Evaluation of the Hardy Brain Camp

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August 2012

Prepared for the Boys and Girls Club of Greater Oxnard and Port Hueneme

Executive Summary

This was an evaluation of one of the Hardy Brain Training Programs—Hardy Brain Camp—designed for the Boys And Girls Club of America. All participants in this study were members of the Boys and Girls Club at a southern California elementary school. The purpose of this study was to determine if the Hardy Brain Camp improved cognitive skills, such as processing speed, and achievement measures, such as reading fluency and math fluency.

The theoretical underpinnings of Hardy Brain Training are that learning improves when processing speed, perceptual-motor, sensory, and cognitive skills improve. The Hardy Brain Training is a two-part training system: 1) a movement to a beat—millisecond timing training (MTT) and 2) a movement to a beat plus a cognitive component—ball bounce activity (Ball Training). In the millisecond timing training participants clap or tap to the beat of the metronome and use both visual and auditory feedback to improve their millisecond timing and motor planning and sequencing. The metronome training is an individualized, modified metronome training using Interactive Metronome Training equipment. In the ball bounce activity, participants bounce a ball through a series of movements while skip counting.

- 62 elementary students between 2nd and 5th grade were separated into 3 experimental groups: Control, MTT alone, and MTT and Ball Training. Before and after the 20 session training period, all participants were given measures of processing speed, reading fluency, and math fluency from the Woodcock Johnson battery of tests. At the end of this training period, three students were excluded and the rest were analyzed for improvement on the tests given.
- In all three measures the individuals with training improved over those without training. Following are the results of the study in terms of age equivalents, when divided into experimental group:
  - Processing Speed had the largest statistically significant changes with an average improvement of 2 years 9.5 months in the MTT and Ball group, 1 year 5.5 months in the MTT group, and 11.5 months in the control group.
  - Math fluency had the second biggest changes with an average improvement of 1 year, 7 months in the MTT and Ball group, 8 months in the MTT group, and 3.5 months in the control group.
  - Reading fluency had an average change of 7.5 months in the MTT and Ball group, 7 months in the MTT group and 1.5 months in the control group.

These results of analysis suggest that the Hardy Brain Training provided moderate improvement in processing speed and smaller improvements in reading and math fluency, based on statistical criteria. This evaluation cannot determine if these changes will be long-term or make academic differences in the participants; to explore such effects would require additional longitudinal measurement strategies.

Evaluation of the Hardy Brain Camp

Introduction

The Hardy Brain Training method's goal is to improve non-academic measures such as motor timing, sequencing, and integration through direct training in order to improve cognitive functioning. Studies such as, "Effects of motor sequence training on attentional performance in ADHD children," (Leisman & Melillo, 2010) and "Improvements in interval time tracking and effects on reading achievement," (Taub, McGrew, & Keith, 2007), provide evidence that this method can be successful. There are strong connections between regions in the brain that regulate motor coordination functioning, such as the posterior parietal cortex and the basal ganglia, and centers of cognitive processing abilities, such as working memory and the ability to inhibit information—in the dorsolateral frontal cortex and prefrontal cortex (Willingham, 1999). The strong connections between these areas suggest that the better integrated they are together, the more successful the individual will be with both of these things. Thus, the goal of Sherrie Hardy's program is to strengthen motor coordination and intentionally improve motor planning, sequencing, and integration to develop cognitive functioning.

In the Hardy Brain Camp, Sherrie Hardy has created a regimen that works with both fine and gross motor processing skills, motor timing, and motor inhibition. This is done through the combination of two activities. The first is a millisecond timing training and the second is a ball bounce activity. The Hardy Brain Camp is innovative because it includes movement put to a specific timed beat with an added cognitive component. Some alternative programs, such as Interactive Metronome, use metronome training (Sommer, & Ronnqvist, 2009), and other programs such as Bal-A-Vis-X or Brain Gym use repetitive movement; however, none of these programs also include a cognitive task. Sherrie Hardy's program uniquely combines these motor elements with a cognitive practice to better integrate the brain connections between motor and cognitive processing areas.

Another difference between the Hardy Brain Camp and other programs is that many other programs focus on specific populations, whereas the Hardy Brain Camp works with groups of children in the general population. For example, much of the previous work with metronome training has been done with students who have learning disabilities. Studies show that millisecond timing training seems to be especially beneficial to students with attention disorders and students with specific learning disorders. Most studies on millisecond timing training have been conducted with participant groups composed of individuals with designated learning difficulties (Shaffer et al., 2001; Breier, Fletcher, Foorman, Klaas, & Gray, 2003). The Hardy Brain Camp, on the other hand, is implemented in general student populations—who may or may not have designated learning difficulties.

This study was an evaluation of the Hardy Brain Camp as it was implemented with the Boys and Girls Club at a central California school. Using measures from the Woodcock-Johnson III NU Tests of Cognitive Abilities and the Woodcock-Johnson III Tests of Achievement, measures of processing speed, reading fluency, and math fluency were administered before and after a training period consisting of 20 training sessions. The difference between pretest scores and posttest scores was used as a measure of change in participants over the period of the training.

The questions addressed in this study are:

1) Does the Hardy Brain Camp improve processing speeds, suggesting an improvement in motor integration and timing for a general population such as that found in the Boys and Girls Club as compared to a control group and a group receiving only metronome timing training?

2) Are there improvements in achievement measures such as reading fluency and math fluency in the students who have done the Hardy Brain Camp?

3) Are improvements greater for participants who have both metronome training and ball bounce training, or does the metronome training alone give the same level of improvement?

4) Are there identifiable trends that suggest that certain subgroups are more likely to improve with the Hardy Brain Camp, such as age groups or gender groups, or does the training seem to benefit children more broadly within treatment groups?

We will begin by describing the procedures used in both the millisecond timing training and the ball bounce activity. Then we will describe the study and give the results of our analysis. Finally, we will conclude with a discussion of the implications of the evaluation.

Millisecond Timing Training Procedure

The millisecond timing training protocols used in this study were created by Sherrie Hardy using the technology from the Interactive Metronome and based on the Interactive Metronome training. The Hardy Brain Training has customized its program by modifying its display, its training procedure, and the number of repetitions necessary in training.

To begin the millisecond timing training, participants are given an initial test to determine how close their natural timing is to ideal timing. This initial inventory looks for close proximity to the metronome beat, the ability to do left side and right side activities, the ability to do bilateral timing movements and the ability to coordinate both sides of the body while balancing on one foot or the other. Participants' strengths and weaknesses on these activities are used to individualize their training. Exercises are selected for students to strengthen particular areas of weakness; for example, if a participant has difficulty with movements on his/her left side, more repetitions in the exercises that practice left-side training will be programmed for that participant. Participants' initial training speed is also determined by how they perform on this inventory. If participants' initial average timing scores are more than 100 milliseconds off of the metronome reference tone, participants enter into Stage One training; if their timing is less than 100 milliseconds off, they enter into Stage Two Training.

The millisecond timing training presents students with a metronome-paced reference tone provided through headphones. Their task is to produce certain movements in time with the metronome beat. There are thirteen total movement exercises, which are practiced in 40-minute practice sessions. Motor timing information is collected via sensors: a hand sensor for when the hands are clapped together or clapped against a body part, and a foot sensor pad for when toes or heels are tapped to the metronome. These sensors are hardwired to a metronome box that is used with a computer system. The computer integration is used to provide participants with instantaneous feedback as to how accurately they are mimicking the metronome's timing and provides trainers with information about how participants are doing with their training. This Interactive Metronome equipment is specifically designed for the Hardy Brain Camp.

On each day of training, participants begin with Task 1, a one-minute "short form" task composed of clapping with visual cues and the reference tone. Task 2 follows this. In this one-minute "short form", participants clap while being provided with a reference tone, with visual feedback as to the number of milliseconds they were off tone and with auditory guide sounds as to whether they were right on, before, or after the tone. After doing these two standardized one-minute sections, each participant continues on to a customized training session composed of a combination of the thirteen movements designed to strengthen individual weaknesses.

At the beginning of the training, repetition segments start off short. Some participants begin with one minute of metronome beats with only visual feedback. After this section, there is a small break between tasks. The lengths of repetition sections are gradually increased until by the end of the training period the student should be able to do a 38-minute repetition section without breaks. The conceptual underpinning of this is that if students can attend to 38 minutes of motor planning and sequencing at one time, they should be able to attend more effectively to an entire lesson in school.

In millisecond timing training, a student's millisecond time response improves over days of training. While very few students are accurate at the beginning of the training period, by the end of the training most of the students are highly accurate in their ability to clap in time with the reference tone. This clapping and toe tapping to the metronome improves initial inhibition of when to move, integrates movements with the reference tone, visual, and auditory feedback, and aids calibration of motor responses in relation to organization of feedback.

