THE PENNSYLVANIA STATE UNIVERSITY
SCHREYER HONORS COLLEGE

DEPARTMENT OF SCIENCE

An Analysis on the Effectiveness of Neuro-Fitness Training Among Collegiate Softball Players

MATTHEW RODA
SUMMER 2020

A thesis
submitted in partial fulfillment
of the requirements
for a baccalaureate degree
in Science
with honors in Science

Reviewed and approved* by the following:

Keefe Manning
Professor of Biomedical Engineering
Thesis Supervisor

Ronald Markle
Professor of Biology
Honors Adviser

Giampietro Vairo
Clinical Associate Professor of Kinesiology, and
Orthopaedics & Rehabilitation
Faculty Reader

* Electronic approvals are on file.

ABSTRACT

With two thirds of our brain's processing information connected to our visual field, there is no debate about the crucial role eyes play in sports. Improving visual, combined with information processing and motor, skills represents a potential area of human performance enhancement, particularly among athletes seeking a competitive advantage. Thus, the role of sports vision training (SVT) has played an increasingly large part in the developmental training of athletes, and is the mission of new companies offering products for this purpose, like Reflexion. This thesis aims to evaluate the effectiveness of SVT on softball players as measured by Reflexion's tests and drills, and to search for a link between improved Reflexion scores and higher achieving players on the field.

To do so, data from the spring 2020 season was analyzed from the University of Maine's softball team by exploring correlations between SVT and batting metrics. Five of Reflexion's drills demonstrated at least one independent cognitive function containing a significant increase in performance, while two showed a decrease, and two showed no change at the team-wide level. When analyzing batting metrics, three drills were found to be correlated to batting average and slugging percentage. These results indicate that Reflexion may be a valuable tool in SVT and could act as a tool in predictive modeling for batting metrics.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGEMENTES

My journey to graduation has been a long one. There were many moments that only the support of others kept my hope alive, and I owe them many thanks.

Dr. Manning, thank you for pushing me, and believing I would get it done. You stepped up to be my adviser, and without your encouragement, this wouldn't have been possible. Dr. Markle, you provided the know-how needed to navigate Penn State academic requirements, and along with Dr. Viaro, offered knowledge as a reader to better this thesis.

Mom and Dad, you provided unwavering support during my graduation journey, I am where I am today because of this.

To my friends, you provided the shenanigans and laughter to keep me sane through it all.

John Galanti, thank you for pushing me to graduate even when it seemed unnecessary. A Penn State degree goes a long way.

Finally, to Matt Campagna, my lifelong friend and co-founder. Thank you for supporting my work to graduate.

Disclosure

Matthew Roda is a founder, majority stakeholder, and board member of Reflexion Interactive Technologies, Inc. The company provided the raw data to be analyzed but held no role or provided any assistance in the writing of this thesis.

Chapter 1 Introduction

At all levels, sports are becoming increasingly competitive. Rather than acting as extra curriculars for students outside of the classroom, there are many institutions dedicated fully to fostering athletic performance in young adults (Eime 2017). Groups like IMG Academy in Florida have been producing NFL-level athletes for decades, and as of 2018, high school sport participation has grown for the twenty-ninth consecutive year (NFHS 2018). The number of participants is growing but also the elite programs are becoming more elite.

As athletic participation grows, so too does our understanding of the human body. Exercise physiology traces its lineage to ancient Greece, where early physicians like Galen coached players in the first days of the Olympics (Berryman and Park 1992). Now, every major athletic program and professional sports team has a sports scientist on staff, if not a whole department, dedicated to improving the way athletes train. Coaches are expanding beyond traditional training methods in search for greater performance on the field (Reed 2020).

History of Performance Training

The continued development of exercise physiology has led to revolutions in sports, even within the last few decades. For example, weight training for athletes was not universally accepted by all sports until the 1990s (Williams 2013). Some believe those exercises would result in too much “bulk” on athletes, which is fine for a football lineman but not an agile soccer player. Eventually, through peer reviewed research and organized discussion, groups like the National Strength and Conditioning Association made resistance training in all sports a necessity for successful programs (Williams 2013; Vecchio 2018; Korhonen 2016).

A similar paradigm shift was seen with analytics in baseball, now popularized by the 2011 film *Moneyball* (Miller 2011), when the Oakland A’s used one of the smallest budgets in

Major League Baseball and performed with the top teams in the early 2000s (Pranav 2018). Previously, scouts were trusted as the oracles for spotting stars, but general manager Billy Beane used data to make his decisions, and it revolutionized the role of analytics in baseball. The last five years has even brought machine learning and neural networks to the table in an attempt to predict outcomes of player performance (Goldstein 2017; University of Wisconsin Data Science Team 2017). However, the exploration of new training techniques and an emphasis on data has allowed a new form of training to rapidly grow.

Vision in Sports

With two thirds of our brain's processing information connected to our visual field, there is no debate about the crucial role eyes play in sports (Appelbaum, 2016). Despite this, coaches do not know that exercises are capable of improving visual skills . As one example, players can train the speed of eye saccades, or eye twitches, to better control where a person is looking, and how long it takes their eyes to get there. In order to be competitive at the professional and collegiate-level, athletes need to have excellent visual skills, and this has been shown frequently in research. Major League Baseball players must have better visual acuity to outperform their peers (Laby 1996), and collegiate-level baseball players have shown superior visual tracking abilities (Uchida 2013) and enhanced contrast sensitivity compared to nonathletic peers (Hoffman 1984). Athletes have also been found to make more efficient eye movements, have faster information processing speeds and can better detect perceptual cues (Mann 2007).

Improving visual skills, combined with information processing and motor ability, represents a potential area of human performance enhancement, particularly among athletes seeking a competitive advantage. Thus, the role of sports vision training (SVT) has played an increasingly large part in the developmental training of athletes (Appelbaum 2016). The term "vision training" can be deceptive because more than just eyes are involved in the process. The eyes are like two high speed cameras that are wired to a complex neural system, so vision training also includes cognitive abilities of the brain to process information and make quick decisions based on what it sees. Some of the primary cognitive functions are reaction time, decision-making speed, inhibition control, eye-hand coordination, and spatial memory, and they are the area of focus for many sports scientists (Fadde 2010).

Beyond just the sports world's interest in better outcomes and winning more games, there are far reaching applications to understanding the role vision and cognitive function plays in performance. Duke University's Optimum Performance Lab, which primarily works with collegiate players, receives funding from the Department of Defense (DoD) to study vision and cognitive training in athletes. Their goal is to use an athlete-soldier (tactical athlete) model to better learn what makes high performers in a tense situation. In-game performance is much easier and safer to measure results and control environmental factors but can be applied to more extreme situations. This is why it is a common model used by the DoD to improve their training methods with soldiers (Appelbaum 2016).

Development of SVT Techniques

Early forms of SVT included simple eye exercises, like changing convergence points between near and far objects as quickly as possible. These analog techniques produced mixed results from research studies (Eccles, 2006), but by the 1980s, technology began to play a bigger role. "Light boards," consisting of small lights and buttons over a large surface area, were the first type of hardware to train visual skills in a more controlled environment. The first of these were created by Henry Wayne, an optometrist who developed a board with twenty-five lights and buttons called the Wayne Saccadic Fixator (Figure 1). Since its introduction in the early 1980s, the products and methods used for SVT have only grown more advanced and analytical.

Figure 1. The Wayne Saccadic Fixator is a light board with twenty-five buttons to measure visual field and response time. (Bernell 2020)

One example of more recently developed technology is “strobe goggles” that have crystalline lenses to temporarily block a person’s view in a strobe manner. The goal is to perform at a normal level while giving your eyes a percentage of the scene it usually receives. For example, a basketball player may wear them during a scrimmage and have it set to block their vision for 100 milliseconds of every second, so requiring the brain to still play basketball with 10% less information (Siegal 2016).

Light boards remain one of the most common form of SVT and are offered by a number of different companies. The BinoviTouch is a modernized version of the Wayne Saccadic Fixator, Dynavision offers a sixty light version that’s a four-by-four foot square, and Senaptec uses a touchscreen TV monitor to accomplish the same goal. Much more recently, Reflexion has developed both a light board and a cloud service to analyze and track results for players. Their mission is to “gamify” vision training and provide a platform for individual athletes to monitor changes in cognitive skills in a fun and competitive way. Drills are done on the Edge® (Reflexion Interactive Technologies Inc, Lancaster, PA) (Figure 2), a two by six-foot light emitting diode (LED) touchscreen, with data processed and viewed by a cloud-based application.

Factors like increased sports participation, athletes’ constant need to gain a competitive

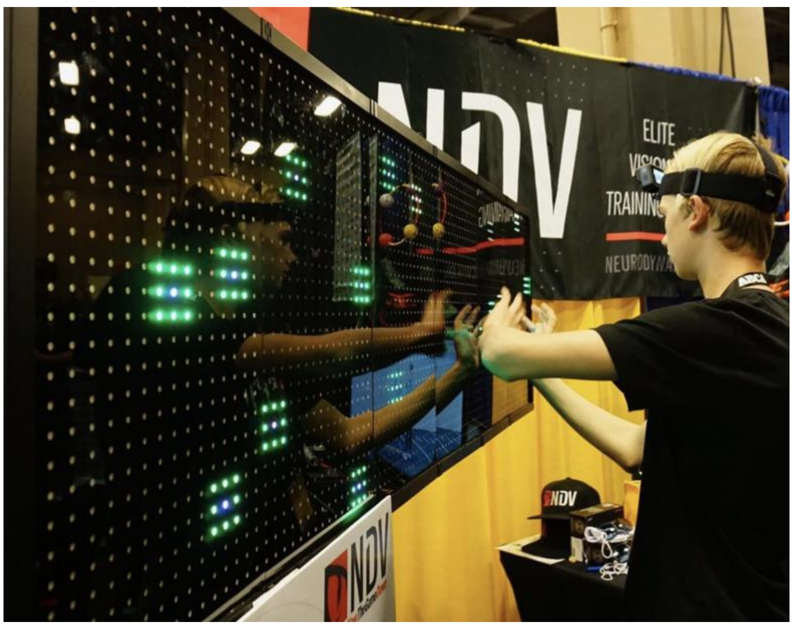

Figure 2. The Reflexion Edge, a 2x6 foot LED touchscreen, during a Minefield drill

edge, growing emphasis on analytics, and a $100 billion global fitness market (IHRSA 2020) have all driven the rise of SVT as common practice in athletics. Despite these powerful driving forces, the research surrounding vision training is not robust, and the link between SVT and direct, sport-specific improvement is not clearly defined.

