A Novel Approach in Virtual Rehabilitation for Children with Cerebral Palsy: Evaluation of an Emotion Detection System

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Abstract. Emotional and behavior alterations are common symptoms in children with Cerebral Palsy (CP). Mental health disorders in this pathology are mainly stress, anxiety, and depression. Since there is a strong relationship between behavior and emotion symptoms, children with CP show difficulties to communicate in terms of family, peer, and attention signs. With a high prevalence of emotional and behavior disorders and few studies in Virtual Rehabilitation focused on the enrichments of this alterations, it is necessary to analyze the use of new groundbreaking technological systems. The purpose of this paper is to analyze behavior and emotion symptoms of a child which CP. For this, we use a novel system that recognizes emotions such as neutrality, happiness, and annoyance, together with the Strengths and Difficulties Questionnaire (SDQ). The preliminary outcomes encourage us to continue analyzing enrichments in terms of emotional and behavior problems.

Keywords: Virtual Rehabilitation · Children with cerebral palsy
Emotions · Behavior · Satisfaction · Psychological alterations

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1 Introduction

Cerebral Palsy (CP) is a group of movement alterations and postural control that produce restrictions in activities of daily living due to non-progressive disorders in the developing fetal or infant brain [1]. Risk factor that are predictors of CP include placental anomalies [2], birth defects [3], maternal infections [4], prematurity birth [5], low birthweight, [6], birth asphyxia [7], etc.

Worldwide, the overall prevalence is 2.11 per each 1000 live births, with different outcomes in function of risk factors [8] related to the birth. These factors are the following: (1) birthweight, the prevalence is 59.18 per 1000 live births if the weight ranged from 1000 to 1499 g and the prevalence is 1.33 per 1000 live births if the weight is over 2500 g; (2) prematurity birth, the prevalence is 111.80 per each 1000 live births if children born before 28 weeks and the prevalence is 1.35 per each 1000 live births if children born after 36 weeks.

With a prevalence that ranges from 25.5% to 60% [9–11] related to emotional and behavioral alterations in children with CP, it is a factor to take into account. These outcomes are based on the severity of the illness, with a strong relationship between behavioral disorders and chronic disease [9].

Mental health disorders (Mhd) in children with CP are composed by a combination of behavioral and/or emotional alterations which produce family, peer, attentional complications, and moods [12]. Mental disorders are an alteration at a psychiatric level diagnosed by the diagnostic and Statistical Manual of Mental Disorders or the International Statistical Classification of Diseases and Related Health Problems (ICD). A recent study focused on the prevalence of Mhd in children with CP [13], describes a prevalence of Mental disorders of 57% by psychiatric conditions, a prevalence of Mhd of 35% using the Strengths and Difficulties Questionnaire (SDQ) [14], and a prevalence of 28% using the Child Behavior Checklist (CBCL) [15].

Motor control alterations such as postural control, reaching, grasping and also dynamic movements (walking), are caused by dyskinesia [16], spasticity [17], hyperreflexia [18], etc. Other type of comorbidities related to CP such as sensorimotor disorders, epilepsy, communication impairment, behavior, cognition, and emotions, reduced well-being in this pathology together with quality of life of families [1].

Children with CP are classified according to the GMFCS (Gross Motor Function Classification System) [19]. GMFCS is a standard that focuses on what the child is able to do instead of his/her limitations. This clinical system identifies five several groups: level I children with CP are able to climb stairs without limitation, in level II they can to climb stairs using a railing, in level III they can walk by using a wheelchair or a walker, in level IV they walk short distances thanks to adult assistance by using the same devices of level III, and in level V children with CP have serious impairments with disorders to maintain the head and the trunk. Thus, GMFCS levels increase as the mobility decreases [20].

Traditional motor treatments are based on the levels of the GMFCS, where treatments of children with CP classified at the first levels are focused on the improvements of the mobility, whereas children with CP included in the last levels, traditional techniques manage improvements in posture/mobility, pain, sleep disorders, etc. [21].

Psychological treatments are based on deficits such as: (1) peers; (2) attentional disorders; (3) withdrawal; and (4) disorders at an emotional level, etc [10]. These impairments have a strong relationship with motor disorders, affecting mainly the behavior of children with CP.