The Hardy Brain training program has a minimum goal of 23,000 repetitions of tone and feedback; however, 32,000 repetitions are the preferred goal, in order to obtain full benefits. For this purpose, each participant in a setting like the Boys and Girls Club is given access to 20 sessions of 40 minutes with a goal of enabling children to participate in at least 15 sessions. A minimum of 12 sessions is designated as completion of training. Fewer than 12 training sessions is not enough repetitions to obtain the benefits of training.

The Role of Daily Monitoring and Training

At the initial evaluation, and on a regular basis thereafter, students' progress and timing is monitored by two groups of individuals: the trainers, who are present at the millisecond timing training (MTT) sessions and deal with day-to-day issues to support participants, and the Hardy program monitors, who work from a distance and support participants by examining patterns of timing, strengths and weaknesses, and improvement in participants. This information is used by both groups to individualize each participant's training: displays, feedback, and exercises.

Trainers and Hardy program monitors communicate to modify and individualize the training for each participant. For example, trainers can call the monitors for immediate changes in exercise customization and displays. Also, the monitors use specific screen backdrops as a code to communicate information to the trainers. Screen backdrops indicate to the trainers which students might need more assistance—a screen with a tiger background shows that a student may need a good deal of assistance, whereas a monkey background screen indicates a student who needs less help.

Throughout MTT, the trainer plays an active role in the training process. In each training session, there are 10 participants working on individual computers with headphones and two trainers circulating around the room and using their expertise to assist students when warranted. This assistance comes in a number of different forms. Displays can be changed or even blacked out; it is not unheard of for a trainer to cover the screen for a participant who seems to do better without the visual display. They can also change the guide sounds provided as feedback. The program monitors also make these modifications when necessary, and can change customization of the exercises programmed for an individual.

In addition to the feedback, exercise and display changes, each metronome unit is equipped with two headphone outlets. This way, a trainer can plug in a set of headphones to the student's reference tone and physically guide the student's clapping. Guiding each of the student's hands, the trainer can help the student feel what the movement would be like closer to the actual beat and provide kinesthetic feedback, in addition to the visual and auditory feedback already provided.

The Role of Positive Feedback in Millisecond Timing Training

Throughout MTT, the participants are given a good deal of positive feedback to support the training process. On the most basic level this consists of a small prize given to each participant on completion of the day's training. After the participant finishes training, the trainer checks to make sure the training has been finished properly and then allows the student to take one item from a treasure chest filled with things like pencils, erasers, bubbles, and other small toys. There is positive verbal feedback as well. Each session, participants write their short form scores on daily record sheets. As these scores improve, trainers are taught to celebrate it and emphasize the improvement. When a student gets four beats exactly on time, this is called a “burst”. The number of bursts a participant gets in a training session is measured, and trainers make a production of celebrating burst improvements and the highest number of bursts a student achieves. Finally, the total number of perfect beats in a row is constantly being tabulated, and the student’s highest number of perfect beats hit in a row is tabulated and celebrated as well. Every day, the participants write their two short form scores, their burst maximum and their highest beats in a row on a form that they use throughout the training. This way, they can see the changes themselves and look at how they have progressed.

The Stages of Training

Stage One Training- Stage One Training begins at a fast pace. Some students have an inability to inhibit movement and move much faster than the selected metronome beat. Ideally, 54 beats per minute is the timing the Hardy Brain Camp works towards. However, many students begin at a natural timing faster than this. For this reason, Stage One begins participants at 80 beats or more per minute. Once students are doing well enough on the 80 beats per minute, the beats move down to 75, 70, 65, and 60, and then finally to 54 beats per minute. If the student’s timing improves rapidly, some of these increments are skipped.

Stage One Training provides the metronome beat through headphones and visual feedback on the computer screen as to how accurate the participant’s clap and foot taps are to the metronome reference tone. This is similar to short form Task 1. While all displays are customized for the individual, a prototypical display might include a row of 4 boxes with a symbol between the left two and the right two on the screen. If the student is perfectly on time, characterized by between 0 to 20 milliseconds off time, the student will have a green box show up closest to the symbol. If he/she is before the tone, the box will be on the left. If he/she is after the tone, the box will be on the right. If his/her time is between 20 and 300 milliseconds (either before or after) the same box will be yellow, instead of green. If he/she is more than 300 milliseconds off-beat, the farthest square from the center will display red; again, if it is before the beat it will be the farthest left box, and if it is after the beat, it will be the farthest right box.

There are many little changes that can be made in the display to accommodate the participant, and the trainers or the daily monitors do this when they determine it is necessary. The displays are adjusted until a shift in milliseconds off the beat is seen, because it has been observed that a display that is suited for the participant will cause the participant to show a large shift in how accurate he/she is in attending to the beat. His/her timing usually becomes much more accurate with the right display.

Once the participant's average score is less than 100 milliseconds off, it is time to move on to Stage Two training. A few participants are able to begin at Stage Two training immediately; some participants never reach Stage Two training. The ones who never reach Stage Two training in the 20 training sessions that are initially offered are given some time off and then brought back for a second round of training.

Stage Two Training- Stage Two training begins at 54 beats per minute. This stage of training gives more feedback than Stage One does. It still provides the metronome reference tone and visual feedback on a screen, but it adds auditory guide sounds for each beat as well. In this stage, like Stage One, the participants hear the reference beat in both ears of the headphones. While screen presentation and auditory guides sound levels can be customized for each individual, a typical display is a computer screen with five boxes on it. If the participant's claps are exactly on time (0-20 milliseconds off) there will be a green box that lights up in the middle of the screen and the participant will get a ding sound in both ears. If the timing is between 20 and 100 milliseconds off, a yellow box close to the center will light up. If the movement is before the beat, the yellow box will be on the left side and the participant will hear a twanging sound in the left headphone. If it is after the beat, the yellow box will be on the right side and the twang will be in the right ear. If the movement is more than 100 milliseconds before the tone, the far left box will light red and there will be a buzzer sound in the left ear. If the clap is more than 100 milliseconds after the beat, the red light will be in the far right box and the buzzer sound will be in the right ear.

Stage Two provides a good deal more feedback for the participant to pay attention to, so it is not unusual for the participant's timing to go up a bit after beginning the training. If, however, the participant's timing does not steadily improve, the trainer will modify the guide sounds or display to support the participant's individual needs. Stage Two training is continued until the end of the 20-session training period.

Ball Bounce Procedure

Like the millisecond time training, the ball bounce activity works with motor timing, sequencing, and implementation; however, it combines these things in a less controlled manner than does MTT. The ball activity is a repetitive motor training that involves bouncing a small rubber ball to a beat, coupled with ball tracking and a concurrent cognitive task of skip counting. This activity includes eye/hand coordination, motor information about how much force to use, rhythm, and bilateral integration in ways that MTT does not. These differences are intended to create improvements or changes that the MTT alone cannot promote. By including repetitive skip counting in the ball bounce practice, the neural connections between motor activities and cognitive processes are intentionally being stimulated and strengthened.

The ball bounce activity is practiced as a group. Each day, when the group has finished MTT, all ten students go to the blacktop outside and perform a patterned practice. Using a beat provided by the trainer, the students recite a skip counting, such as 6, 12, 18, 24, 30, 36, etc., out loud as they perform certain movements. First they bounce the ball with their dominant hands. They go through the number sequence from 6 to 60 while bouncing with their dominant hand three times. Throughout these repetitions, they are calling out the number sequence in time with one another to the beat provided by the trainer.

After they bounce with their dominant hands through three repetitions, participants will hold still and move the ball in front of their bodies at eye level while following the ball with their eyes and reciting the number sequence. They repeat this movement through three number sequences as well. Three sequences with their non-dominant hand follow. Next, they perform a single sequence, writing the numbers with their left feet, and then a sequence writing the numbers with their right feet. They perform three sequences across their midlines—bouncing the ball from their left hands to their right hands. Finally, there are three sequences in which they write all of the numbers in the air with both of their hands simultaneously. In total, this practice takes about 10 minutes to complete.

Each participant is expected to practice 6's, 7's, 8's and 9's over the scope of the 20 training sessions. If a student misses a training session and is behind on repetitions, the child will participate in the regular pattern practice with the group and then make up any missed pattern practice afterwards. In total, each child is expected to have practiced with each of the four numbers 5 times a week for a total of 50 minutes per number sequence. This is a grand total of 200 minutes of ball bounce training in the 20 session training period.

Method

Participants- This study was conducted with 62 students in the Boys and Girls Club at a southern Californian elementary school. The school served close to 500 students between kindergarten and fifth grade. At the time of the study, the school was 96% Latino in constituency and had about 86% of its students receiving free lunches. The school had 230 students from third through fifth grade, the grades targeted for this evaluation. The Boys and Girls Club had about 180 students in its afterschool program, from which the study's participants were selected. With 62 students selected for this study, a large percentage of the population of the Boys and Girls Club was included in this study.