To assist in clarifying the relationship, this study aims to evaluate the success of SVT on softball players as measured by Reflexion’s tests and drills, and identify a link between improved

Reflexion scores and higher achieving players on the field. The hypothesis for this study is that athletes will show significant improvement in visual and cognitive skills on Reflexion's tests over the course of their season, and athletes with relative higher scores on Reflexion's neuro-fitness training system will have better on-field performance than their peers with low scores.

Chapter 2 Theory

Reflexion Edge Technology

The Reflexion Edge® is designed to be a precise measure of visual and cognitive function, able to accommodate all different kinds of training structures based on the needs of the team or athlete. The Edge® is a 6'x 2' touchscreen display that collapses like an accordion for portability. The size of the board is important to capture a person's full field of view as well as engage "functional movement" (or full body movement) (Orr 2009). These two factors are critical components of SVT and why it is so difficult to effectively replicate on a phone or tablet.

With over 2,500 full color LEDs, there are limitless possibilities of drills and assessments the Edge® can embody. The user interacts with different lights/patterns and are judged on speed, hand accuracy, and response correctness in how they react. The drills are designed to be gamified to keep athletes excited during training, and are quick, so many users can be tested during a short period of time (Figure 3). With drills less than sixty seconds, a coach can work

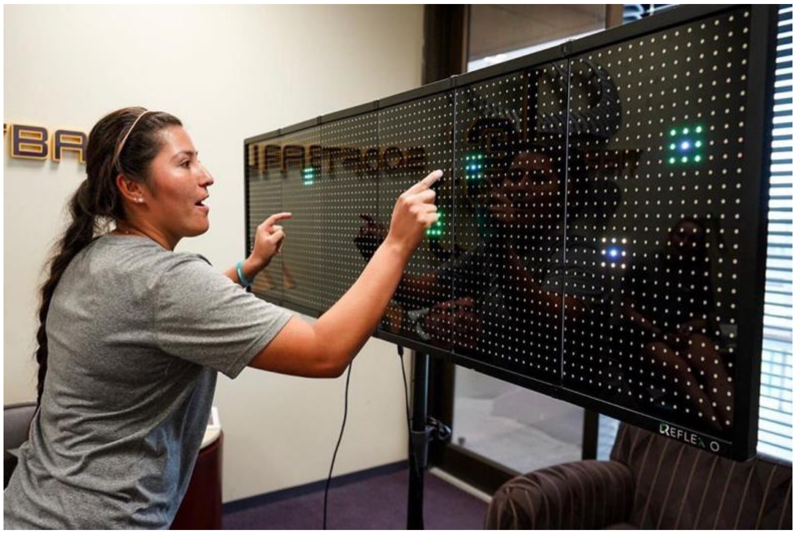

Figure 3. A softball player completing a Minefield drill on the Edge.

individually with an athlete running many drills at a time or train an entire team during a single practice.

The Edge® connects to an iPad® (Apple Inc., Palo Alto) to run drills and view results. After a test is completed, the LED board sends raw, unprocessed information to the iPad, which communicates it to Reflexion's cloud service. Data analysis takes place remotely, and parsed results are transmitted back to the iPad for display. Drills are run on a specific athlete's account, meaning Reflexion can also show trends over time to view a player's progress.

Cognition

Reflexion provides a measurement of multiple cognitive and visual skills, and while these vary based on which drill is being performed, there are common cognitions involved in almost all assessments.

Reaction Time

One of the most fundamental components of human performance is reaction time, or how quickly your brain can process and react to information. On the Edge®, total reaction time is broken down into two parts based on a "home-base" design. This requires the athlete to keep their finger on a square on the Edge and reacting to the targets by removing their finger from it. This allows the technology to record "latency time," or the amount of time in milliseconds required for the athlete to lift their hand from the home base after the target appears. Latency time is an estimate of brain processing speed. "Motor time" is then defined as the time it takes to reach the target after the athlete has lifted their finger from the home base. The sum of latency and motor time is total reaction time (Equation 1).

$$Total\ Reaction\ Time = Latency\ time + Motor\ time \qquad \text{Equation 1}$$

Reaction time is further categorized by the number of unknowns in the test. Simple reaction time (SRT) is when the user knows where the light will appear but not when. If the user does not know when or where the light will appear, the extra layer of complexity makes it is a complex reaction time (CRT) test. These can also be made more difficult by adding a decision, like only responding to lights of certain colors.

Eye-Hand Coordination

The Edge uses capacitive touchscreens, similar to those on a phone or tablet. This allows measurements of touch location to be very precise, so most drills record eye-hand coordination to the nearest millimeter for both accuracy and precision. Accuracy represents the average

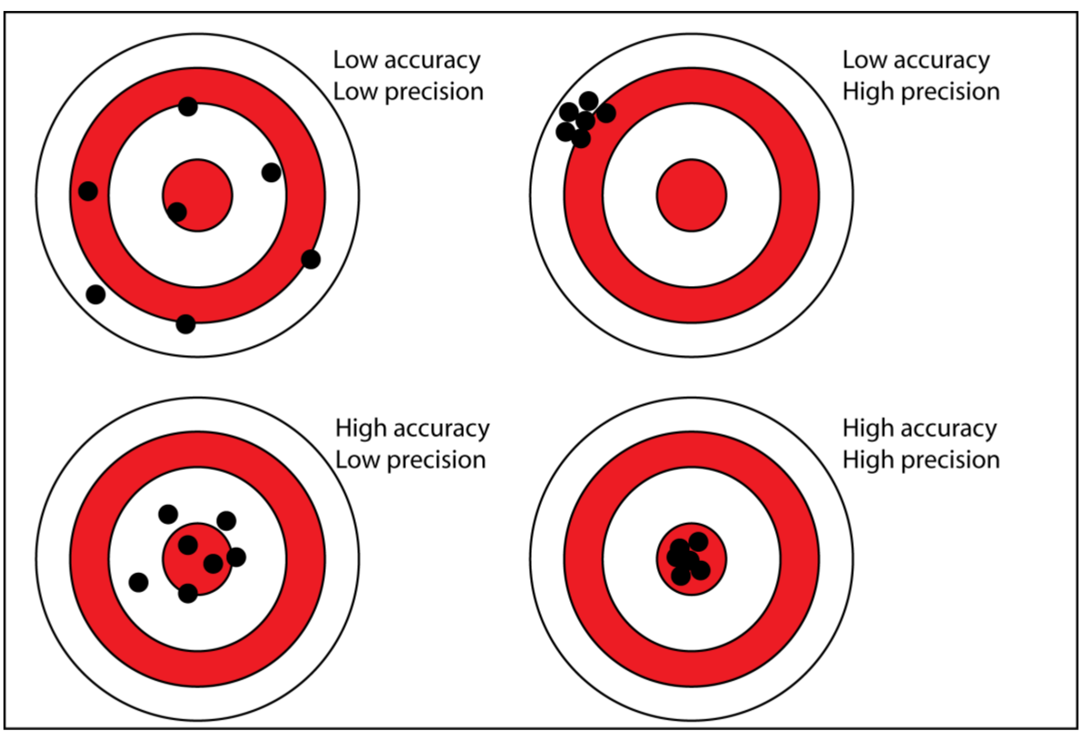

Figure 4. A visualization of the difference between accuracy and precision (Evans 2019).

distance away from the center of the target, while precision measures how consistent, or "clustered," the touches are to each other (Figure 3).

Dual Task

The majority of drills offered by Reflexion include a "dual task" component, or having multiple cognitions involved in a single drill (Kim 2014). Because Reflexion's drills are gamified, they typically are not designed to assess exactly a specific cognition. Rather, one test may be a combined drill of reaction time, hand-eye coordination, and peripheral vision, and the data output may or may not specifically separate those results. While this approach is less surgical in measuring cognitions, it allows for more creative and gamified drills, as well as more complex tasks that imitate sport-specific decisions.

Eight of Reflexion's drills and their descriptions can be found in Table 1.

Table 1. Reflexion drills and their descriptions done by the Maine softball team

Drill	Description
Big G	One at a time, targets will appear. Your goal is to hit them as quickly and as accurately as possible.
Complex Reaction Time	Targets will appear on either the left or right side and your goal is to react to them as quickly as possible.
Expanding Out	Targets will appear one at a time, slowly expanding outwards. Your goal is to hit them as quickly and as accurately as possible while keeping your vision trained in the center of the Edge.
Go No Go	Targets will appear on either the left or right side and will be either red or green. Your goal is to react to the green as quickly as possible, without flinching at the red. For colorblind individuals, the targets are presented as blue for "go" and yellow for "no go"
Memory Saccade	Memorize the order and location of lights that appear on the center two panels of the Edge.
Minefield	Boxes will appear anywhere within your wingspan. They start green and over the course of their detonation time turn red. Your goal is to not let any singular box

	turn completely red or the mine explodes. For colorblind individuals, the targets blue and change to yellow.
Right And Left Execution	Targets will appear one at a time and your goal is to hit them as quickly and accurately as you can. You'll need to hit yellow targets with your left hand and purple targets with your right hand.
Waterfall	Boxes will move from each side of the Edge to the opposite. Touch each box to make it disappear before it reaches its destination.

The output of each drill varies on the cognition it is testing or training. The results are all some form of standard measurement, like millimeters, milliseconds, or percentages, or easily derived therefrom. These descriptions and definitions can be found in Table 2.

Table 2. The output of each Reflexion drill and how it is calculated.