Analysis focused on these psychological alterations is performed by the validity clinical tests that are reliable. The questionnaires test that study emotions specifically are the following: (1) the Vineland Adaptive Behavior Scales II (VABS) [22]: (2) the Child Behavior Checklist (CBCL) [15]; and (3) Strengths and difficulties Questionnaire (SDQ) [14].

With a high prevalence of emotional and behavioral disorders in this pathology and a traditional methodology in the rehabilitation processes focused on physical alterations of children with CP, it is necessary to plan novel strategies that analyze and enrich these mental health symptoms in the clinical community. The intervention and attention by clinical specialist in factors related to behavioral and emotional alterations, not only in children with CP but also in their parents, could be a clear indicator in the traditional rehabilitation.

This paper is organized as follows: Sect. 2 describes the use of Virtual Reality in children with CP and previous analysis based on emotions in this pathology. Section 3 shows the methodology and procedure follow in this study. Section 4 presents the preliminary outcomes of the participant based on her emotional and behaviour disorders. Finally, Sect. 5 describes our discussion and conclusions.

2 Related Work

Virtual Reality is an environment generated by computer technology where realistic images, textures, sounds and other sensations are created in order to simulate the physical presence of the user in a virtual or imaginary environment [23]. Currently, Virtual Reality extends too many fields and it may be used in physical therapy to improve patients with neurological disorders such as the CP. In this sense, the use of Virtual Reality in the patient's therapeutic training is known as Virtual Rehabilitation (VR) [24]. A VR application simulates situations, environments and objects with which the patients can interact, offering them the opportunity to immerse their self in a reality similar to the real world. Thus, the patient can perform movements and actions in a simulated safe environment, his exercises can be adapted to his/her capabilities and the progress of patients may be monitored. Particularly, VR is posed as games that motivate the patient trying to overcome previous limitations.

Several studies have been conducted to evaluate the VR in the improvement of motor function for children with CP [25–27]. In [28], the studies carried out on nine children with CP using a haptic device and gaming simulations in virtual environments suggest improvements in motor skills and motor control. In [27], the authors showed improvements in functional balance and mobility for four adolescents with CP. Finally, [29–31] indicated the use of VR has an effect on the improvement in some motor functions in children with CP.

Currently, there are few studies focused on emotions in VR for children with CP. In the Reid and Campbell's work [32], they pointed out that the children with CP who

participated in their study may have felt more accepted by their non-disabled peers and felt more competent due to the experience with Virtual Reality. In this sense, the Reality Virtual can intensify emotions and feelings in individuals with disabilities.

The purpose of our study is to test the percentage of happy, annoyed, and neutral emotions of children with CP by using a low-cost and a portable system. Our tool, the Emotion Virtual Experience (EVExperience) was designed by experts in accessibility, usability, and designers of VE.

3 Methods

This study was performed thanks to the participation of a child with CP in a neuro-rehabilitation service for the Care of CP children.

3.1 The Participant

The EVExperience system was used by one 10-year-old girl with CP. The patient has Tetraparesis with a loss of sensibility of all four limbs.

The patient has a Gross Motor Functional Classification System (GMFCS) level III, with restricted ambulation and need for a wheelchair. Relating to passive movement, the participant has an Ashworth Scale score of 2. Table 1 shows the main characteristics of the participant.

Table 1. Outcomes of clinical test of the Participant.

Height (cm)	Weight (kg)	Affected Side	GMFCS score	GMFM	MACS
130	29	Right	III	59.45%	II

The inclusion criteria defined by clinical specialist were the following: (1) a suitable level of comprehension in visual, auditory and reading levels; (2) GMFCS level from I to III; (3) MACS level from I to IV; (4) children with CP and their age ranging from 3 to 12 years; and (5) comprehension of EVExperience instructions without the assistance of clinical specialist.

The exclusion criteria were the following: (1) patients with visual disorders that cannot interact correctly with our technological system; or (2) severe affection of upper extremities with an outcome of Asworth scale of 4–5.

The study to test with the participant was approved by the Ethical Committee following the ethical standards of Declaration of Helsinki (DoH). The participant's parents signed a specific consent form before the study.

3.2 Instrumentation

EVExperience [33] is a tool that classifies and recognizes emotions perceived in children through facial features. It was developed with Python and OpenCV [34]. Currently, it recognizes the happy, annoyed and neutral emotions using the Eigenfaces

algorithm [35]. We are thinking to enrich our system by using multimodal evaluation, focusing on attention on interaction with EVExperience [36].