The majority of the students in this study were selected for inclusion based on Boys and Girls Club staff and/or teacher referral. Thus, children with learning, attention, and/or behavioral problems were more likely to be referred and included in the study. The difficulties mentioned were not necessarily documented or tested for by the school, rather they were observation and experience-based referrals. Although most of these students were recommended for this training, some un-referred Boys and Girls Club members were included to increase the number of youth in the study; these youth were not necessarily observed to have any learning or behavior difficulties. A list of students whose parents had consented to the program was created. Once consent forms were returned, these students were randomly assigned to experimental groups. While we would have preferred to have larger group sizes, available students and time constraints related to training group size limited the size of our study.

These 62 students were randomly distributed into 3 groups: a control group (n = 21), an MTT group (MTT) (n = 21), and an MTT plus a ball activity group (MTT and Ball) (n = 20). As age was possibly a factor in this analysis, we took the pre-test age (in months) and the post-test age and averaged them to give us an average age for analysis. When ages across groups were examined, there were two outliers, one almost 15 months older than the next oldest participant and one almost 10 months younger than the next youngest participant. Given that both the tests and the training have important age-dependent aspects, after careful consideration, these two outliers were excluded from analysis. They were both in the MTT group. Furthermore, one child from the MTT and Ball group attended the pretest, but never attended the training or the posttest. He was also excluded from analysis. This reduced the MTT and the MTT and Ball group sizes to 19 participants each for analysis.

Members, Gender, and Age- The control group had 21 members. There were 12 boys and nine girls. They had an average age of 117.38 months, or about 9 years, 9.38 months. When averaged, their grade level was 4th grade. The MTT group had 19 members. This group had 14 boys and five girls in the group. They had an average age of 114.5 months, or about 9 years, 6.5 months. They had an average grade level of 3.89. The MTT and Ball group had 19 members. There were eight male and 11 females in the group. This group had an average age of 121 months, or 10 years, 1 month. They had an average grade level of 4.21. This information is summarized in Table 1.

Table 1

Average Grade, Age, and Male to Female Ratio by Treatment Group

	MTT and Ball	MTT	Control
Average Grade	4.21	3.89	4.00
Average Age in Months	121	114.5	117.38
Male to Female Ratio	8 M: 11 F	14 M: 5 F	12 M: 9 F
Number in Group	19	19	21

Experimental Conditions-The control group received the basic Boys and Girls Club enrichment activities, such as homework help and game playing, for the extent of their time spent in the afterschool program. On a daily basis, the MTT group was taken out of their Boys and Girls Club enrichment activities, received 40 minutes of MTT, and then returned to the basic enrichment activities. The MTT and Ball group received 40 minutes of MTT and 10 minutes of the ball activity, followed by the basic Boys and Girls Club enrichment activities.

All children in the two training groups were offered twenty sessions of training; however, the number of training sessions participants received was affected by their attendance at the Boys and Girls Club. The number of actual sessions participants attended ranged from twelve to twenty. The average number of sessions for the MTT and Ball group was 14.79, and the average number of sessions for the MTT group was 15.74. The attrition rate in the study was very low, with just one student who did the initial pretesting and did not do any training or do the posttesting.

Description of Trainers- There were two trainers who worked with the study participants. The primary trainer was a female in her mid-twenties, who worked for the Boys and Girls Club and had been conducting Hardy Braining Training for approximately two years. She had also been through 20 sessions of the MTT training herself. She was very comfortable with the Hardy Brain Training Programs and would often help participants with kinesthetic guidance, verbal support, and display changes in accordance with the daily off-site monitoring. In the MTT and Ball group, she was the trainer who provided the beat for the ball bounce activity and led the group repetition.

The second trainer was a high school student who worked for the Boys and Girls Club. This study was his first extended period working with the Hardy Brain Training Programs. He was often sent to retrieve participants and do organizational tasks, but also provided participants with kinesthetic guidance and verbal support.

Sherrie Hardy regularly came and observed the training and offered her expertise during the training. She was observed to change displays, guide participants, and praise students for their improvement. She provided verbal support and explanations of the training to the participants.

Testing Procedures- Four measures were used to assess participants in this evaluation: two from the Woodcock-Johnson III NU Tests of Cognitive Abilities: the Decision Speed Test and the Visual Matching Test (these tests were averaged together to give a measure of processing speed), and two tests from the Woodcock-Johnson III Tests of Achievement: the Reading Fluency Test and the Math Fluency Test.

The Visual Matching measure looks at cognitive efficiency—the speed at which an individual can discriminate visual symbols. The participant is asked to locate and circle two identical numbers from a row of six numbers. The difficulty of this task increases throughout the measure. It begins with single digit numbers and increases to triple digit numbers. This test has a three-minute time limit. The Decision Speed test measures how quickly a participant can identify two conceptually related pictures from a row of seven images. A hypothetical example similar to the test would be selecting a football helmet and a top hat from a row that also includes a star, a door, a pen, a duck, and a piano. Participants are also given three minutes to complete this test. These two tests are averaged together to give a processing speed score. This is a cognitive measure.

In the Reading Fluency measure, participants must read through simple sentences and decide if the sentence is true, and circle yes, or false, and circle no. This test has a three-minute time limit. In the Math Fluency measure, the participant is given a series of simple arithmetic problems to complete. There are addition, subtraction, and multiplication problems. The addition problems are at the beginning of the measure, followed by subtraction, then multiplication. This test also has a three-minute time limit.

All four of these tests were administered prior to the training period and again re-administered to all groups after this period. These tests gave us before and after scores of processing speed, reading fluency, and math fluency for each group. The “before” scores were subtracted from the “after” scores to give a difference. This difference was seen as the change in participants over the period of time of the study.

Sherrie Hardy, with an M.A. in Marital and Family Therapy, personally administered all the tests with the help of one or two test monitors. The tests were conducted in groups, with students seated at tables a few seats apart from each other. For each test, the instructions were reviewed together, and any practice problems were gone over. All of these tests were timed tests. The students held their pencils up until they were given the start signal, and all pencils were removed from the paper exactly on the stop signal. Occasionally the students would finish the entire test, but, more often than not, they stopped on the signal instead of at the end of the test. All ages were given the same version of the test.

Woodcock-Johnson Scores- Woodcock-Johnson scores were recorded as a raw form, an age equivalent (AE) score, grade equivalent (GE) score, a standardized form (W), and a normed standard score (SS). This analysis uses the normed standard score (SS). The age and grade equivalent scores would have been easier to interpret; however, those scores are not standardized and so could not be used for statistical analysis. For reporting purposes, W mean scores were converted back to age and grade equivalent scores and the statistically analyzed SS are given. The conversion of W scores to age and grade equivalent scores was done by one of the test authors, Kevin McGrew.

Results

The results explained are reported in a non-technical manner here in the main body of this report; a more complete statistical analysis is presented in the technical appendix. Our statistical analysis was run using the normed, standardized scores (SS) for each test. Our W mean scores were also converted into age (AE) and grade equivalents (GE) to ease understanding of what these differences mean. All three sets of data will be discussed here. For each measure we looked at the effects of training—the MTT and MTT and Ball groups combined—compared to the control group, and the effects of the three treatment groups separately.

SS are averaged using 100 as the average score, with an average standard deviation of 15. Thus, all of these scores will range around the 100 mark. Age equivalent scores are based on how participants did compared to others their age. For each treatment group, the average age and the average scores were used to calculate the AE. Then the pretest AE was subtracted from the posttest AE to show change in scores. Thus, an age equivalent improvement of 12 months suggests the group's average score reflected 12 months of improvement over the 20-session training period. The grade equivalent score is similar to the age equivalent score; however, it is based on a ten-month school year. If a group had a grade equivalent improvement of 1.2 it would suggest that the average score reflects 12 school months of improvement over the 20-session training period.

Differences in Processing Speed- To begin, we analyzed the SS difference for groups with training versus the groups with no training in processing speed. We used *t* tests to compare these differences. On average, those with training had a 16.59 point increase in standard score, a 2.2 GE improvement, and a 2 year, 1 month AE improvement. Those without training had a 7.47 point increase in SS, a .9 grade GE, and an 11.5 month AE improvement. The difference between receiving training and not receiving training was statistically significant and was considered a moderate effect on differences in processing speed. Training improved processing speed scores.

When analyzing differences between the experimental groups in relation to processing speed, on average the control group had a 7.47 SS point increase in score, the MTT group had a 12.16 SS point increase in score, and the MTT and Ball group had a 21 SS point increase in score. This difference is statistically significant, with the MTT and Ball doing significantly better than either the control group or the metronome group.

