ABSTRACT

Children with congenital heart disease (CHD) have deficits in executive functioning and heightened anxiety. Behavioral interventions delivered via technology can improve both cognitive and emotional functioning in youth. Further, data indicate that martial arts and cognitive-behavioral strategies are especially beneficial at enhancing executive functioning and lowering anxiety in children via the combination of exercise, mindfulness, and focus. There is a gap in the literature as to whether martial arts combined with cognitive-behavioral strategies might be taught via technology, and whether this intervention might improve functioning in youth with CHD.

Our goal is to develop a prototype of MartialHearts, an interactive taekwondo and cognitive-behavioral skills game to improve mindfulness, executive functioning, and anxiety for children with CHD. Our central hypothesis is that children playing MartialHearts will demonstrate improved mindfulness, better executive functioning, and lower anxiety than children not receiving the intervention.

Our objectives include: 1) develop a prototype of MartialHearts, an interactive video game that improves mindfulness, executive functioning, and anxiety; 2) conduct a pilot comparison of MartialHearts and a control condition on functioning in youth with CHD; 3) obtain data to successfully compete for federal funds to comprehensively evaluate a more sophisticated version of MartialHearts.

We hope to acquire evidence that incorporating cognitive-behavioral strategies with a mindfulness-based exercise program can improve functioning across domains in youth. Our long-term aims are to use this program to meet the needs of a variety of populations that show executive function, anxiety, and related deficits (e.g., children with ADHD, children from impoverished backgrounds).


**SIGNIFICANCE**

Data indicate that children with congenital heart disease (CHD) show deficits in executive functioning (e.g., short-term memory, attention, impulse control, planning; Miatton, Wolf, Francois, Thery, & Vingerhoets, 2007) and elevations in anxiety (Gupta, Giuffre, Crawford, & Waters, 1998). Executive functioning deficits and anxiety each predict poor academic functioning and socio-emotional adjustment (Biederman et al., 2004; Blair & Razza, 2007; Seipp, 1991; Wray & Sensky, 1999). Research suggests that therapeutic interventions delivered via technology, such as interactive computer games or web-based cognitive-behavioral therapy, can efficiently and cost-effectively improve executive functioning and decrease anxiety (Barak, Hen, Boniel-Nissim, & Shapira, 2008; Bergman-Nutley et al., 2011; Cushing & Steele, 2010; Holmes, Gathercole, & Dunning, 2009; Holmes et al., 2010). In addition, data indicate that martial arts, which combine exercise with mindfulness strategies, might be especially beneficial for improving executive functioning and decreasing anxiety in youth (Baron & Faubert, 2005; Diamond & Lee 2011; Lakes & Hoyt, 2004). Based on extant data and an evidence-based model (Diamond, 2012), we propose a model detailing how an integrated martial arts and cognitive intervention might improve executive functioning and decrease anxiety in youth with CHD (Figure 1).

Our goal is to develop a prototype proof-of-concept version of MartialHearts, an interactive taekwondo and cognitive-behavioral strategies game to improve executive functioning and decrease anxiety in children with CHD. Our central hypothesis is that children who complete the MartialHearts intervention will demonstrate improvement on measures of executive functioning and anxiety. These pilot data will allow us to compete for a large national grant to fund a more extensive version of MartialHearts and to conduct a more comprehensive evaluation of its impact on children’s functioning.

**Aim 1. Develop a prototype of MartialHearts, an interactive, computerized taekwondo game that improves mindfulness, executive functioning, and anxiety in children.** We will develop, with systematic patient involvement, a prototype version of MartialHearts and evaluate its usability. We hypothesize that quantitative and qualitative measures will show that MartialHearts is easy to use, engaging, and rated favorably by children with CHD and their parents.
Aim 2. Test the hypothesis that children who complete an intervention using a prototype of MartialHearts will show greater improvements in mindfulness, executive functioning, and anxiety than age-matched controls. Children’s executive functioning and anxiety will be assessed via pre- and post-intervention measures. It is expected that children exposed to MartialHearts will have greater pre- to post-treatment change scores on executive functioning and anxiety than children in the age-matched control condition.

Aim 3. Assess patient and parent satisfaction and solicit recommendations for further development of MartialHearts. Qualitative interviews will be conducted with study participants to assess their satisfaction with MartialHearts and to gather their input regarding further improvements that can be made before implementing a larger randomized clinical trial.

