

Protocol

The Effectiveness of a Computer Game-Based Rehabilitation Platform for Children With Cerebral Palsy: Protocol for a Randomized Clinical Trial

Anuprita Kanitkar¹, MScPT; Tony Szturm², PhD; Sanjay Parmar³, PhD; Dorcas BC Gandhi⁴, PT; Gina Ruth Rempel⁵, MD; Gayle Restall², OT, PhD; Monika Sharma⁶, MD; Amitesh Narayan⁷, PhD; Jeyaraj Pandian⁴, MD; Nilashri Naik⁸, PT; Ravi R Savadatti⁹, PhD; Mahesh Appasaheb Kamate¹⁰, DM, MD

¹Applied Health Sciences, University of Manitoba, Winnipeg, MB, Canada

²College of Rehabilitation Sciences, University of Manitoba, Winnipeg, MB, Canada

³SDM College of Medical Sciences and Hospital, Rajiv Gandhi University of Health Sciences, Dharwad, India

⁴Christian Medical College and Hospital, Department of Neurology, Baba Farid University of Health Sciences, Ludhiana, India

⁵Max Rady College of Medicine, Rady Faculty of Health Sciences, Department of Pediatrics and Child Health, University of Manitoba, Winnipeg, MB, Canada

⁶Christian Medical College and Hospital, Department of Pediatrics, Baba Farid University of Health Sciences, Ludhiana, India

⁷Kasturba Medical College, Department of Physiotherapy, Manipal University, Mangalore, India

⁸Department of Physiotherapy, Ushas School for Exceptional Children, Hubli, India

⁹SDM College of Physiotherapy, Rajiv Gandhi University of Health Sciences, Dharwad, India

¹⁰JN Medical College and Hospital, Department of Pediatrics, KLE University, Belgaum, India

Corresponding Author:

Tony Szturm, PhD

College of Rehabilitation Sciences

University of Manitoba

R 106

771 McDermot Ave

Winnipeg, MB, R3E0T6

Canada

Phone: 1 204 787 7747

Fax: 1 204 789 3927

Email: tony.szturm@umanitoba.ca

Abstract

Background: It is difficult to engage young children with cerebral palsy (CP) in repetitive, tedious therapy. As such, there is a need for innovative approaches and tools to motivate these children. We developed the low-cost, computer game-based rehabilitation platform CGR that combines fine manipulation and gross movement exercises with attention and planning game activities appropriate for young children with CP.

Objective: The objective of this study is to provide evidence of the therapeutic value of CGR to improve upper extremity (UE) motor function for children with CP.

Methods: This randomized controlled, single-blind, clinical trial with an active control arm will be conducted at 4 sites. Children diagnosed with CP between the ages of 4 and 10 years old with moderate UE impairments and fine motor control abnormalities will be recruited.

Results: We will test the difference between experimental and control groups using the Quality of Upper Extremity Skills Test (QUEST) and Peabody Developmental Motor Scales, Second Edition (PDMS-2) outcome measures. The parents of the children and the therapist experiences with the interventions and tools will be explored using semi-structured interviews using the qualitative description approach.

Conclusions: This research protocol, if effective, will provide evidence for the therapeutic value and feasibility of CGR in the pediatric rehabilitation of UE function.

Trial Registration: Clinicaltrials.gov NCT02728375; <http://clinicaltrials.gov/ct2/show/NCT02728375> (Archived by WebCite at <http://www.webcitation.org/6qDjvszvh>)

(*JMIR Res Protoc* 2017;6(5):e93) doi:[10.2196/resprot.6846](https://doi.org/10.2196/resprot.6846)

KEYWORDS

repetitive task practice; cerebral palsy; fine motor skills; game-based exercise; randomized controlled trial; upper extremity function

Introduction

Background and Rationale

Canada and India face a growing population of children with cerebral palsy (CP), with the condition occurring in 2 to 4 of every 1000 live births in North America and India, respectively [1-3]. Children with CP have deficits in fine and gross motor skills, often with co-occurring deficits in visual-spatial processing skills [4-6]. The ability to perform functional tasks with the upper extremities (UEs) is an important predictor of success in daily activities and participation in school, leisure, and social activities [7]. Therapy programs designed to improve UE motor and visual-spatial processing skills must strive to maximize neurodevelopmental capacities and prevent secondary disabilities [8,9].

There are different approaches to therapy for children with CP [10-17]. The effectiveness of these programs is proportional to the intensity and amount of training and the task-specificity of the exercise regime [18-21]. For example, constraint-induced movement therapy (CIMT) and hand-arm bimanual intensive therapy (HABIT) are promising rehabilitation programs for restoration of hand-arm function. These treatment approaches stress that both functional demands and repetitive intensive training are important in the rehabilitation of fine motor skills and to restore functional skills. Typically CIMT needs administration of 6 hours a day and the child can use only the affected arm, making bimanual activities impossible to perform. There is growing evidence to support the idea of activity-dependent central nervous system (CNS) plasticity [22]. In addition, the notion is emerging that neural reorganization reflects learning achieved through generating real experiences, applying focused attention, simulating close-to-normal movements, and repetition [23]. However, it is difficult to engage children with CP in therapy for long periods of time and sustain motivation for the intense repetitive task practices. Thus, there is a need for innovative and cost-effective therapeutic approaches and tools that motivate children with CP to complete long-term neurorehabilitation programs and that provide opportunities to improve neurodevelopmental outcomes.