When looking at the results of the experimental group differences in relation to GE, the MTT and Ball group had a 2.7 grade improvement, the MTT group had a 1.4 grade increase, and the control group had a .9 grade improvement. In terms of AE, the MTT and Ball group had a 2 year, 9.5 month improvement, the MTT group had a one year, 5.5 month improvement, and the control group had an 11.5 month improvement. These results show that the MTT and Ball group did better than the other two groups in terms of processing speed. Table 2 summarizes these results

Table 2

Average Pretest, Posttest, and Differences in Processing Scores by Treatment Group

Measure	Control			MTT			MTT and Ball		
	SS	GE	AE	SS	GE	AE	SS	GE	AE
Pre Processing	99.14	4.3	115.5	100.00	4.1	113.5	94.47	4.1	113.5
Post Processing	106.62	5.2	127.0	112.16	5.5	131.0	115.47	6.8	147.0
Change/ Difference	7.48	0.9	11.5	12.16	1.4	17.5	21.00	2.7	33.5

Differences in Reading Fluency- When looking at differences in reading fluency between those individuals who were trained versus the control group, those who were trained had slightly higher difference scores than those who were not trained. Those who were trained had an average difference in reading fluency of 2.55 points in SS, a GE grade improvement of .5, and an AE improvement of 7.5 months. The control group had an average grade improvement of .1 in GE and 1.5 months on AE. However, because the time between pretest and posttest for this group averaged a little more than 1.5 months, these scores suggest a decline instead of an improvement. The control group on average did worse in reading fluency on the posttest. They lost an average of .33 points on the SS score. These results in both directions are considered small, but reflect statistically significant differences. Training improved reading scores.

When compared across the three treatment groups, the MTT and Ball group had an average improvement of 3.05 points on the SS score, the MTT group had an average improvement of 2.05 points on the SS score, and the control group scored .33 points worse on average. In terms of GE scores the reading fluency scores were very close in the MTT and Ball and MTT groups, with both having an average improvement of .6 grade, while the control group only had an improvement of .1 grade. In AE, the reading fluency scores were 1.5 months improvement for control, 7 months improvement for the MTT, and 7.5 for the MTT and Ball. When compared across the three treatment groups, these differences in reading fluency were also statistically significant but the differences were of smaller magnitude. Table 3 summarizes these results.

Table 3

Average Pretest, Posttest, and Differences in Reading Fluency by Treatment Group

Measure	Control			MTT			MTT and Ball		
	SS	GE	AE	SS	GE	AE	SS	GE	AE
Pre Reading	93.33	3.5	105.5	98.21	3.9	110.5	95.89	4.2	114.5
Post Reading	93.00	3.6	107.0	100.26	4.5	117.5	98.95	4.8	122.0
Change/ Difference	-.33	0.1	1.5	2.05	0.6	7.0	3.05	0.6	7.5

Differences in Math Fluency- When comparing those having training to those having no training in math fluency, those with training did significantly better than those without training, although the point differences were small. On average, those with training improved 6.66 SS points, 1 year, half a month improvement in AE, and a .9 grade improvement in GE. Those with no training only scored 2.57 SS points better, and had 3.5 months improvement AE and a .3 grade improvement in GE.

When comparing each treatment group and the control, a significant difference between the groups could be seen in math fluency. The MTT and Ball group had an average increase in SS scores of 10.11 points, while the MTT group had an average increase of only 3.21 points, and the control group had an average increase of 2.57 points. In this case, the MTT group and the control group performed very similarly, whereas the MTT and Ball group did significantly better than both other groups. This suggests that the MTT and Ball combination was more successful for math fluency than were the other two treatment conditions. When looking at grade equivalent scores (GE), the MTT and Ball group improved an average of 1.5 grades, the MTT group improved an equivalent of .6 grade, and the control group increased an average of .3 grade. In terms of AE, the MTT and Ball group improved one year, 7 months, the MTT group improved 8 months, and the control group improved 3.5 months. These results are summarized in Table 4. Figure 1 graphically represents the grade equivalent scores for all three measures by treatment group.

Table 4

Average Pretest, Posttest, and Differences in Math Fluency by Treatment Group

Measure	Control			MTT			MTT and Ball		
	SS	GE	AE	SS	GE	AE	SS	GE	AE
Pre Math Fluency	91.00	3.5	106.0	103.11	4.6	120.0	98.11	4.6	119.0
Post Math Fluency	93.57	3.8	109.5	106.32	5.2	128.0	108.21	6.1	138.0
Change/ Difference	2.57	0.3	3.5	3.21	0.6	8.0	10.10	1.5	19.0

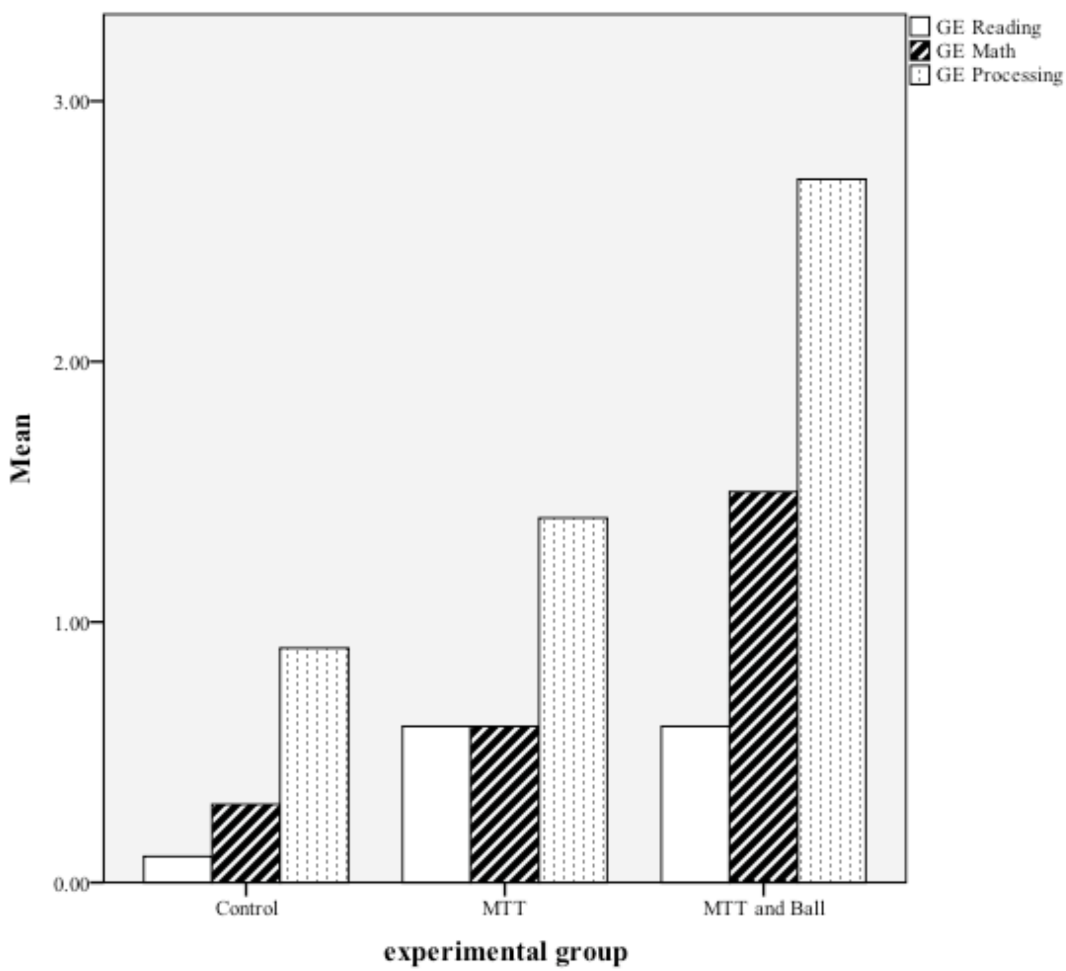

Figure 1. The grade equivalent scores for all three tests, by treatment group.

Overall Improvements in All Tests- An important question is whether the group differences were due to some individuals having received more benefit from the training than others or whether the benefits of the two treatment conditions were found across most or all of the participants. To assess for this, we ran an exploratory linear regression using gender, training, and age as possible variables that might affect test scores. If they affected test scores, they would be linearly related to the final score—someone could partially predict the participants' posttest scores from the variable. In all three tests, the only variable that could be used to predict the posttest scores was the variable of training. This shows that the other variables did not create a reliable difference in scores. This allows us to assume age and gender did not affect how much the training benefited these individuals.

In another examination of the data, we looked at how participants did across all three tests. The line for improvement was set at zero. If the participant was seen to have scored a higher SS on the posttest than the pretest, the participant was said to have improved. When analyzing improvement over zero across the three measures, there were patterns that emerged in overall score changes. In the control group, there was one individual who did not improve on any of the three tests: his/her score was always negative or zero. Six individuals in the MTT group and six individuals in the control group improved on only one test. Nine individuals in the control group, five individuals in the MTT group, and four individuals in the MTT and Ball group improved on two of three tests. Five individuals in the control group, eight individuals in the MTT group, and 15 individuals in the MTT and Ball group improved in all three tests. This suggests that, overall, the MTT and Ball condition created more global improvements than did the regular enrichment program or the MTT alone. This is graphically represented in Figure 2.