Drill	Relevant Results Output	Higher is Better or Lower is Better	Description
Big G	Accuracy	Lower	Average distance from touches to the center of the target
	Average Reaction Time	Lower	Average time between light appearing and touching the target.
Complex Reaction Time	Accuracy	Lower	Average distance from touches to the center of the target
	Latency Time	Lower	Time required to lift the user's hand from the home base after the target appears
	Motor Time	Lower	Time required to touch the target after the user's lifts their hand from the home base
Expanding Out	Central Latency & Motor Time	Lower	Reaction time measured when the target is directly in front of the subject's vision
	Peripheral Latency & Motor Time	Lower	Reaction time measured when the target is outside 60° of the subject's vision
	Reaction time per degree field of view	Higher	A ratio of reaction time at various places in your field of view to calculate a decimal of peripheral vision
Go No Go	Latency per correct percentage	Higher	Average latency time divided by the percent correct response. This is a way to factor both speed and response correctness in a single number

	Latency Time	Lower	Time required to lift the user's hand from the home base after the target appears
	Motor Time	Lower	Time required to touch the target after the user's lifts their hand from the home base
	Correct Percentage	Higher	Ratio of targets correctly responded to and total number of targets
	Accuracy	Lower	Average distance from touches to the center of the target
Memory Saccade	Memory Accuracy	Lower	Average distance from touches to the where the center of the target was before it disappeared
	Total Memory Time	Lower	Amount of time to guess where the targets had been
Minefield	Hits	Higher	Number of mines touched before the drill ended
	Misses	Lower	Number of touches near, but not on, a target
	Total Score	Higher	Misses subtracted from Hits
Right And Left Execution (R.A.L.E.)	Latency per correct percentage	Lower	The average latency time divided by the percent correct response. This is a way to factor in both speed and response correctness in a single number
	Latency Time	Lower	Time required to lift the user's hand from the home base after the target appears
	Motor Time	Lower	Time required to touch the target after the user's lifts their hand from the home base
	Correct Percentage	Higher	Ratio of targets correctly responded to and total number of targets
	Accuracy	Lower	Average distance from touches to the center of the target
Waterfall	Total Score	Higher	Total number of targets hit before the drills ends

Chapter 3 Methods

Structure of University of Maine's Softball Season

The University of Maine softball team used Reflexion as their primary provider of vision and cognitive training for the Spring 2020 season. No Internal Review Board (IRB) was involved, as the team purchased Reflexion and participated in this program while working with the business entity. Data was provided to the researchers after the program had finished. The team's twenty-two players trained on the Edge three times per week for roughly 2-3 minutes each, with the goal to improve reaction time, peripheral vision, eye-hand coordination, and spatial memory. A training schedule was developed by Reflexion for the team and can be viewed in Appendix A.

The training schedule was designed to increase softball specific cognitions by increasing the difficulty of Reflexion drills as the season progressed. University of Maine female athletes started by performing tests on relatively easy levels and working their way up to "competition" mode or even harder variants. Drills completed on competition mode require excellent coordination and reaction time as to be challenging for a collegiate-level athlete. By design, some drills were stressed more than others during the training program, there is an unequal distribution of drills, players, and dates.

Training was meant to take place from mid-February until the end of the season in May, but the COVID-19 pandemic caused a shutdown of the university and all sports programs. Unfortunately, the team only participated in the program for four weeks, thus limiting the effects of training. Table 3 shows the number of drills performed by each player during this program, and the full training schedule can be seen in Appendix A. Despite having less data than planned, it is still possible to investigate improvements in cognition as a result of training and correlations between on-field performance and Reflexion scores.

Table 3. Total number of sessions each subject performed over the course of the season per Reflexion drill.

	Big G	CRT	Exp. Out	GNG	Minefield	Memory Saccade	N+1	RALE	SRT	Waterfall
Subject 1	6	1	2	3	6	5	1	1	2	4
Subject 2	5	1	2	3	6	2	0	1	2	6
Subject 3	6	1	2	3	10	2	1	1	2	6
Subject 4	5	1	2	3	9	5	1	0	2	5
Subject 5	6	1	2	3	10	5	1	1	2	6
Subject 6	5	1	2	3	7	5	1	0	2	4
Subject 7	6	1	2	3	12	4	1	1	2	7
Subject 8	7	1	2	3	11	5	1	1	2	6
Subject 9	7	1	2	3	8	6	1	1	2	6
Subject 10	6	1	2	2	8	5	1	1	2	6
Subject 11	6	1	2	3	8	7	0	1	2	7
Subject 12	6	1	2	3	6	7	1	1	2	6
Subject 13	5	1	2	3	4	2	1	1	2	7
Subject 14	6	1	2	3	6	6	1	1	2	5
Subject 15	5	1	2	3	7	2	1	0	2	4
Subject 16	7	1	2	4	8	4	1	0	2	5
Subject 17	5	1	2	3	7	2	1	0	2	5
Subject 18	6	1	2	3	8	6	1	1	2	5
Subject 19	6	1	2	3	6	5	0	0	2	4
Subject 20	6	1	2	3	6	5	1	1	2	5
Subject 21	6	1	2	3	6	5	1	0	2	5
Subject 22	6	1	2	2	7	2	1	0	2	6

Exclusion Criteria for Performance Improvement Analysis

Certain criteria excluded tests from the analysis when searching for increased performance. Of the ten drills completed by the team in total (see Table 1), drills with less than three dates of training were removed, as at least three data points were desired to increase the significance of the improvement. This included five of the ten drills: Complex Reaction Time, Expanding Out, N+1, R.A.L.E., and Simple Reaction Time. Of the remaining data, subjects with less than three dates of training on a certain drill were removed from that drill's dataset for the same reason. The final list of subjects and total drill count can be viewed in Table 4.

Table 4. Final list of subjects and drill count per each drill for the performance improvement analysis. Strikethrough cells in red indicate subjects not included in that drill's dataset.

	Big G	GNG	Minefield	Memory Saccade	Waterfall
Subject 1	6	3	6	5	4
Subject 2	5	3	6	2	6
Subject 3	6	3	10	2	6
Subject 4	5	3	9	5	5
Subject 5	6	3	10	5	6
Subject 6	5	3	7	5	4
Subject 7	6	3	12	4	7
Subject 8	7	3	11	5	6
Subject 9	7	3	8	6	6
Subject 10	6	2	8	5	6
Subject 11	6	3	8	7	7
Subject 12	6	3	6	7	6
Subject 13	5	3	4	2	7
Subject 14	6	3	6	6	5
Subject 15	5	3	7	2	4
Subject 16	7	4	8	4	5
Subject 17	5	3	7	2	5
Subject 18	6	3	8	6	5
Subject 19	6	3	6	5	4
Subject 20	6	3	6	5	5
Subject 21	6	3	6	5	5
Subject 22	6	2	7	2	6
Total sessions in analysis (n)	**129**	**61**	**166**	**85**	**120**

There was one additional instance of data filtering. Testing that took place on March 10th, 2020 significantly skewed results for the drill Minefield. This will be discussed in more detail.

Statistical Approach

Performance Improvement on Reflexion Drills

Results for each drill were matched to the training session number for the player, then a Pearson product-moment correlation was run for the individual subject and mapped to a linear regression line. For example, if it was the subject's second time completing a drill, that result was matched to two, then on the third time completing the drill, their result was matched to three, and so on. This gave a positive or negative correlation (*r*) for the relationship, with stronger results closer to the absolute value of one.

After finding the correlation coefficient *r*, the standard error was calculated. Subsequently, this was used to derive the p-value obtained from a T distribution table (Hogg 2020) in order to find its significance.

With the season cut short, some of the athletes had as little as three sessions for a drill during the season, and never more than twelve sessions, making it difficult to see statistically significant changes on the individual level. However, evaluating the entire team's movement in Reflexion results provides a clearer picture of the overall effect of neurocognitive training. Thus, the statistical analysis was performed on both an individual player's improvement as well as the entire team's results together.

Relation to Batting Metrics

In order to examine if there is a relation between high Reflexion scores and top performers on the field, a similar analysis was completed by comparing average player results to their on-field softball metrics. There were three key measures used in this evaluation: batting average (BA), on base percentage (OB %), and slugging (SLG %). The short season also meant that not all players had enough data for on-field statistics, but the list of performance measures can be viewed in Table 5.

Table 5. On-field performance statistics of the subject

Subject	BA	SLG %	OB %
1	0.294	0.353	0.333
2	0.235	0.412	0.235
3	0.071	0.071	0.133
4	-	-	-
5	0.091	0.182	0.333
6	0.385	0.462	0.385
7	-	-	-
8	0.091	0.091	0.091
9	0.286	0.429	0.375
10	0.111	0.111	0.111
11	-	-	-
12	0.25	0.292	0.308
13	0.25	0.25	0.4
14	0.357	0.429	0.438
15	0.143	0.214	0.143
16	-	-	-
17	0.167	0.167	0.231
18	0.357	0.357	0.471
19	-	-	-
20	-	-	-
21	-	-	-
22	-	-	-

The subjects' batting statistics were matched to the season average of their Reflexion scores on every drill's results, and a correlation was performed to find a relationship between the two. Upon finding r, the test statistic and p-value were calculated to determine significance.

Chapter 4 Results and Discussion

Relevant Measurements per Drill

Some drills contain many outputs that provide slightly different versions of the same cognition and are calculated by using some of the same variables. For example, "Total Reaction Time" for Go No Go is calculated by adding the latency and motor times together, shown in Equation 1. Latency time and motor time will also have the same trends, as they both measure a form a reaction time. While all drill results were analyzed and investigated, only independent outputs are presented here to not be repetitive, which are listed in Table 3.

Table 6. Independent measurements used to evaluate changes in cognition.

Drill	Relevant Results Output
Big G	Average Reaction Time
	Accuracy
Go No Go	Latency per correct percentage
	Accuracy
Memory Saccade	Memory Accuracy
	Total Memory Time
Minefield	Total Score
Waterfall	Total Score

Performance Improvement using Reflexion

Each drill is evaluated by its relevant cognitions to investigate if there was an improvement in cognitive function. Cells with a p value below 0.1, or a 90% confidence rate in the existence of a correlation, are highlighted green if the result supports the hypothesis, red if it is statistically significant against the hypothesis, and left blank if there was no significance.

Big G

An average of six sessions per athlete were completed for Big G during the four weeks of training, and only one cognition improved for the softball team as measured. Average Reaction Time showed a team-wide improvement over the course of the season, but the effect of training was very weak, with only a -0.194 correlation to decreasing reaction time with training sessions. The correlations and p values for all drill results can be found in Table 7 and visually seen in Figure 4, and average results of the drills can be viewed in Table 8.

