Visual Stimulation Strategies in Cerebral Visual Impairment

Estratégias de Estimulação Visual na Deficiência Visual Cerebral

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ABSTRACT

PURPOSE: To review visual stimulation (VS) strategies in patients with cerebral visual impairment (CVI) and to design a new VS application (app).

MATERIAL AND METHODS: 394 studies searched with terms "visual stimulation" and "cortical/cerebral visual impairment" were identified, through a search using the PubMed® database from inception to January 9, 2021. From those, 40 were selected. Regarding the development of the VS app, new strategies were applied in a mobile app that is named Steve. The platform was developed in Adobe Phonegap tool, using Javascript, HyperText Markup Language, and Cascading Style Sheets, being compatible with iOS and Android devices and also by other devices using a website. The app allows practicing with innovative animations and geometric shapes with different purposes. The system supports modifiable settings to change the size and velocity of content, to provide personalized learning.

RESULTS: Training with individual objectives, programs and methods of VS have to be adapted for each type of CVI. Stimulation with everyday objects, bright colors and high contrast patterns with smooth movement were the most effective strategies and were inserted into our suggestion of VS app.

CONCLUSION: Our proposal of VS app was created based on previously reported programs to stimulate the children more intensively in a familiar environment. We believe that this project could help the visual rehabilitation process in children, which requires persistence and other behavioral interventions.

KEYWORDS: Mobile Applications; Photic Stimulation; Vision Disorders; Vision, Low

RESUMO

OBJETIVO: Rever as estratégias de estimulação visual (EV) em pacientes com défice visual cerebral (DVC) e criar uma nova aplicação (app) de EV.

MATERIAL E MÉTODOS: Foram identificados 394 artigos com os termos "estimulação visual" e "deficiência visual/cortical/cerebral", através de uma pesquisa na base de dados PubMed®, desde

o início até 9 de Janeiro de 2021. Foram selecionados 40 artigos. Em relação ao desenvolvimento da aplicação, foram aplicadas novas estratégias numa app móvel chamada Steve. A plataforma foi desenvolvida na ferramenta Adobe Phonegap, usando Javascript, HyperText Markup Language e Cascading Style Sheets, sendo compatível com dispositivos iOS, Android e outros dispositivos através de site. A app permite a realização de treinos de estimulação visual, através de animações e formas geométricas com diferentes propósitos. O sistema permite alterar o tamanho e a velocidade do conteúdo, possibilitando uma aprendizagem personalizada.

RESULTADOS: O treino de objetivos, programas e métodos individuais de EV deve ser adaptado para cada tipo de DVC. A estimulação com objetos do quotidiano, cores brilhantes e altos contrastes com movimentos suaves são as estratégias de estimulação mais eficazes, que foram inseridas na nossa sugestão de app.

CONCLUSÃO: A nossa proposta de aplicação reúne estratégias baseadas em programas previamente existentes, permitindo a estimulação das crianças num ambiente familiar. Acreditamos que este projeto pode auxiliar o processo de reabilitação visual em crianças com DVC, que requer persistência e outras intervenções comportamentais simultâneas.

PALAVRAS-CHAVE: Aplicativos Móveis; Baixa Visão; Distúrbios da Visão; Estimulação Visual

INTRODUCTION

Cerebral visual impairment (CVI) is the most common cause of permanent visual loss in children. It is commonly defined as vision loss resulting from damage or disease in areas of the brain involved with visual processing in the absence of any ocular pathology.[1] In recent years, it has also emerged as the leading cause of low vision in children in developed countries,[2,3] being a problem with increasing frequency, mainly because of the progress in neonatal care, which has lowered the mortality rate of children who have brain damage from hypoxia or from other severe medical problems. As a result, CVI is typically associated with neurological deficits including cerebral palsy, Intellectual disability, or motor deficits.[3,4]

Regarding the visual acuity of children with CVI, it differs widely from complete blindness to a minor reduction in visual acuity. However, in spite of the deficits, it is known that those children almost always have some degree of residual vision.[5]

No specific medical treatment for CVI is available. Therefore, the management of the disorder involves, at first, efforts to prevent it or, after that, to rehabilitate the affected children. Literature data showed that the rehabilitation process for patients with CVI is effective and could improve the vision in many patients. It includes not only strategies for visual stimulation, but also a set of postural and motor coordination measures and therapies.[5-7] This work should continue at home, with adjusted strategies for parents and caregivers to make the stimulation process a permanent and progressive activity. In spite of the evidence and the advantages of the rehabilitation programs, very little research is being performed to find new effective visual stimulation strategies. The popularity of the digital era and the wide diffusion of mobile devices have led significant opportunities to explore the potential of smartphones in healthcare, including for the improvement and stimulation of the visual acuity.