Parents and clinicians rate motivation as the most influential personal characteristic for adherence to therapy and for determining motor and functional outcomes in children with CP [24]. An emerging, promising approach to engaging children in therapy is to incorporate computer games in which a range of learning elements with interactive cognitive challenges help children to positively engage in activities. Studies have provided evidence of the benefits of video games in rehabilitation training and show that well-designed interactive games can improve players' motor skills and visual-spatial processing skills [24-30].

For this purpose, we developed the low-cost, computer-aided, game-based rehabilitation and learning platform CGR [31-37]. CGR combines fine or gross motor exercises and visual-spatial cognitive activities appropriate for children with CP in a game-based format. A motion detecting "Therapy Mouse" (Mobility Research, AZ) will be used as the computer game controller. It is a miniature and wireless plug-n-play computer interface device, which contains firmware and inertial sensors that allow physical motion, specifically instantaneous position, to be translated and interpreted as a standard motion of a Universal Serial Bus (USB) mouse, and which has high fidelity and responsiveness. Because the miniature motion mouse can be easily attached with Velcro to many objects, this approach provides a highly flexible therapy tool applied to fine or gross UE motor skills. Many objects with varied sizes, shapes, weights, surface properties, and functional demands can be used for exercise and for practicing a variety of gross or fine motor skills. Importantly, when the motion mouse is attached to the chosen object fun computer games can be played [8,28,31,36-37]. As CGR allows handling and manipulation of many objects (ie, ones commonly used in daily activities), activity goals can be imbedded in the therapy program. Many inexpensive modern games, "exergames," and brain fitness games now exist that are visually rich, fun, and engaging, include a variety of visual-spatial tasks, and require choice and other planning type activities. Performing goal-directed manipulation tasks through engaging and guided repetition creates experiences crucial to improving the brain's ability to learn [10,37].

Study Objectives

A randomized controlled trial (RCT) with an intention-to-treat is proposed to evaluate the effectiveness of the game-based rehabilitation program on fine manual dexterity, upper limb motor skills, and visual-spatial cognitive functions in children aged 4 to 10 years old diagnosed with CP. This single-blind randomized clinical trial with an active control arm will be conducted at 4 sites. Two groups of children will be examined: one group will receive the experimental game-based program and the other group will receive usual therapy (see [Multimedia Appendix 1](#)). The first hypothesis is that an engaging, game-based UE exercise regime will result in greater improvements in hand-arm function as compared to the usual outpatient physical therapy program. The second hypothesis is that the UE exercise program, which uses computer games having a variety of visual-spatial activities, will result in greater improvements in visuospatial cognitive functions as compared to the usual outpatient physical therapy program.

Study Design

This study will evaluate the feasibility of the procedures such as recruitment, intervention delivery, participant retention, and measurement tools. Semi-structured interviews will be conducted with the parents of the children and with the treating therapists. The broad research questions are: “what were the experiences of the study participants with the game-based and current therapy programs, and on what context were the experiences based?” The qualitative findings of participant's and therapists' experiences will help to identify (1) perceived exercise benefits; (2) difficulties with the exercises and using the technologies; (3) engagement and motivational value of the computer games; (4) personal and environmental factors that influenced doing the exercises; and (5) recommendations and modifications for improving the exercise programs.

Methods

Study Setting

This randomized controlled, single-blind clinical trial with an active control arm will be conducted at the following 4 sites: (1) University of Manitoba and Rehabilitation Centre for Children at the Special Services for Children and Youth (SSCY) Centre (Drs Szturm, Rempel, Restall, and Mrs Kanitkar, Winnipeg, Manitoba, Canada); (2) SDM College of Physiotherapy, Dharwad in collaboration with Usha's School for Exceptional Children, Hubli (Drs Parmar, Savadatti, Kamate, and Naik, Karnataka, India); (3) Christian Medical College (Drs Sharma, Pandian, and Gandhi, Ludhiana, Punjab, India); and (4) Kasturba Medical College (Dr Narayan, Mangalore, Karnataka, India).

Inclusion Criteria

Children diagnosed with CP (N=140) between the ages of 4 and 10 years old with moderate UE impairments and fine motor control abnormalities will be recruited. The following screening tools will be used: (1) Manual Ability Classification System (MACS), level 2 to 3 [38]; (2) Gross Motor Function Classification Scale (GMFCS), levels 2 to 4 [39]; (3) Ashworth scale of spasticity in wrist and fingers, level 0 to 1+ [40]; and (4) the pediatric version of the Mini-Mental State Examination assessment scale, level 17 and above. This will be used to the screen level of cognitive function. For each site, we will use a permuted block randomization scheme stratified by age and level of impairment as measured by the MACS and GMFCS [41].

Exclusion Criteria

Exclusion criteria for the study will be (1) visual or auditory impairment such that they cannot see and interact with the video games; (2) secondary orthopedic complications due to neurodegenerative disease (NDD) or as a result of surgery to the upper limb that may have caused permanent changes in upper limb musculoskeletal structure; (3) recent Botulinum toxin therapy (less than 6 months); (4) seizures, or (5) complex communication disorders.

Procedures and Interventions

Ethical approval was obtained from the health research ethics boards of each site. For each site a permuted block randomization scheme will be used and stratified by age where 4- to 6-year-olds will be one subgroup and 6- to 10-year-olds will be the other subgroup. Each program will take 16 weeks, with 3 45-minute sessions per week. A workshop and uniform training program will be organized at SDM College of Physiotherapy, Dharwad, India for physiotherapists who will provide the assessment and the 2 intervention programs. This will be attended by Dr Szturm and Mrs Anuprita Kanitkar who will organize and coordinate the therapy program. The 2 intervention groups will be treated in all 4 locations limiting biases like contamination. The therapists conducting the assessments will be blinded to group assignment.

