therapy on children have proven that there is an improvement in the usage of the diseased extremity of up to 52.1%, compared to a mere 2.1% in general physical therapies [5]. As an integral part of CIMT therapy, the normal arm extremity would be restricted in movements by using a convenient day or night fiberglass splint. This should greatly encourage the use of the diseased arm extremity [4, 6].
2 Problems with constraint-induced therapy

Problems with constraint-induced therapy exist, however. First, it is expensive due to the required amount of professional expertise and investment in training. Second, it is limited to older children who have already learned to use their unaffected extremity to manipulate objects [5]. It is felt that the development of motor plans in the central nervous system (CNS) is necessary for effective transfer of skills to the affected limb. However, this limitation extends the period for the infant to learn that the affected limb does not yield the same results as the unaffected limb, theoretically resulting in unilateral neglect. Third, it is, at present, limited to control of the arms and neglects the legs. Fourth, during the casting session, some children became upset, particularly when a cast saw was used to bivalve the just-applied cast into two parts. Also, during the weekly removal of the cast, children have some skin redness, rash, and/or pinching. Finally, there has been concern expressed that casting the less-affected arm for 3 weeks results in short-term or long-term loss of function in that extremity [1].

CIMT therapy has been reported to be more effective in younger than in older children [7, 8]. Since this is the case, we suggest that, with relevant feedback, infants 7 months old or even younger could be treated [6, 9]. Increasing the magnitude and complexity of reinforcing feedback from the affected extremity will result in enhanced use of the limb. This task can be accomplished by a specially constructed device that will provide response-contingent auditory and visual stimuli in a variety of settings. The combination of auditory and visual feedback would stimulate a will in the child’s mind to work with both arms [6].

Presently, there is no effective procedure for training young children to use their affected arm. This can lead to later physical disabilities. The therapeutic system described in this paper will allow the child to receive auditory and visual feedback when the child extends the fingers of the affected arm. The auditory and visual stimuli preferred by the child will be chosen based on observation and maternal report. Such stimuli will be varied to avoid habituation effects. Three variations of the proposed device can be developed for a similar (but slightly different) training:

a) The first variation is implemented with a small glove wired with sensors to detect the angle of the fingers. When the fingers are extended, music would be played and light-emitting diodes (LEDs) or images on a computer screen would light up in an interesting pattern. Other visual effects, such as a face of the mother, could be also implemented.

b) The second variation will be used to train a child to lift an affected arm with a glove containing a sensor. When the child lifts the arm and touches the board installed on a certain level in the front of a child, the audio/video module would be activated.

c) The third variation is used to train a child to clap using both affected and unaffected arms. The gloves on both arms will be wired with sensors. One sensor acts as a transmitter and the other one as a receiver. When the child claps, the video/audio module will be activated based upon baseline assessment of the distance to which the child can already hold both hands.

3 Device design

Since early diagnosis and treatment greatly helps in development in CP affected children, we suggest that young children of 7 months old and even younger could be treated solely with the help of music and signs. They understand actions and are attracted towards sound and light, which clearly suggests how effective response-contingent auditory and visual therapy could be for treatment. A palm mountable device suitable for fitting to a child’s palm is being designed. Three variations of the proposed device are being tested in the laboratory. The first variation will be used for training an infant (child) to open the fist without need for casting the unaffected arm. The fingertips and the base of the palm will have the piezoelectric devices for transmitting and receiving acoustical signals (Fig. 1). The intensity of the transmitted ultrasound signal will be controlled below the acceptable by FDA level [10 - 13].
The device will have the circuit OFF when the fist is clenched and the sensors are directed towards one another (Fig. 2).

The opening of the fist will turn ON the electronic circuitry and consequently the Audio/Video module (Fig. 3). Care will be taken to avoid any direct electrical contact to the palm.

The electronic circuit will suitably be powered by the battery, which will ensure the safety of the device. Utmost care will be taken to prevent access of batteries or other swallow-able parts by the child. The child will be taught to open the fist/palm. When the fist opens, the musical system will start playing musical notes and LEDs will light up in a pattern that has been determined to be interesting to the child (using standard choice procedures developed in infancy research) [14, 15].

The second variation will encourage the child to raise the affected arm (Fig. 4).

The child will be positioned near a small board made of wood or plastic. Various levels of the board will be marked and a circuit would close when the child touches specific marked points. The higher the level the child reaches the more of a reaction he or she would receive. The response as usual would be in form of music, specially coupled with glowing LED patterns. The schematic diagram displaying the training of arm extension is presented in Fig. 5. To ensure that a child activates the system by extending his arm rather than by walking the glove towards the board, the child may be temporarily restrained in a chair and placed before the “Board”. Alternatively, the chair includes a pressure activated seat cushion with pressure sensors. When the child sits on cushion, system will operate as normal. When, however, cushion does not detect a child’s weight, system is deactivated to thereby ensure that the child remains in the chair during the exercise. The pressure threshold of cushion may be adjusted depending upon the weight of the child.

The third variation will be applicable for children who need to be taught to clap or do a similar activity. It may also be the joining of two hands (Fig. 6). The child will wear the gloves with an attached piezoelectric sensors on both arms (Fig. 7). When the child claps, the audio/video module is activated, provided audio/video outputs described above. For this particular training, the use of gloves with attached piezoelectric sensors on both arms could be unavoidable to make sure that both arms act simultaneously. In this case, one piezoelectric sensor will be used as a transmitter and the other one as a receiver. Daily practice with all suggested modifications of the device will help the child to
coordinate its motor activities including, eye and arm coordination. The extended reach will result in improved use of the extremities irrespective of them being diseased or normal.

**Fig. 5.** The schematic diagram displaying the training of the arm extension.

The devices under development will be tested in the laboratory to evaluate their safety for children. All parts and components, used in the project, will satisfy the standards for medical applications. Electrical isolation of the gloves with the built-in sensors and necessary electronics will be tested for both dry and wet gloves. Wires and cables will be fixed reliably to the sleeves to prevent any possibility of misuse or suffocation. Inability to reach the batteries or any other swallow able parts or components by the child will be tested and all possible precautions will be implemented.

**Fig. 6.** Training a child to clap.

**4 Summary**

A physical therapy system for rehabilitating infants and children diagnosed with hemiplegic cerebral palsy is described in detail. Even though, CIMT has demonstrated positive results in rehabilitating the disabled limbs of children diagnosed with hemiplegia, significant limitations exist. Specifically, it is limited to older children who have already learned to use their unaffected extremity to manipulate objects. In addition, casting of the unaffected extremity for a period of several weeks may lead to loss of function in that extremity. The therapy system described in this paper will avoid these limitations by encouraging children from 7 to 25 month old to use the affected extremity by emphasizing self-generated voluntary actions in a variety of settings. The device can provide auditory and visual feedback to the infant or toddler when the child uses that arm to engage in a desired activity.

**References:**


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