The primary objective of the study is to summarize strategies previously applied to vision stimulation in children with CVI and to develop a clinical app for those individuals. The app name is Steve and it was developed based on training purposes and functionalities, which are made to be implemented on a daily basis to improve the visual skills and, in consequence, the quality of life.

This work represents a challenging connection between all the professionals included in the different programs of rehabilitation and the family members of children with CVI, which are an essential piece for visual stimulation and must be involved in the whole process.

MATERIAL AND METHODS

A search about previously applied strategies in CVI was conducted, before the creation of the app. We selected relevant studies through a search using the PubMed® database from inception to January 9, 2021. This involved literature about vision rehabilitation and interventions including randomized controlled trials and other evidence-based studies. The weaknesses and strengths of each intervention were our priority, to gather the most appropriate strategies for the effective use of the app. Three hundred and ninety-four studies searched with terms "visual stimulation" and "cortical/cerebral vision impairment" were identified. From those, forty were selected. Articles were excluded if they were letters, editorials, notes, caregiver questionnaires, or qualitative data-only reports.

Our purpose of app aims to get together some characteristics of previous programs, with new strategies, functionalities, and challenges. The platform was developed in *Adobe Phonegap* tool, an open source framework for building cross-platform mobile apps. To build the application we used Javascript, HyperText Markup Language (HTML5) and Cascading Style Sheets to be compatible with a lot number of devices. The logo was created in *Looka* Dashboard, an open platform which allows generating a logo according to our requirements. For the mobile app de-

sign, we used *MobileUI.JS* framework, which provides support for the development of HTML5-based user interfaces for all popular mobile device platforms, supported also by *FontAwesome* Icons. The core functionality of the application was developed relying on *anime.js* and *fabric.js* toolkit libraries, which allows creating innovative animations and geometric shapes with different types and categories. We developed also a library for internationalization that support multiple languages in the application.

The source code of the app is completely free and open-source and allows the scientific community to contribute with ideas or re-use the platform for other purposes.

RESULTS

From literature, there are not so many interventions that aimed specifically the improvement of visual function in patients with CVI. Many data focus on interventions with other sensory experiences to compensate impaired vision and increase visual information.[8]

The early intervention approach follows the theories of various authors, in particular, the concept of early low vision training proposed by Barraga *et al*, in 1964.[9] In this study, they concluded that formal training which specified instructions should increase the efficiency of visual impaired children who had not been visual stimulated yet. After that, some studies has corroborated these findings, with the inclusion of suggestions by other authors such as Hyvärinen *et al*[10,11] and Zeschitz *et al*.[12,13] Another important concept was developed by Frostig *et al*, regarding perceptual training.[14] Children with CVI often fail to recognize scenes, faces, shapes and objects and the reality is confused and disorganized because there are always incoming so much information and the surrounding world is too noisy and complex for them.[14] Through the perceptual training, some improvements in areas such as figure discrimination and visual acuity were noted. Until now, some other interventions were developed and support the importance of early intervention.[14,15] An essential factor to its success is the environment, which must have some specific characteristics. The light is crucial and it is important to favor high-contrast patterns, simple objects with bright or intensified colors, with or without smooth movement. The maintenance of a simple visual background and atmosphere are critical for the assimilation of the information and the stimulus.[14,15]

During the past decade, with the development of new technologies, some applications and programs were developed to facilitate the rehabilitation process in children. Serious games, computer-based games designed for training, were created with both pedagogical and entertaining purposes, to enhance the potential of patient's recovery. Regarding the serious games applied in CVI, we can highlight "Catch me! Where is Peppa / George going?", to train attention, using a cartoon character, or some apps designed for iPad such as "CVI training recovery", "CVI visual tracking", "CVI training patterns", "CVI training color" or "Eye move", designed to improve not only the visual attention, but also the discrimination, the eye movement, saccades or tracking. The problem with the first one is about the complexity of the cartoons and objects, for severe cases of CVI, that makes it impossible to see the pictures correctly. Regarding the previously cited apps, the difficult is that they are only available on the App store, and accessible only by iPad.