Control Group Intervention

The control group (n=70) will receive the usual, comprehensive physical therapy for 45 minutes per session 3 times a week for 16 weeks. The therapy protocols will be individualized for every participant according to their level of impairment and preset goals, based on the principles of intensive repetitive task practice programs such as CIMT and HABIT. These consist of stretching of spastic muscles (activity-based dynamic stretching with child's active involvement to the spastic upper limb muscle, particularly muscles which are required for preparatory techniques will be involved in lengthening) and UE weight bearing exercises (ie, UE weight bearing in fundamental or functional position in the form of scapular and upper thoracic rotation and/or push and pull with a vestibular ball while maintaining corrected scapular positioning). A variety of arm and hand activities will be practiced, such as reaching for rings, removing and putting them back, ball throwing, opening a bottle cap, turning a door knob, clay activities, picking marbles from sand, and putting pellets and pegs into sockets, etc.

Experimental Group Intervention

A typical session for the experimental group (n=70) will consist of stretching exercises followed by the game-based exercise program. Similar to the concept of “shaping,” and consistent with CIMT principles, CGR takes advantage of ergonomic properties of common objects to amplify limited and small amounts of voluntary movement and then allows opportunities for an appropriate switch to objects having more demanding movement requirements or functional demands. CGR allows object properties (size, weight, texture, and surface properties) to be easily manipulated in therapy. This provides graded practice for activities that need to be repeated in daily activities and in play. An important element of the platform is the ability to incorporate movement precision. In this regard, we target finger-hand function and not just transport and/or reaching movements.

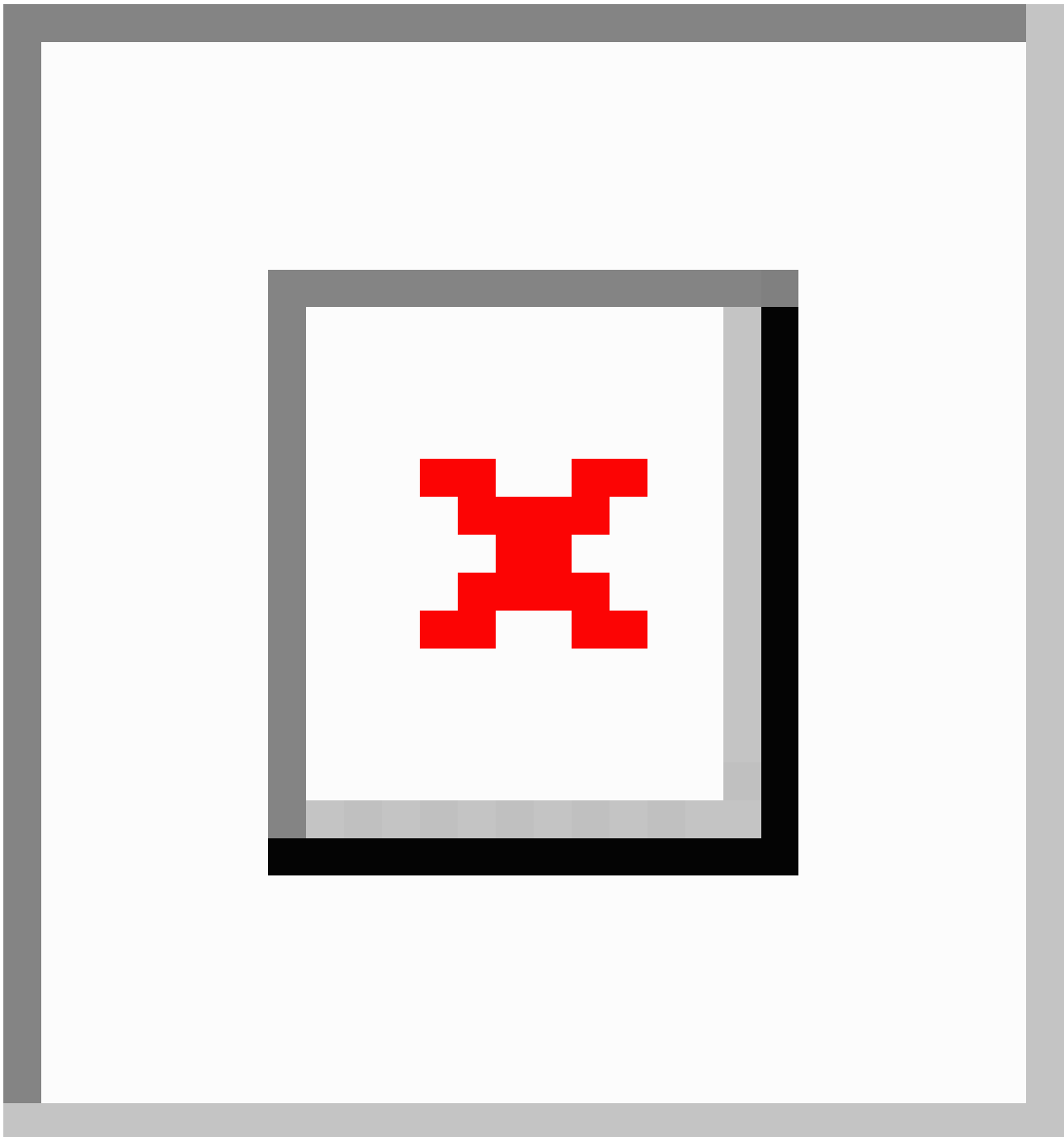
Different computer games require different levels of movement amplitude, speeds, precision levels, as well as repetition and appeal to individual preferences. Furthermore, many inexpensive “off the shelf” computer games have a broad range of visuospatial cognitive content. Knowledge of the therapeutic value (object and games activities) can allow the therapist to

prescribe an integrated program to target specific goals, for example, speed, accuracy, endurance, visuospatial functions, and cognitive inhibition, and to exercise 2 or 3 fingers, the whole hand, and bimanual tasks tailored to individual child abilities.