Impact. Achieving our aims will introduce an application to improve executive functioning and anxiety in CHD populations; studies have shown that executive functioning proficiency and decreased anxiety in childhood predict a multitude of positive outcomes including better academic performance, lower incarceration rates, decreased substance dependence, and better overall health (e.g., Moffitt et al., 2011). This program could eventually be used to meet the needs of a wide variety of populations that show executive function deficits (i.e., children with ADHD, children from impoverished backgrounds) and/or anxiety problems. Finally, our program will demonstrate how information technology can improve the effectiveness, efficiency, and accessibility of comprehensive training to improve functioning in children. Our program of research and planned studies share aims with HIP to provide high quality, cost-efficient, and widely accessible healthcare to pediatric patients.

APPROACH (Table 1)

Aim 1. Develop a Prototype of MartialHearts

Participants. 6 participants (6- to 12-year-olds with CHD) will be involved in the development of MartialHearts.

Measures.

Family Background Information. Parents will complete the Family Information Form, which assesses demographic information including parent’s relation to child, gender, age, ethnicity, race, education, and income; and child’s age, gender, ethnicity, race, and relevant medical history.

Qualitative Interviews. Participants will engage in individual semi-structured interviews about MartialHearts until theoretical saturation is reached (Glaser and Strauss, 1967), at which point no new narratives are emerging from the semi-structured interviews. All interviews and field notes will be audiotaped and subsequently transcribed by research assistants. The data from the interviews will be used to refine MartialHearts.

Game Development and Refinement. Given the high cost of designing a computer game, we plan to develop a very basic prototype that interfaces with the Microsoft Kinect for Windows system. The Kinect motion capture system will allow us to track participant movement and game responses through a laptop. However, this pilot will be rudimentary in terms of motion capture; we will not attempt to do full body accurate motion capture, but rather track whether a particular quadrant in our coordinate frame has been activated by physical motion. The pilot data from this project will allow us to compete for a larger grant to build a more complete and comprehensive game for Kinect that would allow us to capture more comprehensive motion data, track accuracy of technique, expand upon visual aspects and mechanics of the game, and conduct a more extensive scientific evaluation.

The initial development of our MartialHearts prototype will be based on current best practices in game-based computerized training for decreasing anxiety and improving executive functioning (e.g., Holmes, Gathercole, & Dunning, 2009; Holmes et al., 2010). These games, which make progressively greater demands on working memory and attentional control, will be adapted to deliver such demands via taekwondo training. Thus, MartialHearts will comprehensively challenge executive functions and encourage mindfulness and anxiety management through structured training and practice of instructed skills. This prototype version of MartialHearts will begin with an instructional video in which a black belt taekwondo instructor demonstrates...
specific moves and asks that the child complete each move. The child will be told that there will be objects on the computer screen to virtually “touch” when completing a move. The quadrants (9 total quadrants) on the screen will correspond to the real space around the child (e.g., the lower right quadrant of the computer screen might correspond to a right low kick, the upper left quadrant will correspond to an upper arm movement).

At the outset of the game, the child will be taught cognitive-behavioral coping techniques (e.g., mindfulness, relaxation, deep breathing) as part of the initial taekwondo training, which will be a video of a taekwondo expert trainer on the computer screen. The child will then be taught structured taekwondo movements (e.g., horse stance and reverse punch) and will be asked to memorize a number for each movement. The game will then show a sequence of shapes that each appear in one of the 9 quadrants on the computer screen, which correspond to real space around the child. In the center of the screen will be a figure representing the child and mirroring the movement of the child. The child will be prompted to respond with the correct movement (indicated by a number); this movement in real space will “break” the shape in the correct on-screen quadrant (see image). Feedback on the screen will show the figure breaking the shapes in correspondence with the child’s movement. This game has similarities to the simple yet popular Fruit Ninja game. Successful completion of the sequence will advance the child to the next level and provide a score. Incorporating increasing challenge in the game has been shown to improve executive functions (Bergman-Nutley, 2011). The total game will span approximately 30 minutes. The child will receive a score indicating accuracy in “breaking” the shapes in the correct quadrants. The game will track and store activity, reaction time, and accuracy as additional data. Our GTRI team has successfully created games that interface with the Kinect system on prior projects. In addition to expertise in game development with the Kinect system, the team includes a GT game developer and computer engineer who is also a black belt martial artist who has taught taekwondo for years.

**Aims 2 & 3. Conduct a MartialHearts Randomized Control Trial and Evaluate the Effectiveness of MartialHearts for Improving Patient Mindfulness, Executive Functioning, and Anxiety.**

**Hypotheses.** We hypothesize that children using MartialHearts will have greater pre- to post-treatment change scores on measures of mindfulness, executive functioning, and anxiety than children in the age-matched control condition.