In this work, we develop an app named Steve, with a simple design and easy accessibility for all (Fig. 1).

Figure 1. Steve App logo

Before its implementation, we have to consider whether other developmental functions are impaired in children. Individual programs, objectives, methods, and stimuli should be adapted for each one, based on the results of the first assessment. At first, to eliminate language barriers, and to allow global access, even to less intellectually developed classes, the app is available in different languages, such as Portuguese, English, Spanish, French and German. Second, the app is completely free and compatible with iOS (from August 2020 - https://apps.apple.com/pt/app/steve-visual-stimulation/id1527939104) and Android (from July 2020, https://play.google.com/store/apps/details?id=org.bujecas.vsa) devices and also can be accessed by other equipment, such as a computer or a TV with Internet connection, through a website (https://www.steve-app.com). The system supports modifiable settings for each task, allowing the change of level of difficulty, through the alteration of size, velocity, and colors of contents on each category, to provide personalized learning. The types of stimuli included images of simple forms, e.g., geometric forms and patterns and basic everyday objects, including simple flowers or animals. Regarding the organization of the app, on the main menu, there are some sets to explore (Fig. 2).

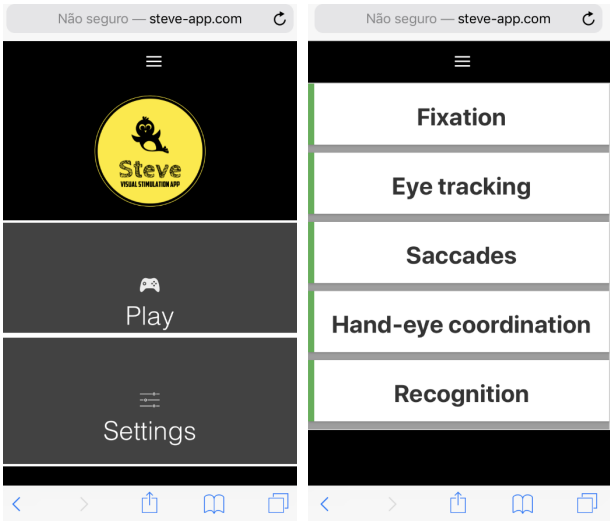

Figure 2. Main menu of Steve App.

The training menu is divided into categories, according to the purpose of the training program, such as fixation, eye tracking, saccades, hand-eye coordination, and recognition. In the first category, the children were encouraged to maintain fixation on a stated pattern, with can be previously chosen, with high contrast, or on a single object which is continuously being presented with more or less magnification in the same place, to improve fixation and visual attention. In the second category, children required to maintain fixation on a moving stimulus (Fig. 3), to train eye tracking. In the third category, the stimulus disappears and reappears in another location to train the saccades. Whenever possible, they were also instructed to do a fourth category of exercises, where they have to press a moving stimulus to obtain auditory feedback form the action, to improve hand-eye coordination. In the fifth category, simple drawings and real-life figures are presented, with or without movement, and, for those who had better acuity and attention, the instruction is to match correctly the figures. Despite this organization, in the more complex categories[3-5], hand-eye coordination, fixation, tracking, and saccades are simultaneously stimulated. In all exercises, the music option could be considered.

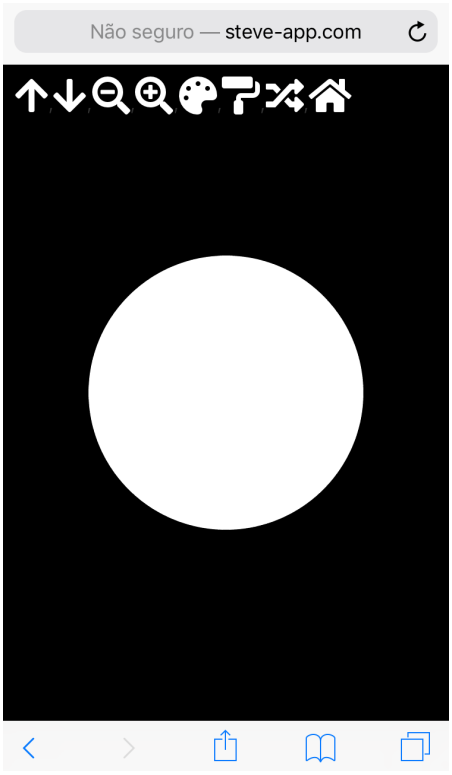

Figure 3. Example of training program: combination of visual stimulation and motor training. The child is required to follow the movement of the ball.