In a manner similar to interval training, 6 to 8 objects selected for specific therapy goals will be used to play computer games. Objects can be selected for motor skill training of finger/wrist or elbow and shoulder motions, and also of bimanual controls. Each object manipulation exercise will be used for 2 to 4

minutes. A number of possible objects which, when instrumented with the motion mouse, can be used for the game-based exercise program is shown in [Figure 1](#) (see also Szturm et al [31]). Many action and cognitive-type computer games are available to play; these will be selected by the treating therapist based on (1) degree of difficulty; (2) movement amplitude, speed, and accuracy; (3) visual-spatial processing requirement; and (4) personal preferences of the child. Common computer games that will be used in the game-based exercise program are shown in [Textbox 1](#).

Figure 1. Descriptions of the object manipulation tasks and their respective therapy values for assessment and/or treatment. A miniature, wireless motion mouse is attached with Velcro to each object. Each object manipulation task has specific fine or gross motor skill qualities for therapeutic exercise or ergonomic properties.



Textbox 1. Computer games that will be used in the exercise program.

Computer game
1. Aqua Ball and Action Ball.
a. Horizontal, single-axis brick buster with slow to moderate speed, and low to moderate movement precision.
b. Small to moderate number of distracters and simple to complex 2D backgrounds.
2. Jar of marbles and butterfly escape.
a. Horizontal, single-axis matching colors with slow to moderate speed and low to moderate movement precision.
b. Small to moderate number of distracters and simple and moving backgrounds.
3. Owls and bubbles.
a. A single-axis game that requires the player to move the mouse cursor on bubbles to pop them and free the owls to fly away.
4. Hummingbird.
a. A single-axis game that requires the player to move the bird up and down so that it touches the flowers.
5. Feeding frenzy.
a. Two-axis game play with slow motion element and low to moderate movement precision.
b. Moderate to large number of distracters.

Primary Outcome Measures

The Quality of Upper Extremity Skills Test (QUEST) is a commonly used outcome measure that evaluates quality of dissociated movements, UE gross motor function, and object manipulation in children with CP. It consists of 36 tasks evaluated in 4 domains: dissociated movement, grasp, protective extension, and weight bearing. The tool has demonstrated excellent test-retest reliability [42], and through construct validity studies, has been demonstrated as a good measure of UE motor skill [43].

The following subtests of the Peabody Developmental Motor Scale, Second Edition (PDMS-2) will be used: (1) object manipulation (24-item subtest that measures a child's ability to manipulate balls); (2) grasping (a 26-item subtest that measures a child's ability to use his or her hands [44]); and (3) Visual-Motor Integration (VMI) subtest (a 72-item subtest that measures a child's ability to use visual perceptual skills). Both the PDMS-2 fine motor composite score and the VMI subtest score have shown high test-retest reliability and have good construct validity [45,46].

Immediately following the 16-week intervention, a semi-structured interview format will be used to ask parents about the 5 most important activities their child was trying or wanted to do, but was having difficulty performing and/or difficulty in retaining.

Results

We will test the difference between the experimental and control groups on the QUEST and PDMS-2 outcome measures using analysis of covariance (ANCOVA); the dependent variable will be the post-intervention measurement of the outcome and the covariates will be the pre-intervention measurement and group

membership as the between-subjects effect. Residual diagnostics will be carried out for the ANCOVA model and if their normality assumption fails to hold, appropriate transformations of the response, such as logarithmic, will be explored. Based on published data for the primary outcome measures (QUEST and PDMS-2) [37-41], a power analysis was conducted to determine the required sample size to test the difference between the experimental and control groups using the ANCOVA model. We selected the case (QUEST) which gave the largest sample size. Assuming a correlation of at least 0.6 between baseline and final outcome, then with a sample size of 128 and a standard deviation of 25 we will be adequately powered to detect a difference of 10 units with 80% power, and 5% alpha post intervention. We expect an attrition rate of 10% over the study period. Given this, we propose to recruit a sample of 140 children to participate in equal numbers to be randomized to each group. All calculations were made with PROC GLMPOWER of SAS version 9.3 (SAS Institute, Cary, NC).

Feasibility will be evaluated on the basis of the 2010 Thabane et al model [47] which evaluates 4 domains: process, resources, effectiveness, and human and data management. Process evaluates feasibility of key study processes, such as participant recruitment rates, dropout rates, eligibility criteria, and participant retention rates. Resources, such as time taken to complete study assessments and other resource problems, will be reported over the study period by the project site leads from each site and the data will be compiled.

The parents of the children and the therapist experiences with the interventions and tools will be explored using semi-structured interviews using the qualitative description approach. The following open-ended questions will be asked of the children's parents: (1) when you agreed to participate, how did you hope your child would benefit from the therapy program? (2) Were there things about the game (or exercise

therapy program) for your child you liked and things you did not like? (3) What did you think about the computer games your child was asked to play? Did your child enjoy the games? Were there games which your child did not seem to enjoy? (4) Did you feel that this therapy program helped your child? (5) If you were provided with the right setting, would you want your child to continue with these exercises?