Table 7. Big G correlations for individual and team wide improvement

Cognition	Average Subject Improvement			Team Wide		
	Sessions	Correlation	p value	Sessions	Correlation	p value
Accuracy	6	-0.0957	0.7721	129	-0.0243	0.7843
Average Reaction Time	6	-0.3042	0.4444	129	-0.1944	0.0272

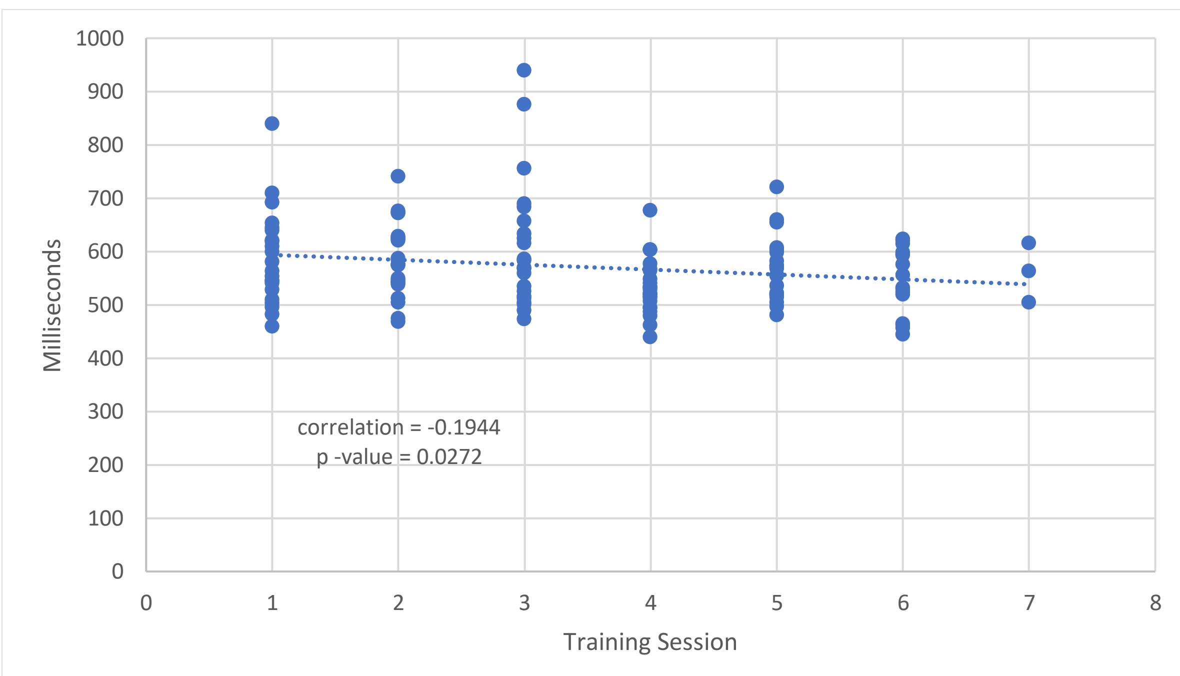

Figure 5. A graph of the average reaction time per training session for the entire softball team

Table 8. Big G team-wide averages and standard deviations of results.

Cognition	Average	Standard Deviation
Accuracy (mm)	24.29	7.02
Average Reaction Time (ms)	570.94	81.80

The results for Big G showed little change over the season, with only the team wide analysis for average reaction time showing significant improvements (r = -0.194). On the individual basis, there was actually a stronger correlation for improvement (r = -0.304), except the variability was far too high to draw any conclusions (p = 0.444). Considering the training program was cut short and only lasted four weeks, it is unsurprising to see the increased reaction time was not more significant.

Accuracy showed no improvement, though this drill emphasizes speed more than precision of touches. Reacting quickly was the priority for the athletes, and coordination was sacrificed.

Go No Go

An average of three sessions were completed for Go No Go. Both important scores for this drill worsened over the course of the season on a team wide level. Cognitions on the individual level only show one that is counter to the hypothesis, with Latency per Correct Percentage increasing (Table 9). This result is the most representative datapoint for the drill. The team wide trend can be viewed in Figure 5, and average results in Table 10.

Table 9. Go No Go correlations for individual and team wide improvement.

Cognition	Average of Individual Players			Team Wide		
	Sessions	Correlation	p value	Sessions	Correlation	p value
Latency per correct percentage	3	0.6984	0.0341	58	0.5411	0.0000

Accuracy	3	0.6378	0.1553	58	0.2816	0.0321

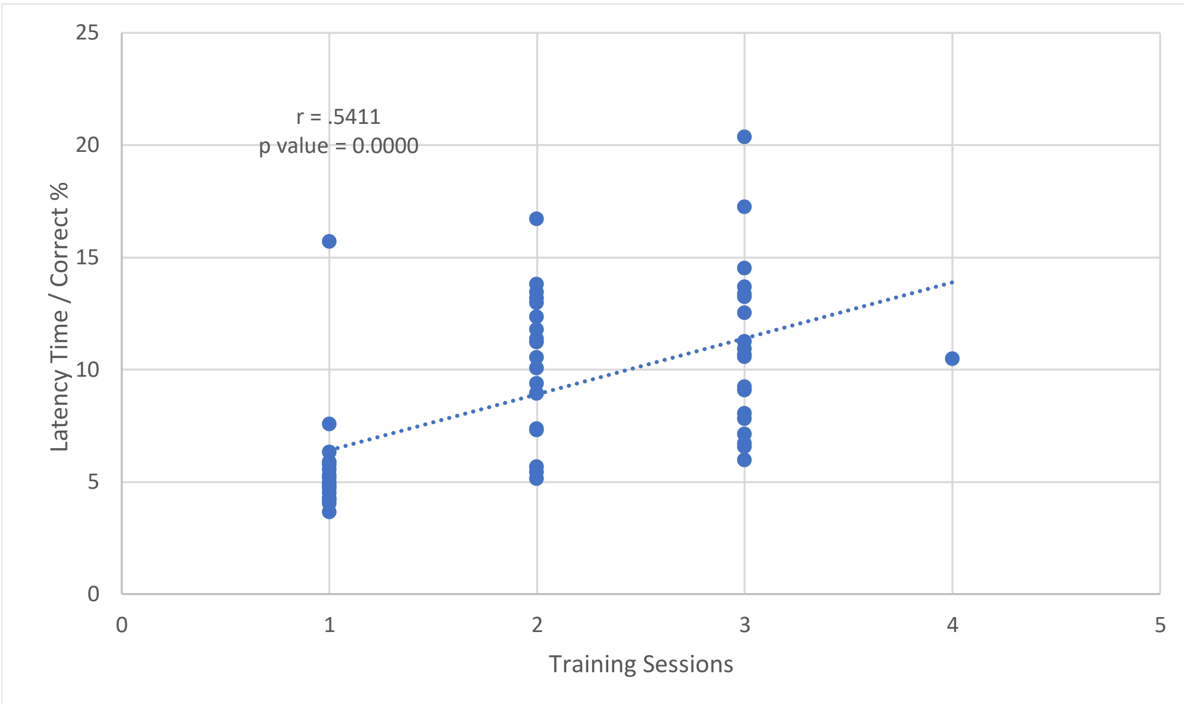

Figure 6. A graph of the latency time per correct percentage at each training session for the entire softball team.

Table 10. Go No Go team-wide averages and standard deviations of results.

Cognition	Average	Standard Deviation
Latency per correct percentage	8.98	3.95
Accuracy	20.60	11.07

While many results contained small and large changes to support the hypothesis of improved cognitive function, only Go No Go consistently showed a decrease in performance on multiple measurements. The decline in drill score is so strong that if it were supportive to the hypothesis, its correlation, r = 0.541, would be almost tied with the most supportive result, waterfall, with r = 0.564. Go No Go also was one of the few drills to support the hypothesis on Reflexion correlating to softball performance metrics.

The negative change over time is believed to be the caused by the nature of the Go No Go drill. Most of the drills regularly performed by athletes on Reflexion are fast-paced, competitive, and “gamified.” Waterfall is a perfect example of this, and the gamification component keeps users motivated to beat their previous score.

In comparison, Go No Go is a boring drill. Athletes are standing still for a long period waiting to react in the same way in the same place. As the season progressed, it is theorized that athletes viewed the drill as dull and were not engaged by it, causing them to respond more slowly, and thus receive worse results over time.

Minefield

An average of eight sessions were completed for Minefield. With no modifications, the drill did not show any changes to Reflexion scores. All correlations and p values can be seen in Table 11 and Figure 6, with average scores and their standard deviations in Table 12.

Table 11. Minefield correlations for individual and team wide improvement.

Cognition	**Average of Individual Players**			**Team Wide**		
	Sessions	**Correlation**	**p value**	**Sessions**	**Correlation**	**p value**
Score	8	0.1577	0.2617	174	0.0940	0.2172

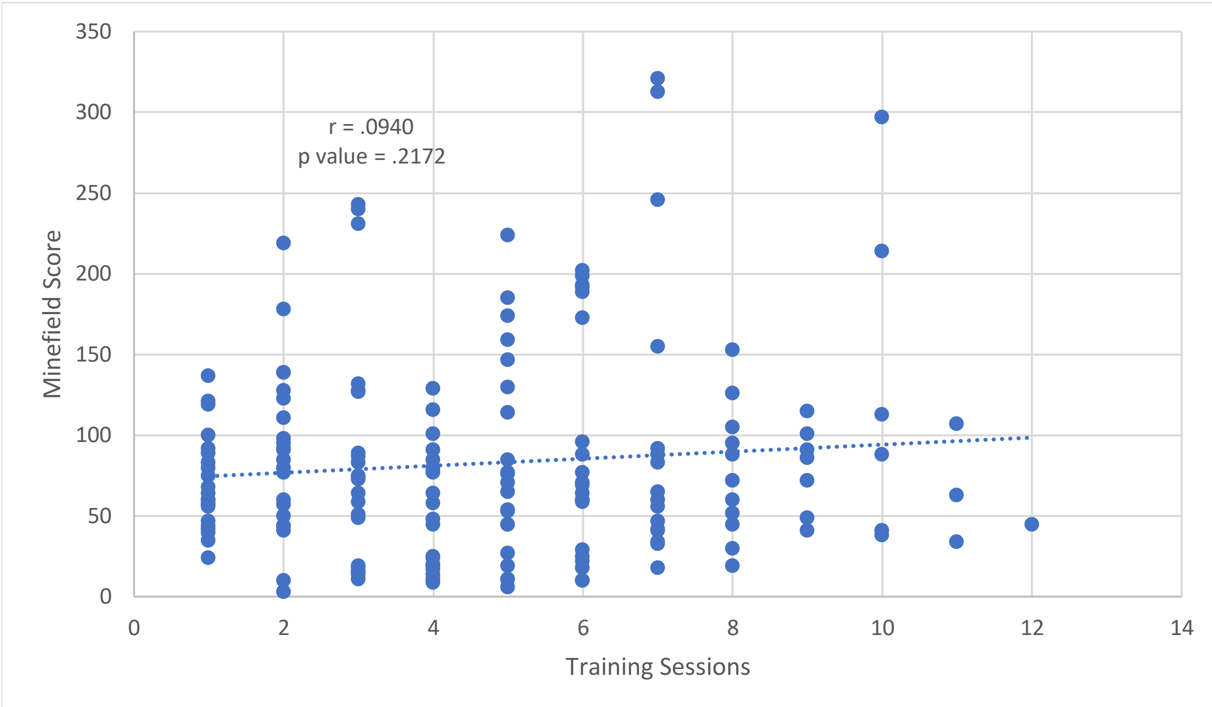

Figure 7. A graph of Minefield score at each training session for the entire softball team.