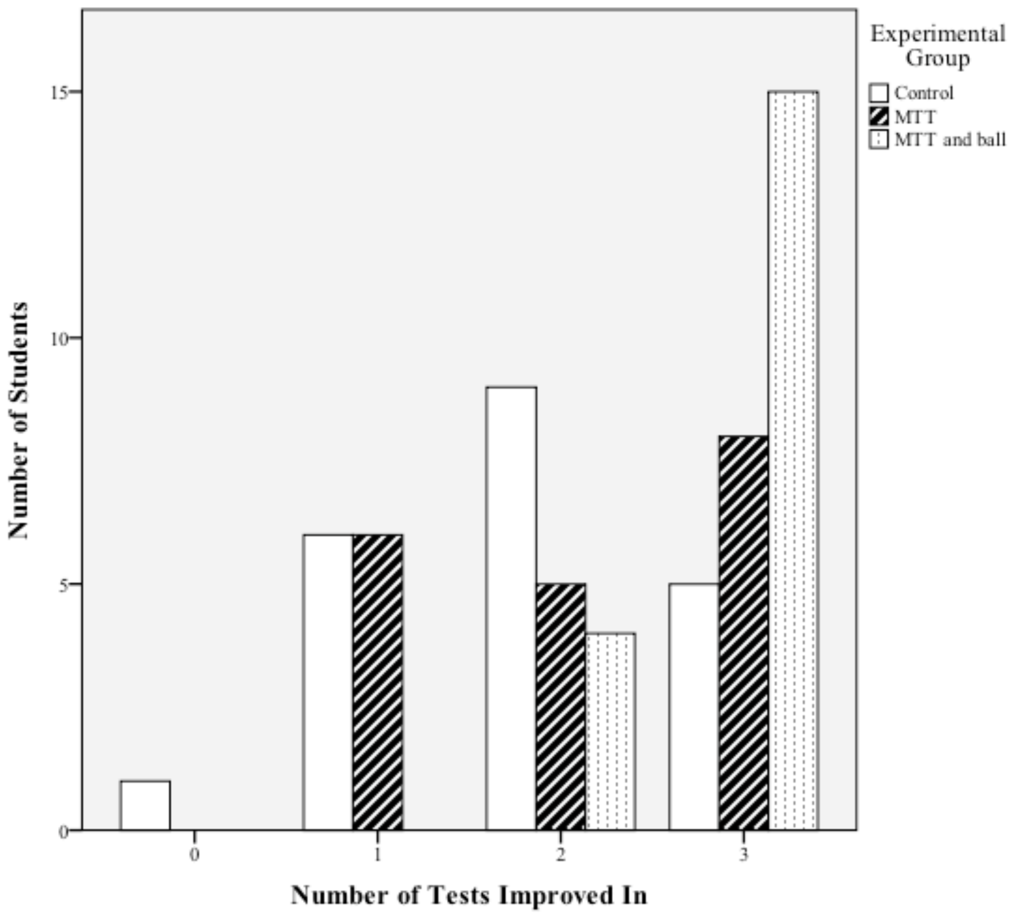

Figure 2. The number of the three tests on which students improved by treatment group.

Discussion

This evaluation showed moderate improvement in processing speed and small improvements in reading and math fluency in those individuals who were trained versus those who were not. When compared by experimental groups, the MTT and Ball group—

which is the Hardy Brain Camp—improved students in all three measures more than the basic Boys and Girls Club enrichment or the millisecond timing training alone did. These findings are promising, but they do come with some caveats.

Sample Size- The sample size in the evaluation was small. With bigger samples, statistical analyses of differences are more robust. More research should be conducted with larger samples to gain stronger evidence of actual differences caused by various interventions associated with Hardy Brain Camp.

Measures- In this evaluation, we used processing speed, reading fluency, and math fluency as measures of student improvement in cognitive functioning and academic achievement. These measures do not directly relate to measures of academic achievement as measured by the schools, such as state-implemented standardized tests. For this reason, while the changes in these attributes were statistically significant, we cannot make claims about the direct academic benefits of any of these measures based upon the design of this evaluation.

Longevity- In this study, a pretest was given before training, and a posttest given after training. The changes we were measuring were immediate. This evaluation can make no statements about the long-term benefits of the Hardy Brain Training Program or of MTT. Further research would need to be conducted to assess for this.

Conclusion

The questions that were considered by this evaluation and the answers that can be supported by statistical analyses of measured results are:

1) Does the Hardy Brain Camp improve processing speeds, suggesting an improvement of motor integration and timing for a general population such as that found in the Boys and Girls Club?

   The evidence from our analyses does suggest that the Hardy Brain Camp improves processing speeds, with the MTT and Ball training group improving more than other treatment groups.

2) Are there improvements in achievement measures such as reading fluency and math fluency in the students that have done the Hardy Brain Camp?

   The evidence from our analyses does show small improvements in both reading fluency and math fluency using the Hardy Brain Camp, with the MTT and Ball training group improving more than the other treatment groups.

3) Are improvements greater for participants who have both MTT and ball activity training, or does the MTT alone give the same level of improvement?

   The evidence from our analyses does show that there are greater improvements from the Hardy Brain Camp than from only a MTT program, especially for processing speed and math fluency. The differences in reading fluency were found to be similar with the MTT and MTT and Ball groups. Overall, though, participants in the Hardy Brain Camp group performed better on more tests than did the participants in other treatment groups.

4) Are there identifiable trends that suggest that certain subgroups are more likely to improve with the Hardy Brain Camp, such as age groups or gender groups, or does the training seem to benefit children more broadly within treatment groups?

The evidence from our analyses did not show improvement benefits related to age or gender. None of these factors were linearly related to score changes in processing speed, reading fluency, or math fluency. The only factor that linearly related to improvement on the measures was having training. In addition, more children showed improvement on all three measures in the Hardy Brain Camp than in the other two groups.

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Technical Appendix

All statistical analysis was conducted using SPSS 19 for Macs.

Initial Analysis

The purpose of this evaluation was to determine if there was a significant mean score difference in the three dependent variables in relation to the independent variable of experimental condition. Analysis began by checking descriptive statistics of the primary variables. The descriptives are summarized in Table 1. For all three variables, the pre-test scores are considered to be normally distributed. For this reason, group comparison *t* tests were run on the difference between pre test and post test for all three dependent variables to compare metronome training versus no training. This was looked at to analyze the research question: after groups were split into training groups, did training make a statistical difference in how well the students did in all three measures?

The next research question was did the type of training significantly matter in in terms of the difference between pre and post scores? For this analysis three one-way ANOVAS were run, factored by experimental group: control, MTT, and MTT and Ball.

Results of Initial Analysis

Three independent samples *t* tests were performed to assess whether processing speed, reading fluency, and math fluency differed significantly for the 21 participants who had no MTT training (control group) compared with the 38 participants who had practiced MTT. Preliminary data screening indicated that scores on processing speed, reading fluency, and math fluency were normally distributed. The tests of normality are found in Table 2.

Processing Speed

Beginning with processing speed, the assumption of homogeneity of variance was assessed by the Levene test, $F = .350$, $p = .557$; this indicated no significant violation of the equal variance assumption; therefore, the pooled variances version of the *t* test was used. The mean differences in pre and post processing speeds between the two groups differed significantly, $t(57) = 3.62$, $p = .001$, two-tailed. The mean difference score for the training group ($M = -16.58$, $SD = 9.41$) was about 9 points more than the mean difference score for the no training group ($M = -7.48$, $SD = 8.959$). The effect size, as indexed by η^2, was .19; this was a moderate effect. This analysis suggests that MTT training may significantly improve processing speed, with an increase on test scores on the order of 9 points in the Woodcock Johnson combined measure of processing speed.

Reading Fluency

For reading fluency scores, the assumption of homogeneity of variance was assessed by the Levene test, $F = 1.25$, $p = .268$; this indicated no significant violation of the equal variance assumption; therefore, the pooled variances version of the *t* test was used. The mean differences in pre and post reading fluency between the two groups differed significantly, $t(57) = 2.35$, $p = .022$, two-tailed. The mean difference score for the training group ($M = -2.55$, $SD = 4.82$) was about 2.5 points more than the mean difference score for the no training group ($M = .33$, $SD = 3.90$). The effect size, as indexed by η^2, was .09; this was a small effect. This analysis suggests that MTT training may significantly improve reading fluency, with an increase on test scores on the order of 2.5 points in the Woodcock Johnson reading fluency test.

Math Fluency

Finally, looking at the differences in math fluency, the assumption of homogeneity of variance was assessed by the Levene test, $F = .01$, $p = .94$; this indicated no significant violation of the equal variance assumption; therefore, the pooled variances version of the *t* test was used. The mean differences in pre and post math fluency between the two groups differed significantly, $t(57) = 2.30$, $p = .025$, two-tailed. The mean difference score for the training group ($M = -6.66$, $SD = 6.49$) was about 4 points more than the mean difference score for the no training group ($M = -2.57$, $SD = 6.61$). The effect size, as indexed by η^2, was .08; this was a small effect. This analysis suggests that MTT training may significantly improve math fluency, with an increase on test scores on the order of 4 points in the Woodcock Johnson math fluency test.