The following open-ended questions will be asked of each treating therapist who delivered the game-based therapy program: (1) compared to usual therapy exercises how easy or difficult was it to implement the game exercise program for the children? (2) What kind of difficulties did you face, if any, regarding the use of the motion mouse or other parts of the technology? (3) What qualities did the computer game based intervention possess, if any, that made it more engaging and fun for the children than the conventional protocol? (4) Why would you like to recommend this intervention and technology to your peers, colleagues, and patients? (5) Are there any thoughts, queries, or doubts regarding this treatment method that you would like to express or discuss with us?

The responses of the parents and therapists will be analyzed with content analysis methods using the descriptive as well as interpretative approaches [48,49]. The data collected during the semi-structured interviews will be in the local language. Responses will be transcribed and translated by authorized personnel to organize the data by labelling, structuring, and familiarizing processes. Each participant's data will be reviewed and analyzed by 2 researchers. Their narrative summary will then be sent back to the parents and therapist for review and approval to ensure trustworthiness of the transcribed and summarized data. Direct quotes from parents' and physiotherapists' interviews will be used while writing the descriptive report to illustrate a range of issues faced during the

study, behaviors, experiences, and opposing views of participants and strategies. These will be used to develop general statements and hypotheses, which can be tested in subsequent studies. A second order analysis will take place by creating a coding plan based on the research questions. Once the data is coded and sorted, these responses will be categorized to identify themes. The recurrent themes and response clusters are helpful to build event sequences.

Discussion

Emerging game-based rehabilitation technologies have the potential to improve child participation in repetitive task practice, and therefore, enhance function. The purpose of the study is to provide evidence of the therapeutic value of CGR to improve UE motor function for children with CP. CGR is designed to be used with modern, common computer games, which are low-cost and easily available. Commercial games offer a wide range of levels of precision and movements that vary in speed, amplitude, direction, and accuracy. There is also a wide range of executive cognitive activities available in commercial games for children. It is important to have a large variety of exercise and cognitive activities in games to maintain high levels of motivation and interest among participating children. Knowledge of the therapeutic value (object and games) can allow the therapist to prescribe an integrated program to target specific goals.

The qualitative findings of participants and therapists will help to identify the perceived exercise benefits, any difficulties with the exercises and using the technologies, the engagement and motivational value of the computer games, personal and environmental factors that may have influenced doing the exercises, and any recommendations and modifications for improving the exercise programs.

Acknowledgments

This study was supported by Mitacs Globalink Research Award.

Conflicts of Interest

None declared.

Multimedia Appendix 1

CONSORT flow diagram.

[[PDF File \(Adobe PDF File\), 347KB - resprot_v6i5e93_app1.pdf](#)]

Multimedia Appendix 2

CONSORT checklist.

[[PDF File \(Adobe PDF File\), 46KB - resprot_v6i5e93_app2.pdf](#)]

References

1. Silberberg DH. Neurodevelopmental disorders in India: from epidemiology to public policy. *World Neurology* 2014 Dec;29(6):2-3.
2. Suresh KR, Mark RF. Neurodevelopmental disorders among indian children: needs attention. *Electron Physician* 2012;4(2):493-496.