The hardware component of the system was a standard laptop with the official Windows 8 and a webcam. In this phase no other specific devices were need to test the participant's behavior.

In the session, the participant watched several videos related to annoyance, happiness, and neutrality (two per each emotion). These videos were selected by an expert in emotions that was tested previously with children without disabilities.

The main objective of our tool is to reinforce adherence and motivation of the children with CP in the therapeutic rehabilitation sessions. In a near future, we are developing a specific virtual scenario related to one instrumented activity of daily living, to make a salad that will be composed of typical products: tomatoes, potatoes, onions, lettuces and black olives, oil, and salt. Figure 1 shows the VE that we are adding to EVExperience.

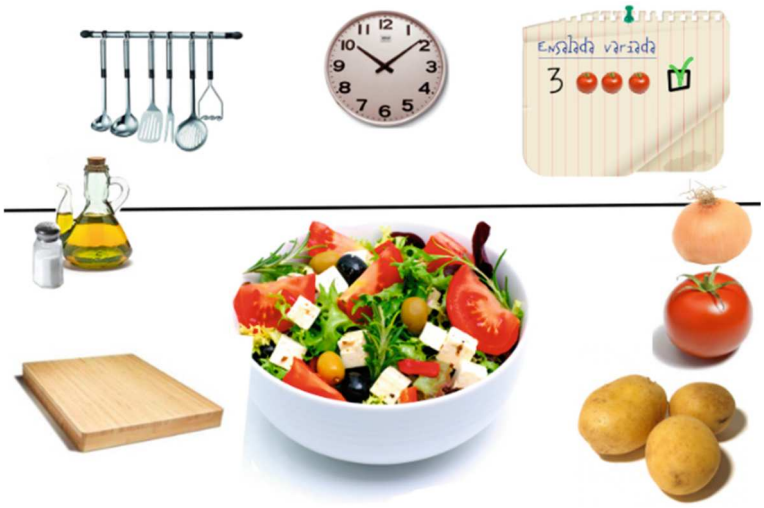

Fig. 1. The Virtual salad in the EVExperience system

3.3 Procedure

The study was carried out in a specific neuro-rehabilitation service of a large metropolitan city. A Child with CP tested our novel system. The length of the session was around 30 min with resting periods of four-minutes between each video. In the session, the participant interacted with EVExperience system (see Fig. 2).

Previous the session, the team analyzed the three questionnaires based on behaviors and emotions: Child Behavior Checklist (CBCL) [13], Strengths and Difficulties Questionnaire (SDQ) [14] and Cerebral Palsy Child (CPCHILD) [15]. Finally, the team decided to select SDQ clinical test due to clarity of questions which compose this test.

Fig. 2. Participant interacting with the EVExperience system

CBCL identifies behavioral problems in children including social withdrawal, somatic complaints, anxiety and depression, social interaction problems, etc. SDQ detects probable mental and behavioral disorders. It consists of twenty-five items that are divided into five scales. Four scales measure problematic behaviors: Emotional symptoms, conduct problems, hyperactivity and inattention, and peer problems. The fifth scale refers to positive behaviors: Prosocial behavior scale. The four scales that measure problematic behaviors compose a sixth scale called total difficulties. Lastly, CPCHILD measures health status and well-being of children with CP. It comprises 37 items distributed among six sections: activities of daily living/personal care, positioning, transferring and mobility, comfort and emotions, communication and social interaction, health, and overall quality of life.

At the end of the virtual session, following the recommendations of the clinical specialist, the parents answered the SDQ and filled out a satisfaction questionnaire (USEQ) [37], with the goal to analyze the level of satisfaction of the user (see Fig. 3).

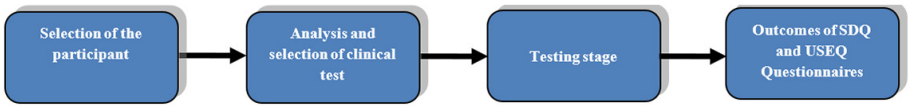

Fig. 3. Timeline of clinical session

4 Results

A first clinical evaluation has been made with one child with CP. The outcomes are described in Table 1. The testing session was performed in a neuro-rehabilitation service with clinical supervision.