Table 12. Minefield team-wide averages and standard deviations of results.

Cognition	Average	Standard Deviation
Score	82.64	62.17

"Gamification" is part of Reflexion's design for some of their drills, knowing that athletes are competitive by nature, and making exercises fun will encourage compliance and overall use. Minefield is a prime example of this, with the drill getting harder and harder until the user fails. In simplicity, the quicker the athlete is, the higher their score, and this drives a desire to improve. Waterfall also exhibits these traits, and so Waterfall and Minefield would be two drills expected to show a significance increase. This is why it is unusual to find no correlation with Minefield when looking holistically at the data, especially when Waterfall does show a very high correlation in improving over time (see Waterfall section).

During data analysis, it was noted that on March 10th, 2020, Minefield scores for every individual on the team worsened compared to the previous session. This can be observed in the data on Figure 6, with many of the latter sessions producing lower scores. Because it was a universal decrease in performance, a second analysis was performed after removing all sessions from that date, and the results can be observed in Table 13, Table 14, and Figure 7.

Table 13. Minefield correlations for individual and team wide improvement after removing the March 10th, 2020 testing date.

Cognition	Average of Individual Players			Team Wide		
	Sessions	Correlation	p value	Sessions	Correlation	p value
Score	7	0.4274	0.0287	153	0.2400	0.0027

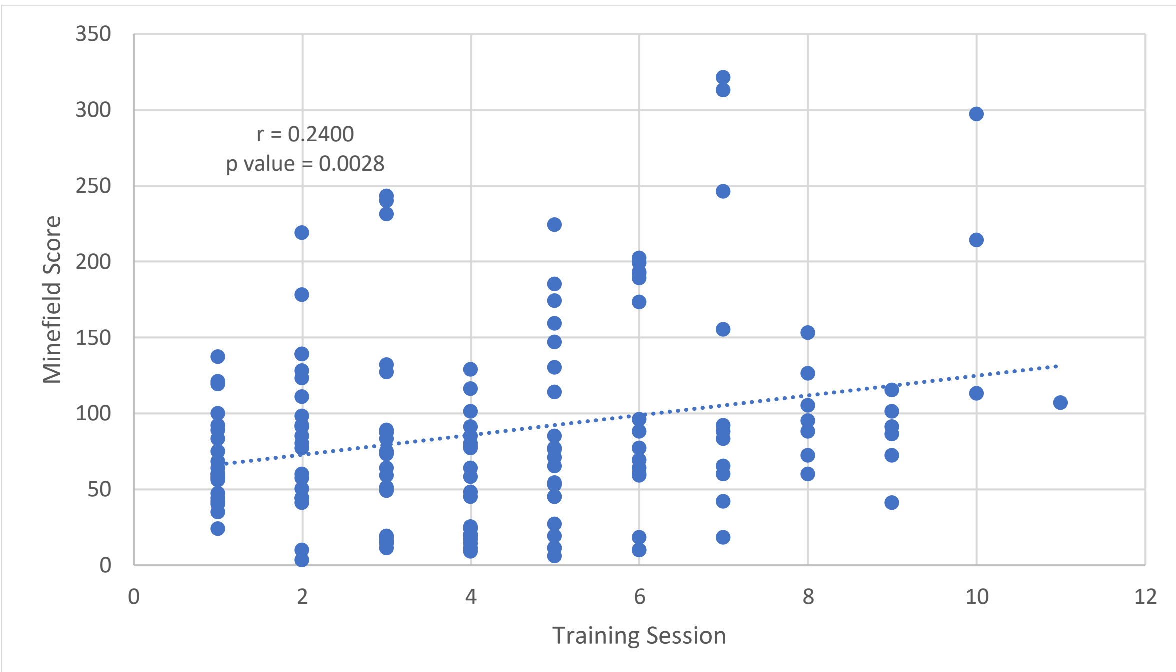

Figure 8. A graph of Minefield score at each training session for the entire softball team removing the March 10th, 2020 testing date.

Table 14. Minefield team-wide averages and standard deviations of results with March 10th tests removed.

Cognition	Average	Standard Deviation
Score	87.96	64.23

The head softball coach provided the following theory as to why March 10th showed such a low score in an email.

> We were getting ready to jump on a bus Wednesday [March, 11th] to drive to North Carolina, not knowing if we were going to play or not. Originally we were going to fly, but changed to bus because of the virus. It may have been anxiety, stress or environmental factors that impacted focus.

Big G was the only other drill exercised by the athletes on that day, but the reaction time scores did not exhibit the same deficiency and were roughly on par with previous dates. This can be viewed in Figure 4 on the fourth, fifth, or sixth sessions.

The theory presented by the head softball coach is that extraneous stress caused by the COVID-19 virus led to a poor performance on Minefield. Shutdowns and lifestyle changes happened rapidly during early March, and undoubtedly many athletes were worried about loved ones and issues that go beyond softball practice. That is a logical explanation, but it is unusual to see a heavy decrease in Minefield and not on Big G, the only other drill performed that day.

One potential explanation of Minefield's decline and not Big G's is Minefield was designed to be stressful. The "mines," or green squares, appear very rapidly and in the user's entire field-of-view, requiring the person to maintain composure and balance to achieve a good score, whereas Big G is a simple, fast-paced reaction time test. Thus, outside stress and anxiety became amplified when doing Minefield, resulting in worse scores on March 10th.

<u>Memory Saccade</u>

An average of five sessions were completed for this drill. There was a slight improvement in cognitions trained by Memory Saccade on the team wide analysis. Improvements were seen on the individual level, but the number of sessions for each athlete was too low to be statistically significant. All correlations and p values can be seen in Table 15 and Figure 8, with average scores and their standard deviations in Table 16.

Table 15. Memory Saccade correlations for individual and team wide improvement.

Cognition	Average of Individual Players			Team Wide		
	Sessions	Correlation	p value	Sessions	Correlation	p value
Memory Accuracy	5	-0.3130	0.4169	85	-0.2418	0.0257
Total Memory Time	5	-0.3266	0.47602	85	-0.1916	0.0788

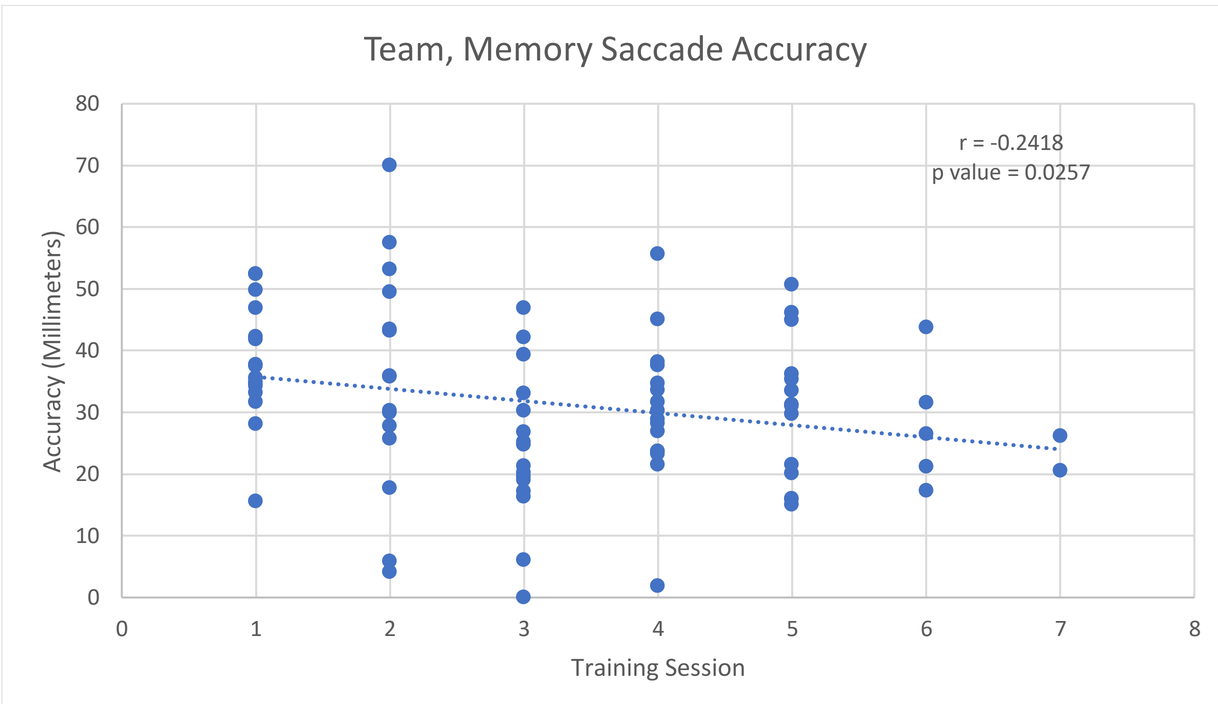

Figure 9. A graph of Memory Saccade Accuracy at each training session for the entire softball team.