3. Human Development Unit South Asia Region. The World Bank. 2009. People with disabilities in India: from commitments to outcomes URL: <http://documents.worldbank.org/curated/en/577801468259486686/pdf/502090WP0Peopl1Box0342042B01PUBLIC1.pdf> [WebCite Cache ID 6qRSUusuf]
4. Srivastava RN, Seth R, van Niekerk J. Forms of child abuse and neglect. In: Child Abuse and Neglect: Challenges and Opportunities. India: Jaypee Brothers Medical Publishers; 2013:112-113.
5. Srivastava P, Kumar P. Delhi Psychiatry. 2015 Apr. Disability, its issues and challenges: psychosocial and legal aspects in indian scenario URL: <http://medind.nic.in/daa/t15/i1/daat15i1p195.pdf> [WebCite Cache ID 6qRTCNm55]
6. Office of the Registrar General & Census Commissioner, India. Ministry of Home Affairs, Government of India. Distribution of Disabled in the age-group 0-6 by type of disability, sex and residence for scheduled castes (India & States/UTs) URL: <http://censusindia.gov.in/> [accessed 2017-02-03] [WebCite Cache ID 6o0WW3X6I]
7. Rosenbaum P, Stewart D. The World Health Organization International Classification of Functioning, Disability, and Health: a model to guide clinical thinking, practice and research in the field of cerebral palsy. *Semin Pediatr Neurol* 2004 Mar;11(1):5-10. [Medline: 15132248]
8. Kleim JA. Neural plasticity and neurorehabilitation: teaching the new brain old tricks. *J Commun Disord* 2011;44(5):521-528. [doi: 10.1016/j.jcomdis.2011.04.006] [Medline: 21600589]
9. Hanna SE, Law MC, Rosenbaum PL, King GA, Walter SD, Pollock N, et al. Development of hand function among children with cerebral palsy: growth curve analysis for ages 16 to 70 months. *Dev Med Child Neurol* 2003 Jul;45(7):448-455 [FREE Full text] [Medline: 12828398]
10. Bonnechère B, Jansen B, Omelina L, Degelaen M, Wermenbol V, Rooze M, et al. Can serious games be incorporated with conventional treatment of children with cerebral palsy? A review. *Res Dev Disabil* 2014 Aug;35(8):1899-1913. [doi: 10.1016/j.ridd.2014.04.016] [Medline: 24794289]
11. Sandlund M, Domellöf E, Grip H, Rönnqvist L, Häger CK. Training of goal directed arm movements with motion interactive video games in children with cerebral palsy - a kinematic evaluation. *Dev Neurorehabil* 2014 Oct;17(5):318-326. [doi: 10.3109/17518423.2013.776124] [Medline: 23863100]
12. Chen Y, Lee S, Howard AM. Effect of virtual reality on upper extremity function in children with cerebral palsy: a meta-analysis. *Pediatr Phys Ther* 2014;26(3):289-300. [doi: 10.1097/PEP.000000000000046] [Medline: 24819682]
13. Sakzewski L, Carlson S, Shields N, Ziviani J, Ware RS, Boyd RN. Impact of intensive upper limb rehabilitation on quality of life: a randomized trial in children with unilateral cerebral palsy. *Dev Med Child Neurol* 2012 May;54(5):415-423 [FREE Full text] [doi: 10.1111/j.1469-8749.2012.04272.x] [Medline: 22429002]
14. Aarts PB, Jongerius PH, Geerdink YA, van Limbeek J, Geurts AC. Modified Constraint-Induced Movement Therapy Combined with Bimanual Training (mCIMT-BiT) in children with unilateral spastic cerebral palsy: how are improvements in arm-hand use established? *Res Dev Disabil* 2011;32(1):271-279. [doi: 10.1016/j.ridd.2010.10.008] [Medline: 21051191]
15. Chorna O, Heathcock J, Key A, Noritz G, Carey H, Hamm E, et al. Early childhood constraint therapy for sensory/motor impairment in cerebral palsy: a randomised clinical trial protocol. *BMJ Open* 2015 Dec 07;5(12):e010212 [FREE Full text] [doi: 10.1136/bmjopen-2015-010212] [Medline: 26644127]
16. Odding E, Roebroek ME, Stam HJ. The epidemiology of cerebral palsy: incidence, impairments and risk factors. *Disabil Rehabil* 2006 Feb 28;28(4):183-191. [doi: 10.1080/09638280500158422] [Medline: 16467053]
17. Benfer KA, Jordan R, Bandaranayake S, Finn C, Ware RS, Boyd RN. Motor severity in children with cerebral palsy studied in a high-resource and low-resource country. *Pediatrics* 2014 Dec;134(6):e1594-e1602 [FREE Full text] [doi: 10.1542/peds.2014-1926] [Medline: 25422013]
18. Novak I, McIntyre S, Morgan C, Campbell L, Dark L, Morton N, et al. A systematic review of interventions for children with cerebral palsy: state of the evidence. *Dev Med Child Neurol* 2013 Oct;55(10):885-910 [FREE Full text] [doi: 10.1111/dmcn.12246] [Medline: 23962350]
19. Bodimeade HL, Whittingham K, Lloyd O, Boyd RN. Executive function in children and adolescents with unilateral cerebral palsy. *Dev Med Child Neurol* 2013 Oct;55(10):926-933 [FREE Full text] [doi: 10.1111/dmcn.12195] [Medline: 23809003]
20. Bleyenheuft Y, Gordon AM. Precision grip control, sensory impairments and their interactions in children with hemiplegic cerebral palsy: a systematic review. *Res Dev Disabil* 2013 Sep;34(9):3014-3028 [FREE Full text] [doi: 10.1016/j.ridd.2013.05.047] [Medline: 23816634]
21. van EM, Dallmeijer AJ, van Lith IS, Voorman JM, Becher J. Manual ability and its relationship with daily activities in adolescents with cerebral palsy. *J Rehabil Med* 2010 May;42(5):493-498 [FREE Full text] [doi: 10.2340/16501977-0543] [Medline: 20544163]
22. Cao J, Khan B, Hervey N, Tian F, Delgado MR, Clegg NJ, et al. Evaluation of cortical plasticity in children with cerebral palsy undergoing constraint-induced movement therapy based on functional near-infrared spectroscopy. *J Biomed Opt* 2015 Apr;20(4):046009 [FREE Full text] [doi: 10.1117/1.JBO.20.4.046009] [Medline: 25900145]
23. Bartlett DJ, Palisano RJ. Physical therapists' perceptions of factors influencing the acquisition of motor abilities of children with cerebral palsy: implications for clinical reasoning. *Phys Ther* 2002 Mar;82(3):237-248. [Medline: 11869152]
24. DeLuca SC, Case-Smith J, Stevenson R, Ramey SL. Constraint-induced movement therapy (CIMT) for young children with cerebral palsy: effects of therapeutic dosage. *J Pediatr Rehabil Med* 2012;5(2):133-142. [doi: 10.3233/PRM-2012-0206] [Medline: 22699104]