**Design.** We will use a pilot feasibility randomized controlled trial (RCT) to test Aim 2 hypotheses. Our pilot RCT will adhere to the guidelines detailed outlined by the CONSORT statement (Altman et al., 2001; Moher, Schulz & Altman, 2001; Stinson, McGrath, & Yamada, 2003).

**Participants.** As this is a pilot project, we will enroll a sufficient number of participants to either a) detect a large effect size or b) identify the necessary sample needed to detect a small or moderate effect size in a larger randomized trial federal grant application. Thus, we aim to enroll 20 participants (10 per condition). We intend to have 5 MartialHearts systems, and therefore we will conduct the study in two waves. All children at CHOA Egleston Cardiac clinic identified to have executive functioning and anxiety issues (i.e., impaired planning, attention, concentration, attention, short-term memory, anxiety; referred for neuropsychological evaluation) between the ages of 6 and 12 years will be eligible to participate in the study. Approximately 250 patients meet these inclusion criteria in our setting annually, and our goal of enrolling 20 participants over 13 months should be easily attained.

**Measures.**

**Family Background Information.** Parents will complete the Family Information Form (see Aim 1)

**Mindfulness.** Studies incorporating mindfulness-based interventions have found that increases in mindfulness are related to improved attention, emotion regulation, and social relationships in children. Given
our goal to incorporate mindfulness components into our taekwondo intervention, mindfulness will be measured pre-and-post intervention using the Child and Adolescent Mindfulness Measures (CAMM; Greco, Baer, & Smith, 2011). The CAMM was developed to measure mindfulness in children and adults and has 10 items that are rated on a 5-point scale. The CAMM has been shown to be positively related to quality of life, social skills and academic performance, and negatively related to somatic complaints, externalizing symptoms, and internalizing symptoms such as anxiety (Greco et al. 2011).

**Child Executive Functioning.** Pre-and-post- intervention measures of executive functioning will be assessed using the Digit Span Forward (DSF) and Backward (DSB) subtests from the Wechsler Intelligence Scale for Children- Fourth Edition (WISC-IV; Wechsler, 2003). The Word List Interference task from the NEPSY-II will also be used to assess verbal working memory (Korkman, Kirk, & Kemp, 2007).

**Anxiety.** Both mindfulness and varied exercise interventions have been shown to decrease anxiety in varied child samples, including those with medical conditions, in whom anxiety is commonly elevated (Field, 2012). We will therefore measure child anxiety pre- and post-intervention, using the Revised Children’s Manifest Anxiety Scale 2nd Edition (RCMAS-2), which is a widely used and well-validated self-report measure normed on children from 6-16 years of age (Reynolds & Richmond, 2008), and the Achenbach System of Empirically Based Assessment (ASEBA; Achenbach, 2009), a psychometrically strong parent- and child-report instrument that yields multiple anxiety-related subscale scores for youths from preschool through high school.

**Satisfaction.** At the conclusion of the MartialHearts Randomized control trial, the Treatment Satisfaction Inventory (TSI) will evaluate children’s and parents’ satisfaction with MartialHearts, as well as with Exercise-Only and Control conditions. The TSI is a 10-item measure querying participants’ about their satisfaction with the procedural preparation. Each question is answered using a scale ranging from “Strongly Agree” (1) to “Strongly Disagree” (5). The TSI was based on the Treatment Evaluation Inventory–Short Form (TEI-SF; Kelley, Heffer, Gresham, & Elliott, 1989), a validated measure of parent and staff satisfaction with pediatric interventions. Given that the TEI-SF is not specific to medically-related interventions, the TSI was developed.

**Qualitative interviews.** At the post-study check-in, 5 patients chosen randomly from the MartialHearts study condition will be interviewed concerning their experience. Participants will be prompted to discuss any feelings they had/have about the MartialHearts training and about any improvements that can be made. Questions will be asked using age-appropriate language to ensure participant understanding.

**Procedure.** See the flow chart to the right, which provides an overview of the procedures for Aim 2. The CHOA Neuropsychology clinic receptionist will direct interested families to a researcher who will describe the study, obtain consent and assent, and administer baseline measures. Families will be randomized to either the MartialHearts or standard care (control) groups, which are described below. Given our relatively small sample, we will use the urn randomization (Stout, Wirtz, Carbonari, & Del Boca, 1994) to balance groups by age and baseline executive functioning scores.

**MartialHearts condition.** Following completion of baseline measures at the clinic, children assigned to the MartialHearts group will meet with a trained instructor for 20 minutes to learn basic taekwondo breathing technique and numbered movements. They will also complete one training session with the Kinect system while the research assistant observes. Participants will be instructed to engage in MartialHearts training for 5 30-minute sessions throughout the week, for the next 6 weeks. Their participation will be tracked and recorded by the MartialHearts system.
**Control condition.** After completion of baseline measures, children in the control condition will be asked to continue daily life as normal and to return in 6-weeks for a follow-up visit.