Table 16. Memory Saccade team-wide averages and standard deviations of results.

Cognition	Average	Standard Deviation
Memory Accuracy	31.40	13.24
Total Memory Time	4.94	3.14

Both independent outputs of memory saccade showed improved performance, which is surprising when considering there was an average of only five training sessions per player. With an overall low number of tests run, the increase in skill was still strong enough to be seen in both areas. The average correlation of individual players improving was even stronger, with memory accuracy and total memory time both around a correlation of -0.3, though there was a lot of variance which caused the p values to be high ($p > 0.4$).

Waterfall

An average of five sessions were completed for Waterfall. Scores in this Reflexion drill were considerably the strongest amongst all the other programs, with a highly significant improvement over the course of the season. All correlations and p values can be seen in Table 17 and Figure 9, with average scores and their standard deviations in Table 18.

Table 17. Waterfall correlations for individual and team wide improvement.

Cognition	**Average of Individual Players**			**Team Wide**		
	Sessions	**Correlation**	**p value**	**Sessions**	**Correlation**	**p value**
Score		0.7093	0.1221		0.5637	0.0000

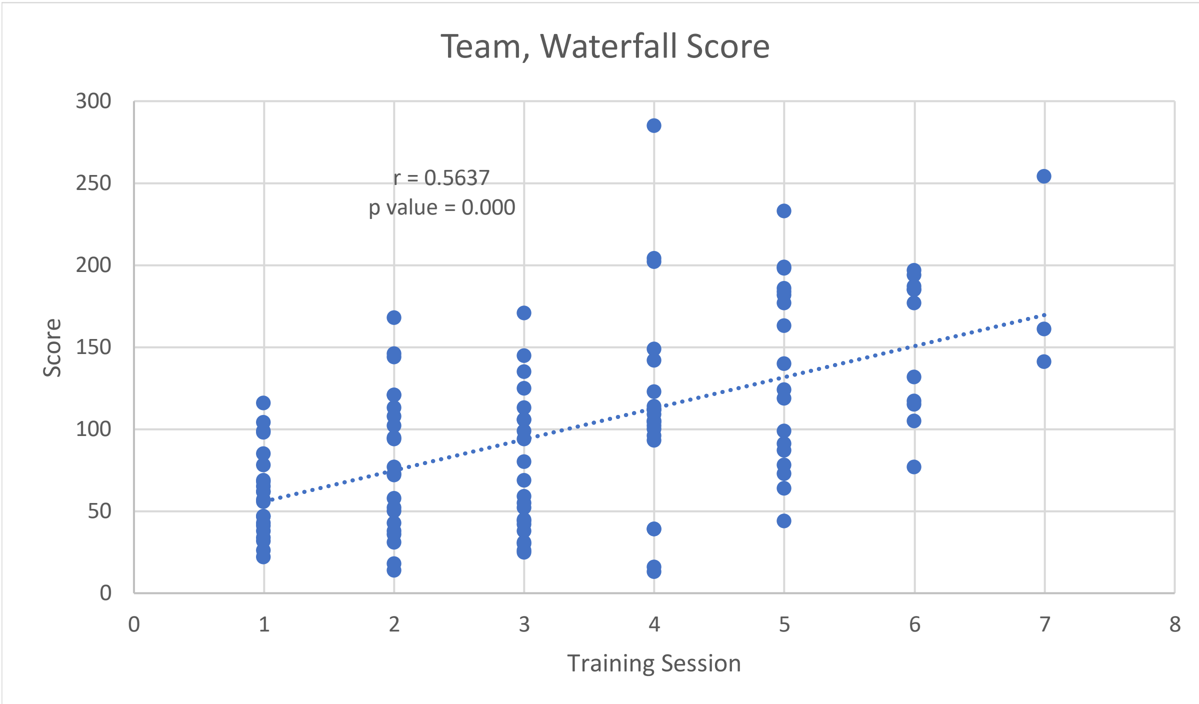

Figure 10. A graph of Waterfall score at each training session for the entire softball team.

Table 18. Waterfall team-wide averages and standard deviations of results.

Cognition	Average	Standard Deviation
Score	99.64	56.80

Like Memory Saccade, Waterfall also averaged five training sessions per player, but showed a much higher correlation (r = 0.563). As explored in other sections, Waterfall is fun to do, and that gamification component certainly resulted in the increased scores over time. If the season had not been cut short due to COVID 19, additional training sessions may have caused the scores to level out. The duration of this program was not long enough to see any result trends flatten, though at such a fast pace of improvement, the scores likely would not have continued at the same rate.

Summary

A summary of all significant performance improvements by the team in Reflexion scores can be seen in Table 19.

Table 19. All significant changes to Reflexion scores during the duration of the season.

Drill, Result	Correlation (r)	P value
Supports Hypothesis of Increased Performance		
Waterfall, Score	0.5637	0.0000
Memory Saccade, Accuracy	-0.2418	0.0257
Minefield with 3/10/20 filtered, Score	0.2400	0.0027
Big G, Average Reaction Time	-0.1944	0.0272
Memory Saccade, Total Memory Time	-0.1916	0.0788
Counters Hypothesis of Increased Performance		
GNG, Latency per Correct Percentage	0.5411	0.0000
GNG, Accuracy	0.2816	0.0321

Relationship between On-Field Metrics and Reflexion Scores

Three on-field performance metrics were used to compare to fifteen Reflexion scores, creating forty-five possible relationships, though Batting Average, Slugging, and On-Base Percentage are dependent variables. Altogether, six significant ($p < 0.1$) correlations were found using four scores from three Reflexion drills: Average Reaction Time from Big G, Latency Time per Correct Percentage & Total Latency Time from Go No Go, and Score from Minefield (with March 10th filtered). These can be view in Table 20.

Table 20. Correlations and p-values between on-field performance metrics and Reflexion scores.

		BA		SLG %		OB %	
		r	p value	r	p value	r	p value
Big G	Accuracy	0.1237	0.674	0.1845	0.528	0.1087	0.712
	Average Reaction Time	-0.5316	0.050	-0.5968	0.024	-0.2291	0.431
CRT	Average Latency Time	-0.1501	0.609	-0.3458	0.226	-0.1153	0.695
SRT	Average Latency Time	-0.1944	0.505	-0.4055	0.150	0.1025	0.727
Exp Out	Average Latency per Degree of Vision	-0.0775	0.792	-0.2556	0.378	0.0871	0.767
GNG	Latency Time per Correct Percentage	-0.4720	0.121	-0.5968	0.040	-0.2715	0.393
	Accuracy	0.1543	0.632	0.0360	0.912	0.2474	0.438
	Total Average Latency Time	-0.5204	0.083	-0.6322	0.027	-0.2800	0.378
	Total Average Motor Time	-0.1342	0.662	-0.0829	0.788	-0.0180	0.953
Minefield	Score	0.4014	0.155	0.4441	0.112	0.1747	0.550
Minefield filtered	Score	0.4381	0.117	0.4605	0.097	0.2058	0.480
Memory Saccade	Memory Accuracy	-0.0816	0.835	0.0778	0.842	0.0555	0.887
	Total Memory Time	0.3144	0.410	0.3112	0.415	0.1042	0.790
RALE	Latency Time per Correct Percentage	-0.0612	0.835	-0.0777	0.792	0.1551	0.596
Waterfall	Score	0.3414	0.232	0.2975	0.302	0.1811	0.535

The six significant relationships are presented as graphs in Figures 10-15.

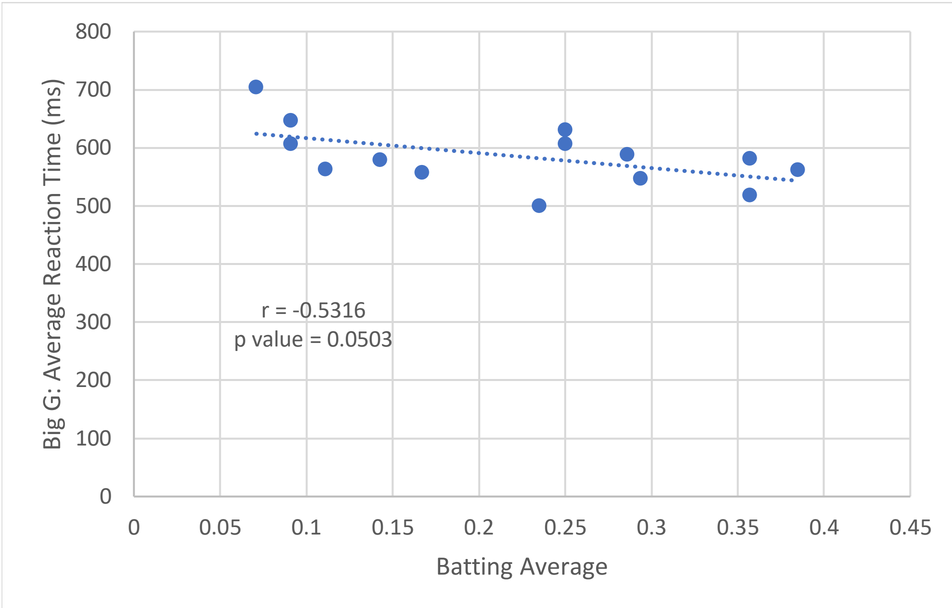

Figure 11. A graph of subjects' batting averages and Big G reaction time results.