25. Jannink MJ, van der Wilden GJ, Navis DW, Visser G, Gussinklo J, Ijzerman M. A low-cost video game applied for training of upper extremity function in children with cerebral palsy: a pilot study. *Cyberpsychol Behav* 2008 Feb;11(1):27-32. [doi: [10.1089/cpb.2007.0014](https://doi.org/10.1089/cpb.2007.0014)] [Medline: [18275309](https://pubmed.ncbi.nlm.nih.gov/18275309/)]
26. Rios DC, Gilbertson T, McCoy SW, Price R, Gutman K, Miller KE, et al. NeuroGame Therapy to improve wrist control in children with cerebral palsy: a case series. *Dev Neurorehabil* 2013 Dec;16(6):398-409. [doi: [10.3109/17518423.2013.766818](https://doi.org/10.3109/17518423.2013.766818)] [Medline: [23617243](https://pubmed.ncbi.nlm.nih.gov/23617243/)]
27. Yoo JW, Lee DR, Sim YJ, You JH, Kim CJ. Effects of innovative virtual reality game and EMG biofeedback on neuromotor control in cerebral palsy. *Biomed Mater Eng* 2014;24(6):3613-3618. [doi: [10.3233/BME-141188](https://doi.org/10.3233/BME-141188)] [Medline: [25227075](https://pubmed.ncbi.nlm.nih.gov/25227075/)]
28. Weiss PL, Tirosch E, Fehlings D. Role of virtual reality for cerebral palsy management. *J Child Neurol* 2014 Aug;29(8):1119-1124. [doi: [10.1177/0883073814533007](https://doi.org/10.1177/0883073814533007)] [Medline: [24799367](https://pubmed.ncbi.nlm.nih.gov/24799367/)]
29. Akhutina T, Foreman N, Krichevets A, Matikka L, Narhi V, Pylaeva N, et al. Improving spatial functioning in children with cerebral palsy using computerized and traditional game tasks. *Disabil Rehabil* 2003 Dec 16;25(24):1361-1371. [doi: [10.1080/09638280310001616358](https://doi.org/10.1080/09638280310001616358)] [Medline: [14660204](https://pubmed.ncbi.nlm.nih.gov/14660204/)]
30. Klingberg T, Fernell E, Olesen PJ, Johnson M, Gustafsson P, Dahlström K, et al. Computerized training of working memory in children with ADHD--a randomized, controlled trial. *J Am Acad Child Adolesc Psychiatry* 2005 Feb;44(2):177-186. [doi: [10.1097/00004583-200502000-00010](https://doi.org/10.1097/00004583-200502000-00010)] [Medline: [15689731](https://pubmed.ncbi.nlm.nih.gov/15689731/)]
31. Szturm T, Peters JF, Otto C, Kapadia N, Desai A. Task-specific rehabilitation of finger-hand function using interactive computer gaming. *Arch Phys Med Rehabil* 2008 Nov;89(11):2213-2217. [doi: [10.1016/j.apmr.2008.04.021](https://doi.org/10.1016/j.apmr.2008.04.021)] [Medline: [18996252](https://pubmed.ncbi.nlm.nih.gov/18996252/)]
32. Andersen Hammond ER, Shay BL, Szturm T. Objective evaluation of fine motor manipulation-a new clinical tool. *J Hand Ther* 2009;22(1):28-35; quiz 36. [doi: [10.1197/j.jht.2008.06.006](https://doi.org/10.1197/j.jht.2008.06.006)] [Medline: [18950989](https://pubmed.ncbi.nlm.nih.gov/18950989/)]
33. Peters JF, Szturm T, Borkowski M, Lockery D, Ramanna S, Shay B. Wireless adaptive therapeutic telegaming in a pervasive computing environment. In: *Pervasive Computing: Innovations in Intelligent Multimedia and Applications*. London: Springer; 2009:3-28.
34. Lockery D, Peters JF, Ramanna S, Shay BL, Szturm T. Store-and-feedforward adaptive gaming system for hand-finger motion tracking in telerehabilitation. *IEEE Trans Inf Technol Biomed* 2011 May;15(3):467-473. [doi: [10.1109/TITB.2011.2125976](https://doi.org/10.1109/TITB.2011.2125976)] [Medline: [21536526](https://pubmed.ncbi.nlm.nih.gov/21536526/)]
35. Srikesavan CS, Shay B, Szturm T. Test-retest reliability and convergent validity of a computer based hand function test protocol in people with arthritis. *Open Orthop J* 2015;9:57-67 [FREE Full text] [doi: [10.2174/1874325001509010057](https://doi.org/10.2174/1874325001509010057)] [Medline: [25861406](https://pubmed.ncbi.nlm.nih.gov/25861406/)]
36. Szturm T, Polyzoi E, Marotta J, Srikesavan CS. An in-school-based program of combined fine motor exercise and educational activities for children with neurodevelopmental disorders. *Games Health J* 2014 Dec;3(6):326-332. [doi: [10.1089/g4h.2014.0051](https://doi.org/10.1089/g4h.2014.0051)] [Medline: [26192639](https://pubmed.ncbi.nlm.nih.gov/26192639/)]
37. Srikesavan CS, Shay B, Szturm T. Task-oriented training with computer games for people with rheumatoid arthritis or hand osteoarthritis: a feasibility randomized controlled trial. *Games Health J* 2016 Sep 13. [doi: [10.1089/g4h.2016.0005](https://doi.org/10.1089/g4h.2016.0005)] [Medline: [27623532](https://pubmed.ncbi.nlm.nih.gov/27623532/)]
38. Öhrvall AM, Krumlinde-Sundholm L, Eliasson A. Exploration of the relationship between the Manual Ability Classification System and hand-function measures of capacity and performance. *Disabil Rehabil* 2013 Jun;35(11):913-918. [doi: [10.3109/09638288.2012.714051](https://doi.org/10.3109/09638288.2012.714051)] [Medline: [22992179](https://pubmed.ncbi.nlm.nih.gov/22992179/)]
39. Bodkin AW, Robinson C, Perales FP. Reliability and validity of the gross motor function classification system for cerebral palsy. *Pediatr Phys Ther* 2003;15(4):247-252. [doi: [10.1097/01.PEP.0000096384.19136.02](https://doi.org/10.1097/01.PEP.0000096384.19136.02)] [Medline: [17057460](https://pubmed.ncbi.nlm.nih.gov/17057460/)]
40. Bohannon RW, Smith MB. Interrater reliability of a modified Ashworth scale of muscle spasticity. *Phys Ther* 1987 Feb;67(2):206-207. [Medline: [3809245](https://pubmed.ncbi.nlm.nih.gov/3809245/)]
41. Ouvrier RA, Goldsmith RF, Ouvrier S, Williams IC. The value of the Mini-Mental State Examination in childhood: a preliminary study. *J Child Neurol* 1993 Apr;8(2):145-148. [doi: [10.1177/088307389300800206](https://doi.org/10.1177/088307389300800206)] [Medline: [8505476](https://pubmed.ncbi.nlm.nih.gov/8505476/)]
42. Haga N, van der Heijden-Maessen HC, van Hoorn JF, Boonstra AM, Hadders-Algra M. Test-retest and inter- and intrareliability of the quality of the upper-extremity skills test in preschool-age children with cerebral palsy. *Arch Phys Med Rehabil* 2007 Dec;88(12):1686-1689. [doi: [10.1016/j.apmr.2007.07.030](https://doi.org/10.1016/j.apmr.2007.07.030)] [Medline: [18047886](https://pubmed.ncbi.nlm.nih.gov/18047886/)]
43. Thorley M, Lannin N, Cusick A, Novak I, Boyd R. Construct validity of the Quality of Upper Extremity Skills Test for children with cerebral palsy. *Dev Med Child Neurol* 2012 Nov;54(11):1037-1043 [FREE Full text] [doi: [10.1111/j.1469-8749.2012.04368.x](https://doi.org/10.1111/j.1469-8749.2012.04368.x)] [Medline: [22845645](https://pubmed.ncbi.nlm.nih.gov/22845645/)]
44. Tavasoli A, Azimi P, Montazari A. Reliability and validity of the Peabody Developmental Motor Scales-second edition for assessing motor development of low birth weight preterm infants. *Pediatr Neurol* 2014 Oct;51(4):522-526. [doi: [10.1016/j.pediatrneurol.2014.06.010](https://doi.org/10.1016/j.pediatrneurol.2014.06.010)] [Medline: [25266615](https://pubmed.ncbi.nlm.nih.gov/25266615/)]
45. Wang H, Liao H, Hsieh C. Reliability, sensitivity to change, and responsiveness of the peabody developmental motor scales-second edition for children with cerebral palsy. *Phys Ther* 2006 Oct;86(10):1351-1359. [doi: [10.2522/ptj.20050259](https://doi.org/10.2522/ptj.20050259)] [Medline: [17012639](https://pubmed.ncbi.nlm.nih.gov/17012639/)]
46. van Hartingsveldt MJ, Cup EH, Oostendorp RA. Reliability and validity of the fine motor scale of the Peabody Developmental Motor Scales-2. *Occup Ther Int* 2005;12(1):1-13. [Medline: [15962696](https://pubmed.ncbi.nlm.nih.gov/15962696/)]