4.1 The Emotional Outcomes

The analysis related to behaviors and emotions in the SDQ are summarized in Table 2. The outcomes ranging from (1-Not all) to (5-All-Very much) related to the USEQ are described in Table 3.

Table 2. Outcomes in emotional and behaviour disorders.

SDQ	Scores
Emotional symptoms	1
Conduct problems	0
Hyperactivity/inattention	3
Peer problems	0
Total difficulties	4
Prosocial behaviors	10
Impact Score	0

Table 3. Outcomes in the USEQ.

Questions	Outcomes
Did you enjoy your experience with the system?	3
Were you successful using the system?	5
Were you able to control the system?	5
Is the information provided by the system clear?	5
Did you feel discomfort during your experience with the system?	1
Do you think that this system will be helpful for your rehabilitation?	4
Total Score	27

The outcomes based on Eigenfaces algorithm are the following: (1) 20% of the samples with neutrality, 50% with happiness, 28% with annoyance, and 2% unidentified, related to videos of neutrality; (2) 20% of the samples with neutrality, 46% with happiness, 33% with annoyance, and 1% unidentified, related to videos of happiness; and (3) 12% of the samples with neutrality, 14% with happiness, 72% with annoyance, and 2% unidentified, related to videos of annoyance (see Fig. 4).

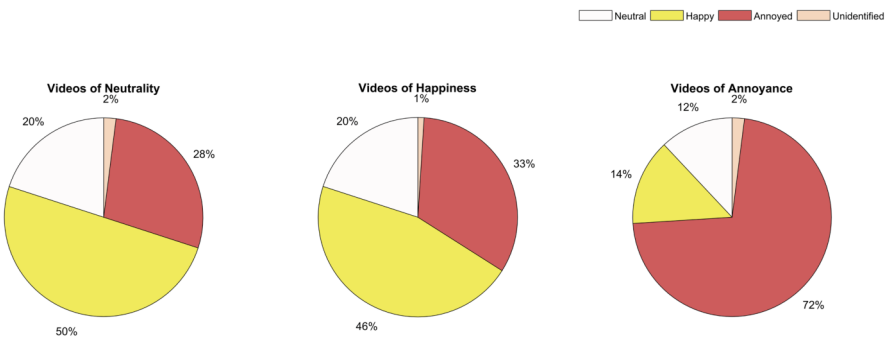

Fig. 4. The outcomes of the EVExperience.

5 Discussion and Conclusions

We tested the clinical specific questionnaire focused on emotions and behavior in children with CP by using a novel Virtual Rehabilitation system, the EVExperience. To accomplish our objective, we measured emotional symptoms of the SDQ clinical questionnaire.

In relation to the satisfaction by using our system, the participant showed a high engagement. We think that this outcome is due because our system is composed of non-invasive device which reproduces specific videos related to the emotions to analyze. Thanks to these initial outcomes, we will enrich our tool based on the proposals of the users in the intervention period.

According to the outcomes of SDQ, we can see the participant had a normal or close to average in all categories (the original 3-band solution and the newer 4-band solution). We think that the participant's score agrees with the work presented in [9], since the severity of the illness is strongly related to behavior disorders and chronic disease. In particular, this case of the study shows a moderate score in GMFCS and a close to average behavior based on SDQ.

Based on parents' opinion, children with CP have mainly emotional or behavioral difficulties; therefore, it can produce frustration and social withdrawal for this pathology [38]. The improvements of emotional levels of children with CP will enrich the rehabilitation process in gross and fine alterations. For this purpose, in EVExperience we will add a specific VE to test the improvements in fine rehabilitation. In a near future, we will deliberate specific clinical questionnaires focused on measure motor skills in children with CP ages from 4 to 21 years. These clinical questionnaires are the following: (1) Bruininks-Oseretsky Test of Motor Proficiency Second Edition; (2) Pediatric Motor Activity Log; and (3) Melbourne Assessment of Unilateral Upper Limb function.

Currently, we are recruiting children with CP to validate our hypothesis by using EVExperience. For this, we are deliberating the correct protocol with the assistance of clinical specialist. Design and acceptance of inclusion and exclusion criteria in our study with a representative sample of children with CP are essential to accomplish our

hypothesis. Therefore, the use of groundbreaking Virtual Systems in traditional treatments for children with CP will enrich emotional and behavior problems.

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