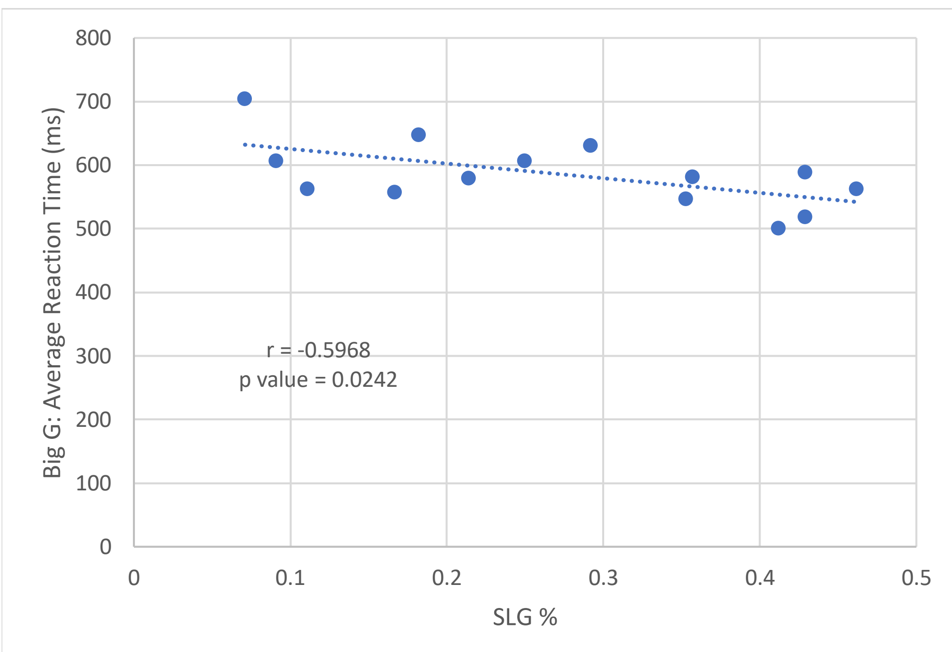

Figure 12. A graph of subjects' SLG % and Big G reaction time results.

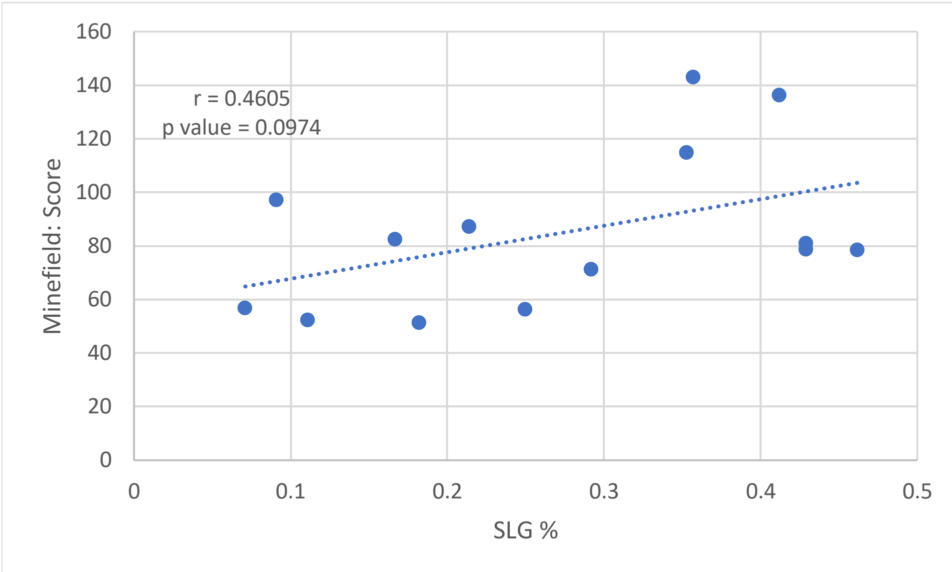

Figure 13. A graph of subjects' slugging percentage and Minefield Score (March 10th, 2020 testing removed).

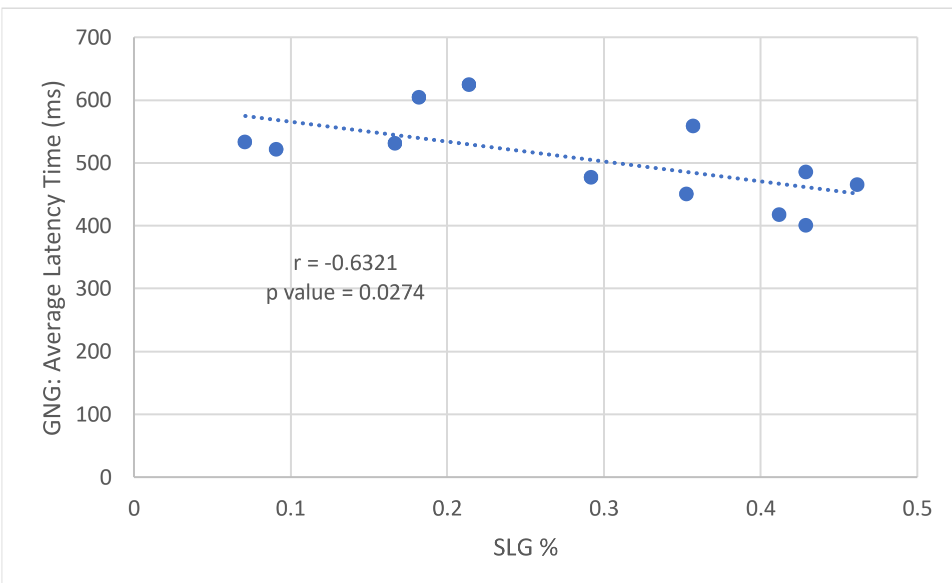

Figure 14. A graph of subjects' SLG % and Go No Go Average Latency Time results.

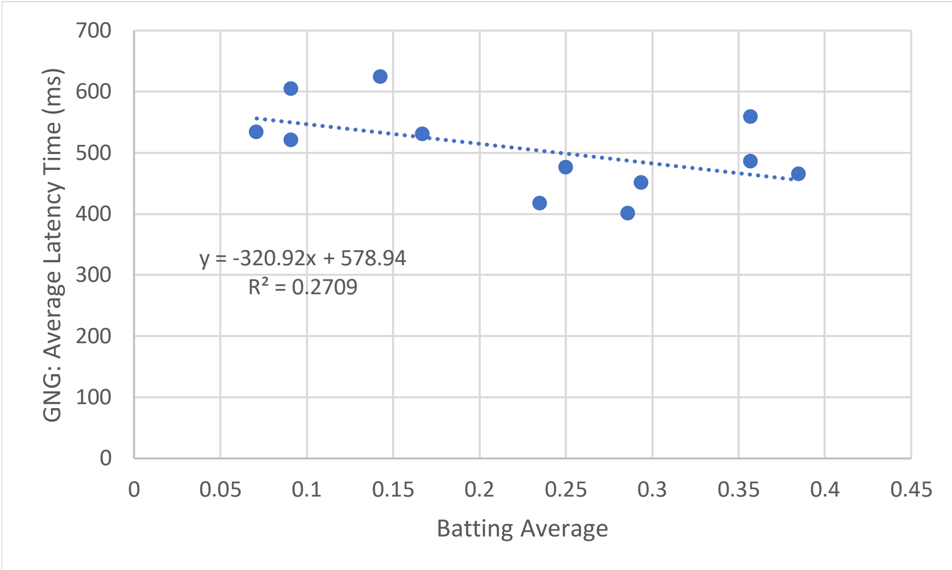

Figure 15. A graph of subjects' SLG % and Go No Go Average Latency Time results.

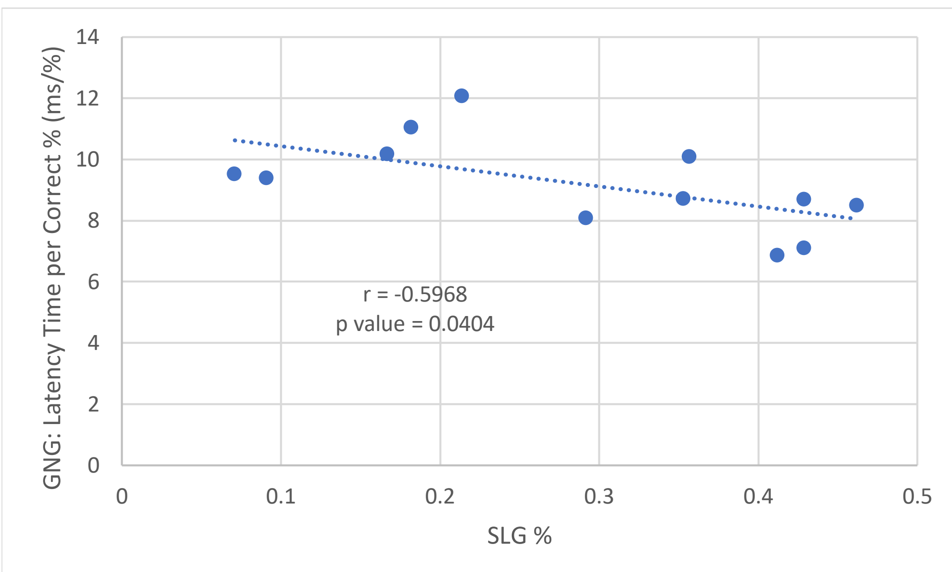

Figure 16. A graph of subjects' SLG % and Go No Go Latency Time per Correct Percentage results.

Big G holds two significant relationships to on-field performance. Because there was only a small improvement during the training sessions, it could be that Big G measures a core cognition that is difficult to train in such a short period of time. With little variability, it could become much more useful as a predictive model, and ultimately, a recruiting tool. Further research should be done to better understand this dynamic.

Go No Go had an average of three training sessions per player, which makes it difficult to assess if there were statistically significant trends with so few datapoints and may have also contributed to the poor results. This fact is less relevant when looking at on-field performance, where the average scores were used in analysis. Like Big G, the supportive relationship to softball skills could indicate this drill has potential as a predictive modeling tool. If the theory that the poor change over time is caused by Go No Go being boring, then this drill would not work as it stands. Further investigation should be done to determine if the trend of decreasing scores trend continues and if this drill has potential in predictive modeling.

In order to see a significant correlation to slugging percentage, the March 10th testing results must be removed. Minefield is unlike the other two drills that showed this relationship, Big G and Go No Go, in that the subjects' Minefield scores substantially improved over time. This indicates that batting metrics can be predicted by drills that focus on specific cognitive functions as well as dual-task drills that substantially increase with training.

Limitations

This research analysis was most significantly hindered by a short duration of training, no researcher involvement in data collection, and no control group for comparison. The softball team's training schedule was meant to unfold over a three-month timeline but was cut short by COVID-19. Theoretically, four weeks is enough time to impact performance from training, but if the schedule was intended to be that length as opposed to being cut in the beginning, likely a much stronger improvement would have been observed. A longer season would have also provided much more data on each drill, which would allow for a more definitive analysis of changes.