Approximately 6 weeks following initial baseline measures, children in the MartialHearts and Control conditions will return to the clinic for post mindfulness, executive functioning, and anxiety assessments.

**Data Analyses, Anticipated Results, and Interpretation.** Preliminary analyses will be conducted to determine whether demographic variables (e.g., age, medical history) are related to study measures.

Primary analysis will use 2 (group) x 2 (time point) Analyses of Variance (ANOVAs) to compare MartialHearts and Control participants on mindfulness, executive functioning, and anxiety. We expect that all participants will show equal deficits in executive functioning and elevations in anxiety at baseline, that Martial Hearts participants will show greater improvements in mindfulness, executive functioning, and anxiety than the Control participants over time (see hypothesized results in figure on right). We expect that ANOVAs will show participants in MartialHearts to be more satisfied than Control participants.

The results of this pilot project will provide preliminary evidence for the efficacy of our intervention, which will support our application for a larger federally-funded randomized control trial.

**Table 1. Project Timeline**

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![Graph showingExecutive Dysfunction](image)
MartialHearts: An Interactive Taekwondo Game Targeting Executive Functioning and Anxiety in Children with Congenital Cardiac Disease

REFERENCES


MartialHearts: An Interactive Taekwondo Game Targeting Executive Functioning and Anxiety in Children with Congenital Cardiac Disease

RESEARCH TEAM

The research team has the unique expertise, prior research experience, and established collaborations to ensure the success of the innovative proposed project. The team includes scientific experts from Georgia State University (GSU), Emory University, Children’s Healthcare of Atlanta (GHOA), and Georgia Institute of Technology (GT). The personnel are briefly highlighted below.

Cohen (Primary Investigator; GSU; CHOA). Lindsey Cohen, Ph.D., will serve as the primary investigator and his core responsibilities will be to oversee the entire project and work closely with collaborators and research assistants via regular meetings. In terms of qualifications, Dr. Cohen has served as PI on 2 prior federally-funded projects involving the development and evaluation of technological interventions to decrease distress and increase coping in children facing medical stressors. Dr. Cohen is currently working on third federally-funded project in this same area. This current project – creating and testing a game to prepare children for radiation therapy – involves collaborators from Emory, CHOA, and GT and has considerable technological and methodological overlap with the current proposal. Dr. Cohen has collaborated with all of the other personnel on the project, and it is expected that the current proposed project will be successful and will provide the necessary data to obtain federal funding to conduct a more extensive evaluation of a more refined version of the game.

Tone (GSU). Erin Tone, Ph.D., is a clinical neuropsychologist with expertise in assessing and treating anxiety in children. Dr. Tone will be instrumental in the measurement and intervention development for both executive functioning and anxiety.

Masuda (GSU). Akihiko Masuda, Ph.D., is a clinical psychologist with expertise in assessing and conducting treatment to improve mindfulness. In addition, Dr. Masuda has conducted research targeting mindfulness and centering with pediatric populations.

Swartout (GSU). Kevin Swartout, Ph.D., is a community psychologist with expertise in both qualitative and quantitative methodology and statistics. He will be instrumental in systematically obtaining feedback from patients to guide development of the game.

Mahle (Emory/CHOA). William Mahle, M.D., is professor of pediatrics and medical director in the Sibley Heart Center. He has conducted numerous studies with patients with congenital heart defects and will be the lead around the medical considerations with the population.

Aylward (Emory/CHOA). Brandon Aylward, Ph.D., is an assistant professor of pediatrics, clinical psychologist, and works in the Sibley Heart Center. He has conducted prior research developing technology for children with congenital heart defects. He will be a key partner in integrating the technology with the unique needs of the pediatric cardiac population.

Hardin (GT). Charles Hardin is a researcher at Georgia Tech Research Institute and he has developed a number of games involving motion capture analysis as will be used in the current proposal. His programing, engineering, and game development technological skills will be key in the current proposal.

Parise (GT). Brian Parise is a research scientist at the Georgia Tech Research Institute and he has ample experience developing games for pediatric populations. In addition, he has previously
conducted a study where he created a game that interfaced with the Kinect system for pediatric patients at Emory/CHOA (i.e., Run4It). Lastly, Dr. Parise has a 4th degree black belt in taekwondo and has served as an instructor of taekwondo for years. He is a key team member as he has the technological and personal experience and expertise to create a taekwondo game for children.