Training Versus No Training

In all three tests there was a significant difference between training and no training. In all cases, training improved participants' scores on the tests being measured. Processing speed was most improved, with an average of about 9 points difference between trained and untrained individuals. Math fluency was the second most improved, with an average of about 4 points difference between trained and untrained individuals. Finally, reading fluency was improved with an average of about 2.5 points difference between trained and untrained individuals. While training had a moderate effect on processing speed, the effects on math fluency and reading fluency were small. In regards to the research question: Does training improve test scores in processing speed, reading fluency, and math fluency, this analysis suggests that training does improve test scores in these areas. These results are summarized in Table 3 and Table 4.

One-Way ANOVAs By Group

Three one-way ANOVAs were performed to assess whether differences in processing speed, reading fluency scores, and math fluency scores could be predicted from experimental group: control, MTT, or MTT and Ball. Based on the Hardy Brain Training Program's hypotheses, MTT and Ball would create the most improvement in test scores, MTT the second most, and the control group would only have the average change brought about by development. Tables 5 through 8 show the assumptions of the ANOVAs. The results of these one-way ANOVAs are summarized in Table 9 and the post hoc tests are shown in Table 10.

Processing Speed

Preliminary data screening was done to assess whether the assumptions for an ANOVA were seriously violated. Examination of K-S scores and descriptive statistics on the variable of processing speed suggested the difference scores were normally distributed within each experimental group. The Levene test indicated no significant violation of the homogeneity of variance assumption.

As predicted, there was a statistically significant difference in processing speed scores based on experimental group: $F(2, 56) = 12.62$, $p < .001$. This shows that there is a statistical difference between the groups. A post hoc Tukey HD test showed significant differences for the MTT and the Ball group, $MD = -13.52$, $p < .001$, compared to the control and for the MTT and Ball group compared to MTT as well, $MD = -8.84$, $p = .007$. No other pair comparison was seen as significant in this post hoc test.

Reading Fluency

The hypothesis for reading fluency was the same as for processing speed, that MTT and ball would do best, followed by the MTT group, and finally the control group. Preliminary data screening was done to assess whether the assumptions for ANOVA were seriously violated. Examination of K-S scores and descriptive statistics on the variable of reading fluency suggested the difference scores were normally distributed within each experimental group. The Levene test indicated no significant violation of the homogeneity of variance assumption. The one-way ANOVA showed trends towards our hypothesis but not a statistically significant difference in reading fluency scores based on experimental group: F (2, 56) = 2.96, p = .060 in a two-tailed test.

Math Fluency

A one-way ANOVA was performed to assess whether differences in math fluency scores could be predicted from experimental group: control, MTT, or MTT and Ball. Preliminary data screening was done to assess whether the assumptions for ANOVA were seriously violated. Examination of K-S scores and descriptive statistics on the variable of math fluency showed that the scores were likely to be normally distributed; however, the assumption of normality in the control group was violated in the more conservative Shapiro-Wilk's test. Nonetheless, this violation was not considered to be too severe, and the Levene test indicated no significant violation of the homogeneity of variance assumption, so analysis continued.

As predicted, there was a statistically significant difference in math fluency scores based on experimental group: F (2, 56) = 9.59, p < .001. This shows that there is a statistical difference between the groups. A post hoc Tukey HD test showed significant differences for the MTT and the Ball group, *MD* = -7.53, *p* = .001, compared to the control and for the MTT and Ball group compared to MTT as well, *MD* = -6.90, *p* = .002. No other pair comparison was seen as significant in this post hoc test.

MTT compared to MTT and Ball

Our next research question was, did the group with MTT and Ball perform better than the MTT group and the control group—i.e., were there benefits to including both aspects of the program? This analysis showed that in processing speed and math fluency there were statisitically significant group differences, with the MTT and Ball group improving more than either of the other two experimental groups. On average in processing speed, the MTT and Ball group did about 13.5 points better than the control group and almost 9 points better than the MTT group. On average in math fluency, the MTT and Ball group did about 7.5 points better than the control group and almost 7 points better than the MTT group. In terms of reading fluency, if this test is examined on a two-tailed basis, it showed trends towards statistical significance. On average in reading fluency, the MTT and Ball group did about 2.4 points better than the control group, *p* =.056, and about 1 point better than the MTT group, *p* = .777; however, with the Standard Error being 1.44 compared to the control and 1.47 compared to the MTT group and the sample size being as small as it was, there is just too much error to show significance on a two-tailed test.

Secondary Analysis

Method

The results from the initial analysis brought up a new research question: could other influencing factors be identified and controlled for to reduce the within group difference and allow the actual correlation between reading fluency and group membership be better represented? Logically, in an ANOVA situation, whatever is between group differences is divided by whatever is within group differences. Since all error is portioned into the within group difference, by identifying and controlling for other factors that might cause within group differences, there would be a greater likelihood of seeing the between group differences of experimental group on the difference in reading fluency scores.

This was attempted in two ways: First, a MANOVA was conducted to see if there was any error based on interdependence of test difference scores in the one-way ANOVAs. Next, an exploratory regression was performed to see if other variables, such as gender, pre-reading SS scores, pre-math SS scores, average age, and pre-processing SS scores, linearly related to the dependent variable of difference in reading fluency scores. For all of these processes, assumptions were checked. Finally, reading fluency was approached as a one-sided, hypothesized test, and a one-tailed ANOVA *p*-value was calculated.

Results

MANOVA

One could argue that skills such as reading fluency, math fluency, and processing speeds could be related to each other. To analyze how these scores correlated with one another the Pearson Correlation was analyzed for each pre-test against each other. Table 11 shows these Pearson Correlations. In almost all cases, when broken into groups, there were statistically significant correlations between pre-test scores. For this reason, there was a question of whether the differences between pre and post-test scores were independent of each other as variables. A MANOVA was conducted on the three dependent variables using the independent variable of group.

As predicted, there was a statistically significant difference in this model based on experimental group using Wilks' Lambda: F (6, 108) = 6.66, $p < .001$ with an observed power of .999. That is to say, when processing speed, reading fluency, and math fluency are combined together there is an overall statistical difference created by experimental condition; that across the three measures training was shown to have an affect. The corrected model of between-subjects effects was the same as the one-way ANOVAs on the three variables, with both differences in processing speed and math fluency being significant and differences in reading fluency showing trends of improvement, but not enough to be significant. Table 12 summarizes the results of the MANOVA and Table 13 summarizes the MANOVA associated ANOVA results.

Exploratory Regression

An exploratory statistical regression was performed to predict differences in reading fluency test scores from the following candidate predictor variables: gender (coded 0 = Male, 1 = Female), processing pre test scores, math fluency pre test scores, reading fluency pre-test scores, average age at tests, and metronome training (coded 0 = no training, 1= training). The total N for this sample was 59. Preliminary data screening included K-S tests for all continuous variables (see Table 14), examination of histograms of scores on all variables, and examination of scatter plots for all pairs of variables. Univariate distributions were reasonably normal with no extreme outliers. Bivariate relations were not very linear for most variables; however, the analysis was continued.

Statistical multiple regression was performed using Method = Forward with the *F*-to-enter criterion value set at $F = 3.00$. That is, in each step, SPSS entered the one predictor variable that would produce the largest increase in R^2. When the *F* ratio for the R^2 increase due to additional variables fell below $F = 3.00$, no further variables were added to the model. This resulted in metronome training being entered into the model and all other variables being excluded. None of the other variables had enough of a predicting value on difference in reading fluency scores to be entered into the equation. From this it was recognized that there would not be another variable that could be controlled for to reduce the within group variance and better show the effect training had on reading fluency. Tables 15 through 18 provide a summary of these results.

One-tailed One-way ANOVA

The MANOVA, and the exploratory regression were all run to try to find ways of reducing the within group variance to better show statistical significance on a two-tailed reading fluency test. This would give us the strongest argument that experimental group influenced the difference in reading fluency test scores. However, with all three analyses, we were unable to factor out any of the error in our within group variance. Nothing else we measured had a predictive relationship with the difference in reading fluency test score besides the metronome training.

While it would be ideal to show a statistical difference on a two-tailed test, this was actually a one-tailed experiment. We hypothesized that we would see improvement through the training. For this reason, we can divide the p of the original one-way ANOVA in half to get the one-tailed significance, $p = .030$. This shows that experimental group creates a statistically significant difference in reading fluency performance.

However, the difference in this case was the control group was significantly lower than either the MTT or the MTT and Ball groups.

Discussion

This evaluation was conducted to see if the Hardy Brain Training Program improved processing scores, reading fluency scores, and math fluency scores in the general population of mixed-gender youth found in the Boys and Girls Club. The analyses show that: 1) when students with metronome training are compared to students without metronome training the students with metronome training do statistically better than the students without metronome training in all three dependent measures, and 2) when students are compared by experimental group, the MTT and Ball group improved more that the metronome group in all three dependent measures.