Because no researcher was present during the administration of the Reflexion training, there was no way to account for certain discrepancies or environmental factors. For example, if a researcher watched Go No Go being run, they could have observed how the athletes interacted with the drill and could better theorize why the scores decreased. This also could have been valuable in understanding why data on March 10th was skewed.

Ideally, a control group would have been tested at the beginning of the softball team's season, then again at the end of training. The control group that did not participate in SVT would have most likely shown little or no differences in Reflexion scores, which would have further validated the improvements seen by the softball team.

Chapter 5 Conclusion

For four weeks, the University of Maine trained on Reflexion to see improvements in vision and cognitive function. Five drills were performed at least three times during the month, with four of the eight independent cognitive functions showing a significant increase in performance, two showing a decrease, and two showing no change at the team-wide level. Waterfall showed a very strong improvement ($r = 0.563$), but otherwise the correlations to increases with added sessions were weak ($r < 0.25$). Go No Go was the only drill to show a significant decrease ($r = .5411$, $r = .2816$) in Reflexion scores. Three drills were found to be correlated to in-game softball metrics, though the results were weak. The performance improvement hypothesis is partially accepted because while there is an overall increase in the majority of Reflexion scores during the season, most are weak improvements. The hypothesis that batting metrics would correlate to Reflexion scores is also partially accepted because three of eight drills showed a weak relationship.

Future Directions

To further investigate cognitive performance in athletes, a longer term study is needed with a control group This can be difficult to structure, as coaches typically do not implement different programs within the same team, but a nonathlete group could still provide insightful data. With more data, it would also be interesting to measure the rate of improvement in drills to see if that relates to on-field performance, hinting that those who can learn faster are also more likely to be successful in their sport. Unfortunately, there was not enough data to investigate that here.

Expanding the cognitions evaluated in performance training would also be valuable. Certain skills like reaction time and peripheral awareness were emphasized during the season, but decision-making and visual pursuit are two important cognitions that were not investigated. Go No Go measures inhibition control, which is a form of decision making, but that data was counter to the hypothesis as discussed.

Appendix A

University of Maine Spring 2020 Reflexion Training Schedule

Week	Monday: Speed — Drill	Monday: Speed — Special Parameters	Wednesday: Memory — Drill	Wednesday: Memory — Special Parameters	Friday: Vision — Drill	Friday: Vision — Special Parameters
2/17/2020	Minefield	detonation time: 7 sec	Memory Saccade	# of targets: 3	Expanding Out	
	Minefield	det time: 7 sec	Memory Saccade	# of targets: 4	Go No Go	location: mid
	waterfall	difficulty: medium	Go No Go	location: near	Go No Go	location: far
2/24/2020	Minefield	competition	N Plus One	starting lights: 4 , disp time: .5 sec	Pursue	
	Waterfall	direction: up and down **only**	Memory Saccade	# of targets: 4 , size: medium	Complex Rxn Time	location: mid
	Big G	competition	Go No Go	location: mid	Complex Rxn Time	location: far
3/2/2020	Waterfall	competition	Memory Saccade	# of targets: 5, size: medium	Go No Go	location: near
	Waterfall	competition	Memory Saccade	competition	Expanding Out	competition
	pursue		CRT	competition	Go No Go	location: mid
3/9/2020	Pursue	competition	Memory Saccade	competition	Big G	competition
	Minefield	size: small, det time: 7 seconds	Memory Saccade	competition	CRT	location: near
	Big G	# of targets: 50	Memory Saccade	# of targets: 7	CRT	location: far

BIBLIOGRAPHY

"2019 Fitness Industry Trends Shed Light on 2020 & Beyond." *IHRSA*, International Health, Racquet, and Sportsclub Association , 9 Jan. 2020, www.ihrsa.org/improve-your-club/industry-news/2019-fitness-industry-trends-shed-light-on-2020-beyond/.

Appelbaum, L. Gregory, and Graham Erickson. "Sports Vision Training: A Review of the State-of-the-Art in Digital Training Techniques." *International Review of Sport and Exercise Psychology*, vol. 11, no. 1, 2016, pp. 160–189., doi:10.1080/1750984x.2016.1266376.

Eccles, D. W. Thinking outside of the box: The role of environmental adaptation in the acquisition of skilled and expert performance. 2016. *Journal of Sports Sciences*, 24(10), 1103–1114. doi:10.1080/ 02640410500432854

Eime, R., et al. "Population Levels of Sport Participation: Implications for Sport Policy." Journal of Science and Medicine in Sport, vol. 20, 2017.

Evans, Ryan. "Accuracy Vs. Precision." *Google Sites*, 9 Apr. 2019, sites.google.com/a/apaches.k12.in.us/mr-evans-science-website/accuracy-vs-precision.

Fadde, Peter J. "Training Complex Psychomotor Performance Skills." Handbook of Improving Performance in the Workplace: Volumes 1-3, 2010, pp. 468–507.

Goldstein, Phil. "Baseball Is Bringing Sports Analytics to the Forefront." *Technology Solutions That Drive Business*, 25 Nov. 2019, biztechmagazine.com/article/2017/07/baseball-bringing-sports-analytics-forefront.

"High School Sports Participation Increases for 29th Consecutive Year." NFHS, National Federation of State High School Associations, 11 Sept. 2018, www.nfhs.org/articles/high-school-sports-participation-increases-for-29th-consecutive-year/.

Hoffman, L. G., Polan, G., & Powell, J. The relationship of contrast sensitivity functions to sports vision. 1984. *Journal of the American Optometric Association*, 55(10), 747–752.

Hogg, Robert V.,Tanis, Elliot A., Zimmerman, Dale L. *Probability and Statistical Inference*. Pearson, 2020.

Kim, Gye Yeop, et al. "Effect of Dual-Task Rehabilitative Training on Cognitive and Motor Function of Stroke Patients." *Journal of Physical Therapy Science*, vol. 26, no. 1, 2014, pp. 1–6., doi:10.1589/jpts.26.1.

Korhonen, Marko. "Effects of Combined Strength and Sprint Training on Bone, Muscle and Performance Characteristics in Middle-Aged and Older Sprint Athletes." *Http://Isrctn.com/*, 2016, doi:10.1186/isrctn17271498.

Laby, D. M., Rosenbaum, A. L., Kirschen, D. G., Davidson, J. L., Rosenbaum, L. J., Strasser, C., & Mellman, M. F. (1996). The visual function of professional baseball players. *American Journal of Ophthalmology*, 122(4), 476–485.

Mann, D. T., Williams, A. M., Ward, P., & Janelle, C. M. Perceptual-cognitive expertise in sport: A meta-analysis. 2007. *Journal of Sport and Exercise Psychology*, 29(4), 457–478

Miller, Bennett, director. *Moneyball*, Columbia Pictures, 2011.

"Origins of the Non-Natural Tradition with the Ancient Physicians." *Sport and Exercise Science: Essays in the History of Sports Medicine*, by Jack W. Berryman and Roberta J. Park, University of Illinois Press, 1992, pp. 12–14.

Orr, Rob. "The Functional Continuum." *PTontheNet.com – Online Education for Fitness Professionals*, PT on the Net, 25 Oct. 2009, www.ptonthenet.com/articles/the-functional-continuum-3251.

Pranav. "Moneyball: The Power of Sports Analytics." *Pranav's Journal*, 21 June 2018, pranavsuri.com/2018/06/moneyball-the-power-of-sports-analytics/.

Reed, Adam. "Coaching Philosophy: Advice from the NSCA on Strength Training for High School Athletes." *Hammer Strength Blog*, NSCA, 2017, blog.hammerstrength.com/coaching-philosophy-advice-nsca-strength-training-high-school-athletes.

Siegal, Nora. "Strobe Glasses." *Conestoga Eye*, 16 May 2016, www.conestogaeye.com/strobe-glasses/.

Uchida, Y., Kudoh, D., Higuchi, T., Honda, M., & Kanosue, K. Dynamic visual acuity in baseball players is due to superior tracking abilities. 2013. *Medicine & Science in Sports & Exercise*, 45(2), 319–325. doi:10.1249/MSS.0b013e31826fec97

UW Data Science Team. *The Story of Moneyball Proves Importance of Big Data and Big Ideas*. University of Wisconsin Data Science, 10 July 2017, datasciencedegree.wisconsin.edu/blog/moneyball-proves-importance-big-data-big-ideas/.

Vecchio, Luke Del. "The Health and Performance Benefits of the Squat, Deadlift, and Bench Press." *MOJ Yoga & Physical Therapy*, vol. 3, no. 2, 2018, doi:10.15406/mojypt.2018.03.00042.

"Wayne Saccadic Fixator." *Bernell* , Bernell Corporation, 2020, www.bernell.com/product/WAYNEFIX/1268.

Williams, E. "Youth Performance and Fitness-Strength and Conditioning Information for Parents." *NSCA*, National Strength and Conditioning Association, 1 Mar. 2013, www.nsca.com/education/articles/ptq/youth-performance-and-fitnessstrength-and-conditioning-information-for-parents/.

Academic Vita

Matthew Roda

mmr5599@psu.edu

Education

PENNSYLVANIA STATE UNIVERSITY **AUG 2020**

· **Schreyer Honors College**
· Eberly College of Science, B.S. General Science

LANCASTER CATHOLIC HIGH SCHOOL **MAY 2015**

· AP Scholar with distinction, St. Augustine Scholar

Experience

REFLEXION | CMO & FOUNDER | 2015 TO PRESENT

· Responsible for directing sales and marketing operations. Built and maintained a sales process that lead to averaged 50% quarterly growth through five quarters.
· Runs customer success team, ensuring Reflexion is an essential service for our customer's operations. This has lead to thousands of monthly end users of our training
· Created relationship with six different research institution to validate the science behind Reflexion, including Penn State, Duke, and University of Tennessee
· Developed messaging and value proposition to different market segments that benefit from neuro-fitness training, a process continuously iterated upon.
· Creates or directs media (videos, pictures, infographics, etc.) for each market segment

MERIDEAN PROPERTY SERVICES | MARKET RESEARCHER | JUN 2016 TO AUG 2016

· Researched and pursued new expansion opportunities grow property management services to government and private buildings in the State of NJ.

Interests

CLASSICAL PIANO

ADVANCED OPEN WATER SCUBA DIVER