47. Thabane L, Ma J, Chu R, Cheng J, Ismaila A, Rios LP, et al. A tutorial on pilot studies: the what, why and how. *BMC Med Res Methodol* 2010 Jan 06;10:1 [[FREE Full text](#)] [doi: [10.1186/1471-2288-10-1](https://doi.org/10.1186/1471-2288-10-1)] [Medline: [20053272](#)]
48. Neergaard MA, Olesen F, Andersen RS, Sondergaard J. Qualitative description - the poor cousin of health research? *BMC Med Res Methodol* 2009 Jul 16;9:52 [[FREE Full text](#)] [doi: [10.1186/1471-2288-9-52](https://doi.org/10.1186/1471-2288-9-52)] [Medline: [19607668](#)]
49. Sandelowski M. What's in a name? Qualitative description revisited. *Res Nurs Health* 2010 Feb;33(1):77-84. [doi: [10.1002/nur.20362](https://doi.org/10.1002/nur.20362)] [Medline: [20014004](#)]

Abbreviations

ANCOVA: analysis of covariance
CIMT: constraint-induced movement therapy
CP: cerebral palsy
GMFCS: Gross Motor Function Classification Scale
HABIT: hand-arm bimanual intensive therapy
MACS: Manual Ability Classification System
PDMS-2: Peabody Developmental Motor Scale, Second Edition
QUEST: Quality of Upper Extremity Skills Test
UE: upper extremities
VMI: Visual-Motor Integration

Edited by G Eysenbach; submitted 21.10.16; peer-reviewed by DP Karlsson, S DeLuca; comments to author 05.01.17; revised version received 03.02.17; accepted 03.02.17; published 18.05.17

Please cite as:

Kanitkar A, Szturm T, Parmar S, Gandhi DBC, Rempel GR, Restall G, Sharma M, Narayan A, Pandian J, Naik N, Savadatti RR, Kamate MA

The Effectiveness of a Computer Game-Based Rehabilitation Platform for Children With Cerebral Palsy: Protocol for a Randomized Clinical Trial

JMIR Res Protoc 2017;6(5):e93

URL: <http://www.researchprotocols.org/2017/5/e93/>

doi: [10.2196/resprot.6846](https://doi.org/10.2196/resprot.6846)

PMID: [28526673](https://pubmed.ncbi.nlm.nih.gov/28526673/)

©Anuprita Kanitkar, Tony Szturm, Sanjay Parmar, Dorcas BC Gandhi, Gina Ruth Rempel, Gayle Restall, Monika Sharma, Amitesh Narayan, Jeyaraj Pandian, Nilashri Naik, Ravi R Savadatti, Mahesh Appasaheb Kamate. Originally published in *JMIR Research Protocols* (<http://www.researchprotocols.org>), 18.05.2017. This is an open-access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/2.0/>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work, first published in *JMIR Research Protocols*, is properly cited. The complete bibliographic information, a link to the original publication on <http://www.researchprotocols.org>, as well as this copyright and license information must be included.