The in-depth analysis of the within group variance in reading fluency was a good example of how training is an important factor in student improvement in these measures. The forward regression showed how training was predictive of improvement when gender, age, and pre test abilities were not. Forward regressions of both processing speed and math fluency showed the same trends, metronome training was predictive of difference in pre and posttest scores while gender and age were not linearly related to the outcome.

Codebook

- Grade = The grade the student is currently in
- Group = Experimental Group (0 = control, 1 = Millisecond Timing Training, 2 = MTT and ball bounce activity)
- Metronome = Training versus no training (0 = no training, 1 = training)
- Gender = Gender (0 = male, 1 = female)
- DatetestingPre = the date of pretest in Month/Day/Year format
- SSPreP = Standard Score in Processing at Pre-test
- SSPreRF = Standard Score in Reading Fluency at Pre-test
- SSPreMF = Standard Score in Math Fluency at Pre-test
- DatePostTest = the date of pretest in Month/Day/Year format
- SSPostP = Standard Score in Processing at Post-test
- SSPostRF = Standard Score in Reading Fluency at Post-test
- SSPostMF = Standard Score in Math Fluency at Post-test
- SSPDiff = Difference in Standard Score between pre and post test for processing speed
- SSRFDiff = Difference in Standard Score between pre and post test for reading fluency
- SSMFDiff = Difference in Standard Score between pre and post test for math fluency

- AgePretest = Age (in months) at pretest
- AgePosttest = Age (in months) at post test
- Ageaverage = The average age of participant as calculated by the pre test age plus the post test age divided by two.

Appendix- SPSS Tables For Results

Table 1

Descriptive Statistic of Student Grade and Pre-Test Scores, and Age at Pre-test, Broken into Experimental Groups

Table 2

Descriptive Statistics

		N	Minimum	Maximum	Mean	Std. Deviation	Skewness		Kurtosis	
Experimental Group		Statistic	Statistic	Statistic	Statistic	Statistic	Statistic	Std. Error	Statistic	Std. Error
MTT and ball	Student Grade	19	3	5	4.21	.787	-.410	.524	-1.208	1.014
	SS pre processing	19	68	111	94.47	11.539	-.864	.524	.435	1.014
	SS pre reading fluency	19	76	110	95.89	9.712	-.395	.524	-.503	1.014
	SS pre math fluency	19	80	118	98.11	11.406	.159	.524	-.868	1.014
	Age at Pre-test	19	102	133	120.58	8.946	-.411	.524	-.474	1.014
	Valid N (listwise)	19								
MTT	Student Grade	19	2	5	3.89	.737	-.756	.524	1.488	1.014
	SS pre processing	19	74	124	100.00	14.591	.119	.524	-.861	1.014
	SS pre reading fluency	19	81	113	98.21	8.848	-.244	.524	-.309	1.014
	SS pre math fluency	19	79	125	103.11	11.785	-.054	.524	-.095	1.014
	Age at Pre-test	19	100	130	113.79	9.077	.079	.524	-.479	1.014
	Valid N (listwise)	19								
Control	Student Grade	21	3	5	4.00	.707	.000	.501	-.807	.972
	SS pre processing	21	77	127	99.14	12.163	.182	.501	.110	.972
	SS pre reading fluency	21	79	103	93.33	6.959	-.486	.501	-.748	.972
	SS pre math fluency	21	78	116	91.00	11.189	.724	.501	-.418	.972
	Age at Pre-test	21	103	129	116.67	7.398	-.448	.501	-.594	.972
	Valid N (listwise)	21								

Test of Normality For Pre-test Scores

Tests of Normality

	Experimental Group	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
SS pre processing	Control	.100	21	.200*	.982	21	.951
	MTT	.129	19	.200*	.959	19	.558
	MTT and ball	.186	19	.083	.925	19	.138
SS pre reading fluency	Control	.157	21	.190	.944	21	.259
	MTT	.095	19	.200*	.975	19	.871
	MTT and ball	.114	19	.200*	.956	19	.495
SS pre math fluency	Control	.167	21	.131	.901	21	.037
	MTT	.098	19	.200*	.985	19	.984
	MTT and ball	.100	19	.200*	.963	19	.631

a. Lilliefors Significance Correction
*. This is a lower bound of the true significance.

Table 3

Group Statistics for Comparison Independent Samples t-Test

Group Statistics

	Metronome training	N	Mean	Std. Deviation	Std. Error Mean
SS Difference Processing	No training	21	-7.48	8.959	1.955
	training	38	-16.58	9.406	1.526
SS Difference Reading Fluency	No training	21	.33	3.903	.852
	training	38	-2.55	4.819	.782
SS Difference Math Fluency	No training	21	-2.57	6.607	1.442
	training	38	-6.66	6.486	1.052

Table 4

Independent t-Test of Difference Scores Showing Training Versus No Training

Independent Samples Test

		Levene's Test for Equality of Variances		t-test for Equality of Means						
									95% Confidence Interval of the Difference	
		F	Sig.	t	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	Upper
SS Difference Processing	Equal variances assumed	.350	.557	3.619	57	.001	9.103	2.516	4.065	14.140
	Equal variances not assumed			3.671	43.135	.001	9.103	2.480	4.102	14.104
SS Difference Reading Fluency	Equal variances assumed	1.254	.268	2.349	57	.022	2.886	1.229	.425	5.347
	Equal variances not assumed			2.496	49.072	.016	2.886	1.156	.563	5.209
SS Difference Math Fluency	Equal variances assumed	.006	.940	2.302	57	.025	4.086	1.775	.532	7.641
	Equal variances not assumed			2.289	40.729	.027	4.086	1.785	.481	7.692

Table 5

Descriptive Statistics of Difference Scores and Average Age, Broken into Experimental Groups

Descriptive Statistics

Experimental Group		N Statistic	Mean Statistic	Std. Deviation Statistic	Skewness Statistic	Skewness Std. Error	Kurtosis Statistic	Kurtosis Std. Error
MTT and ball	SS Difference Processing	19	-21.00	8.035	-.112	.524	-.377	1.014
	SS Difference Reading Fluency	19	-3.05	4.708	.265	.524	-.505	1.014
	SS Difference Math Fluency	19	-10.11	5.476	-.549	.524	.390	1.014
	Average age for tests	19	121.0000	8.92873	-.387	.524	-.471	1.014
	Valid N (listwise)	19						
MTT	SS Difference Processing	19	-12.16	8.719	-1.243	.524	1.871	1.014
	SS Difference Reading Fluency	19	-2.05	5.005	.067	.524	-.893	1.014
	SS Difference Math Fluency	19	-3.21	5.603	-1.173	.524	2.133	1.014
	Average age for tests	19	114.5000	9.03389	.051	.524	-.507	1.014
	Valid N (listwise)	19						
Control	SS Difference Processing	21	-7.48	8.959	.522	.501	.395	.972
	SS Difference Reading Fluency	21	.33	3.903	-.344	.501	-.282	.972
	SS Difference Math Fluency	21	-2.57	6.607	-.527	.501	-.321	.972
	Average age for tests	21	117.3810	7.37208	-.417	.501	-.594	.972
	Valid N (listwise)	21						

Table 6

Tests for Normality for Pre Tests by Group

Tests of Normality

		Kolmogorov-Smirnov[a]			Shapiro-Wilk		
	Experimental Group	Statistic	df	Sig.	Statistic	df	Sig.
SS pre processing	Control	.100	21	.200*	.982	21	.951
	MTT	.129	19	.200*	.959	19	.558
	MTT and ball	.186	19	.083	.925	19	.138
SS pre reading fluency	Control	.157	21	.190	.944	21	.259
	MTT	.095	19	.200*	.975	19	.871
	MTT and ball	.114	19	.200*	.956	19	.495
SS pre math fluency	Control	.167	21	.131	.901	21	.037
	MTT	.098	19	.200*	.985	19	.984
	MTT and ball	.100	19	.200*	.963	19	.631

a. Lilliefors Significance Correction
*. This is a lower bound of the true significance.

Table 7

Tests for Normality for Difference Scores by Group

Tests of Normality

	Experimental Group	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
SS Difference Processing	Control	.109	21	.200*	.970	21	.725
	MTT	.184	19	.088	.912	19	.080
	MTT and ball	.091	19	.200*	.983	19	.967
SS Difference Reading Fluency	Control	.139	21	.200*	.979	21	.907
	MTT	.136	19	.200*	.958	19	.525
	MTT and ball	.127	19	.200*	.969	19	.749
SS Difference Math Fluency	Control	.136	21	.200*	.936	21	.179
	MTT	.190	19	.068	.896	19	.041
	MTT and ball	.193	19	.060	.922	19	.124

a. Lilliefors Significance Correction
*. This is a lower bound of the true significance.