After one year of creation, the Steve App was used in 17 countries around the world (Portugal, United States of America, United Kingdom, Poland, Brazil, Italy, Romania, India, China, Austria, Spain, Canada, Malaysia, Netherlands, Finland, Ireland and Philippines), with more than 250 users in all operative systems. Regarding the 2nd semester of 2020, active sessions of use are expressed in Fig. 4.

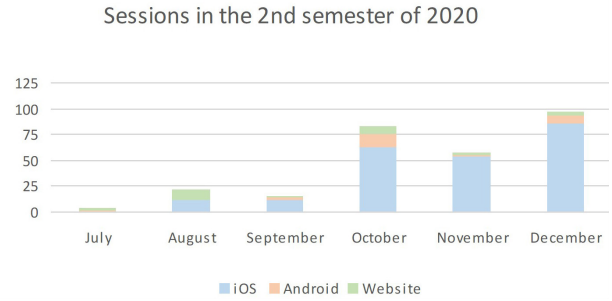

Figure 4. Steve App usage statistics.

DISCUSSION

The main goal of this intervention is to help preserve and optimize residual visual function and to improve the perceptual process in children with CVI. The maximum plasticity of the visual function is considered to occur within the first 2 years of age, therefore the earlier the visual stimulation, the better results will be obtained.[16]

Visual training should be conducted by the doctor during an office visit and requires simultaneously interventions of a team with therapists, special educators, physicians, and caregivers, because a comfortable environment, proper posture and the implementation of some compensatory strategies are fundamental prerequisites to reach better results.[17,18] Therefore, it is essential to involve the last ones into the stimulation program. At first, we must help them to understand the child's disease, difficulties, and requirements, explaining the slow or long reaction time and respecting the child's rest period. The main purpose is to help to recognize the child's wills. Second, we should explain how to properly use the app, according to the needs of each one.

Steve app was designed to help the children to acquire better hand-eye coordination, attention, fixation and eye movements. In consequence, visual perception and recognition could also be improved with visual stimulation training.

We know that visual attention is greater if the stimulus is moving slowly, so, to encourage keeping the visual attention, instead of being static, we adapted some movement and variant sizes of the stimuli. Regarding eye movement training, it is known that horizontal tracking usually developed first, followed by vertical tracking and later, circular tracking,[19] so we insert the option to choose the trajectory of the movement of the object/form. In this item, simultaneously, the child is training tracking and saccadic movements across the midline, important strategies to prevent developing a deviant tactic to avoid the midline area. Regarding the hand-eye coordination and the visual perception, it can be difficult because of a delay and the weakening of the child's reflex functions. To improve this, we applied another functionality that requires more interaction between the child and the app, by the discovery of a stimulus and the active process of touching it, with a following auditory recompense. The idea is to have not a purely visual isolated stimulation, but rather, an enrichment of sensory experiences. Also, everyday objects were implemented to recognition, encouraging visual attention for the surrounding reality.

In conclusion, early interventions in children affected

by CVI is mandatory because it can influence the development of visual pathways and improve residual vision. It is crucial to involve the children and help them to achieve both visual and, as much as possible, other sensory inputs.

This innovation aims to reach not only pediatric ophthalmologists, but all the ophthalmologists, in a harmonious way, when any child with CVI or low vision are observed. As the tool can be accessed anytime and anywhere, being completely free and intuitive, all the physicians, therapists and family members can easily use it with a daily contribution for recovery.

This stimulation work should be done in an optimistic emotional setting that enhances the child's motivations and relationships to improve the rehabilitation process.

Steve app could be a way to help children to learn that the act of looking is something positive and can make their life something better.

ETHICAL DISCLOSURES

Conflicts of interest: The authors have no conflicts of interest to declare.

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