Table 8

Levene's Test of Variance for Three Dependent Variables

Test of Homogeneity of Variances

	Levene Statistic	df1	df2	Sig.
SS Difference Processing	.040	2	56	.960
SS Difference Reading Fluency	.480	2	56	.622
SS Difference Math Fluency	.453	2	56	.638

Table 9

One-Way ANOVAs of Differences Between Pre and Post Tests for the Three Dependent Variables.

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
SS Difference Processing	Between Groups	1863.456	2	931.728	12.616	.000
	Within Groups	4135.764	56	73.853		
	Total	5999.220	58			
SS Difference Reading Fluency	Between Groups	122.150	2	61.075	2.962	.060
	Within Groups	1154.561	56	20.617		
	Total	1276.712	58			
SS Difference Math Fluency	Between Groups	677.469	2	338.735	9.590	.000
	Within Groups	1978.090	56	35.323		
	Total	2655.559	58			

Table 10

Post Hoc Tests for the Three Dependent Variables.

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Experimental Group	(J) Experimental Group	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
SS Difference Processing	Control	MTT	4.682	2.721	.207	-1.87	11.23
		MTT and ball	13.524*	2.721	.000	6.97	20.07
	MTT	Control	-4.682	2.721	.207	-11.23	1.87
		MTT and ball	8.842*	2.788	.007	2.13	15.55
	MTT and ball	Control	-13.524*	2.721	.000	-20.07	-6.97
		MTT	-8.842*	2.788	.007	-15.55	-2.13
SS Difference Reading Fluency	Control	MTT	2.386	1.438	.230	-1.08	5.85
		MTT and ball	3.386	1.438	.056	-.08	6.85
	MTT	Control	-2.386	1.438	.230	-5.85	1.08
		MTT and ball	1.000	1.473	.777	-2.55	4.55
	MTT and ball	Control	-3.386	1.438	.056	-6.85	.08
		MTT	-1.000	1.473	.777	-4.55	2.55
SS Difference Math Fluency	Control	MTT	.639	1.882	.938	-3.89	5.17
		MTT and ball	7.534*	1.882	.001	3.00	12.06
	MTT	Control	-.639	1.882	.938	-5.17	3.89
		MTT and ball	6.895*	1.928	.002	2.25	11.54
	MTT and ball	Control	-7.534*	1.882	.001	-12.06	-3.00
		MTT	-6.895*	1.928	.002	-11.54	-2.25

*. The mean difference is significant at the 0.05 level.

Table 11

Correlations between Pre-Test Scores

Correlations

Experimental Group			SS pre processing	SS pre reading fluency	SS pre math fluency
MTT and ball	SS pre processing	Pearson Correlation	1	.566*	.561*
		Sig. (2-tailed)		.012	.012
		N	19	19	19
	SS pre reading fluency	Pearson Correlation	.566*	1	.306
		Sig. (2-tailed)	.012		.203
		N	19	19	19
	SS pre math fluency	Pearson Correlation	.561*	.306	1
		Sig. (2-tailed)	.012	.203	
		N	19	19	19
MTT	SS pre processing	Pearson Correlation	1	.761**	.637**
		Sig. (2-tailed)		.000	.003
		N	19	19	19
	SS pre reading fluency	Pearson Correlation	.761**	1	.664**
		Sig. (2-tailed)	.000		.002
		N	19	19	19
	SS pre math fluency	Pearson Correlation	.637**	.664**	1
		Sig. (2-tailed)	.003	.002	
		N	19	19	19
Control	SS pre processing	Pearson Correlation	1	.655**	.492*
		Sig. (2-tailed)		.001	.023
		N	21	21	21
	SS pre reading fluency	Pearson Correlation	.655**	1	.494*
		Sig. (2-tailed)	.001		.023
		N	21	21	21
	SS pre math fluency	Pearson Correlation	.492*	.494*	1
		Sig. (2-tailed)	.023	.023	
		N	21	21	21

*. Correlation is significant at the 0.05 level (2-tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

Table 12

Manova of Difference of Test Scores

Multivariate Tests[d]

Effect		Value	F	Hypothesis df	Error df	Sig.	Noncent. Parameter	Observed Power[b]
Intercept	Pillai's Trace	.777	62.799[a]	3.000	54.000	.000	188.398	1.000
	Wilks' Lambda	.223	62.799[a]	3.000	54.000	.000	188.398	1.000
	Hotelling's Trace	3.489	62.799[a]	3.000	54.000	.000	188.398	1.000
	Roy's Largest Root	3.489	62.799[a]	3.000	54.000	.000	188.398	1.000
Group	Pillai's Trace	.488	5.918	6.000	110.000	.000	35.508	.997
	Wilks' Lambda	.533	6.656[a]	6.000	108.000	.000	39.934	.999
	Hotelling's Trace	.837	7.392	6.000	106.000	.000	44.350	1.000
	Roy's Largest Root	.787	14.421[c]	3.000	55.000	.000	43.264	1.000

a. Exact statistic
b. Computed using alpha =
c. The statistic is an upper bound on F that yields a lower bound on the significance level.
d. Design: Intercept + Group

Table 13

MANOVA ASSOCIATED ANOVA RESULTS

Tests of Between-Subjects Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Noncent. Parameter	Observed Power[b]
Corrected Model	SS Difference Processing	1863.456[a]	2	931.728	12.616	.000	25.232	.995
	SS Difference Reading Fluency	122.150[c]	2	61.075	2.962	.060	5.925	.554
	SS Difference Math Fluency	677.469[d]	2	338.735	9.590	.000	19.179	.976
Intercept	SS Difference Processing	10800.007	1	10800.007	146.237	.000	146.237	1.000
	SS Difference Reading Fluency	148.947	1	148.947	7.224	.009	7.224	.752
	SS Difference Math Fluency	1650.968	1	1650.968	46.739	.000	46.739	1.000
Group	SS Difference Processing	1863.456	2	931.728	12.616	.000	25.232	.995
	SS Difference Reading Fluency	122.150	2	61.075	2.962	.060	5.925	.554
	SS Difference Math Fluency	677.469	2	338.735	9.590	.000	19.179	.976
Error	SS Difference Processing	4135.764	56	73.853				
	SS Difference Reading Fluency	1154.561	56	20.617				
	SS Difference Math Fluency	1978.090	56	35.323				
Total	SS Difference Processing	16497.000	59					
	SS Difference Reading Fluency	1414.000	59					
	SS Difference Math Fluency	4253.000	59					
Corrected Total	SS Difference Processing	5999.220	58					
	SS Difference Reading Fluency	1276.712	58					
	SS Difference Math Fluency	2655.559	58					

a. R Squared = .311 (Adjusted R Squared = .286)
b. Computed using alpha =
c. R Squared = .096 (Adjusted R Squared = .063)
d. R Squared = .255 (Adjusted R Squared = .229)

Table 14

K-S test of Normality of Average Age Separated into Experimental Group

Tests of Normality

	Experimental Group	Kolmogorov-Smirnov[a] Statistic	df	Sig.	Shapiro-Wilk Statistic	df	Sig.
Average age for tests	Control	.125	21	.200*	.952	21	.365
	MTT	.139	19	.200*	.949	19	.381
	MTT and ball	.091	19	.200*	.962	19	.618

a. Lilliefors Significance Correction
*. This is a lower bound of the true significance.

Table 15

Model Summary of Forward Exploratory Regression

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics: R Square Change	F Change	df1	df2	Sig. F Change	Durbin-Watson
1	.297[a]	.088	.072	4.519	.088	5.516	1	57	.022	1.750

a. Predictors: (Constant), Metronome training
b. Dependent Variable: SS Difference Reading Fluency

Table 16

Model ANOVA of Forward Exploratory Regression

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	112.650	1	112.650	5.516	.022[a]
	Residual	1164.061	57	20.422		
	Total	1276.712	58			

a. Predictors: (Constant), Metronome training
b. Dependent Variable: SS Difference Reading Fluency

Table 17

Metronome Training as the Only Coeffients of Forward Linear Regression

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.	Correlations Zero-order	Correlations Partial	Correlations Part
1	(Constant)	.333	.986		.338	.737			
	Metronome training	-2.886	1.229	-.297	-2.349	.022	-.297	-.297	-.297

a. Dependent Variable: SS Difference Reading Fluency

Table 18

Excluded Variables of Forward Linear Regression

Excluded Variables[b]

Model		Beta In	t	Sig.	Partial Correlation	Collinearity Statistics Tolerance
1	Average age for tests	-.046[a]	-.359	.721	-.048	1.000
	SS pre math fluency	-.162[a]	-1.189	.239	-.157	.859
	SS pre reading fluency	.043[a]	.327	.745	.044	.957
	SS pre processing	-.020[a]	-.160	.873	-.021	.995
	Gender	-.068[a]	-.531	.598	-.071	1.000

a. Predictors in the Model: (Constant), Metronome training
b. Dependent Variable: SS Difference Reading Fluency