

Optimizing The Learning of a selected Gymnastics Activity

A DISSERTATION  
SUBMITTED TO THE FACULTY OF THE GRADUATE SCHOOL  
OF THE UNIVERSITY OF MINNESOTA  
BY

Saqer Almulla

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS  
FOR THE DEGREE OF  
DOCTOR OF PHILOSOPHY

Dr. Michael G. Wade, Advisor

July 2012

© Saqer Almulla

## ACKNOWLEDGMENTS

I would never have been able to finish my dissertation without the guidance of my committee members (Dr. Michael Wade, Dr. Herbert Pick, Dr. Thomas Stoffregen, and Dr. Bruce Overmier). Without them my dissertation wouldn't be as what it is right now. Many thanks to my advisor Dr. Michael G Wade who I will always give my deepest gratitude. Dr. Wade provided me with excellent guidance, caring, patience, and with an excellent atmosphere for conducting research.

I would like to thank my mother for being the beautiful smile in my life, for believing in me, and for letting me achieve my dream of earning a PhD just to see her smile. Special thanks to my wife Fatemah Marafi, who made sacrifices and spent her time raising my children, and for being with me through thick and thin during the whole time.

I would like to thank Dr. Mohammad Althuwaini for being everything beautiful on this journey. Without his help

and support, I wouldn't be what I am today.

I would like to thank Dr. Salman Hajji for being there for me every time I needed him. Also to Dr. Hussain Almukaimi for guiding me to the school of Kinesiology in the University of Minnesota. Likewise, to Abdulatif Murad, who has been more than a brother to me; no thankful words would appreciate his support and guidance. Also, to my children Jory, Ghanem, and Bader who I spent my time studying away from them, I thank them every day because they gave me the motivation to study harder, to provide them with a better life.

Gratitude for the Public Authority for Applied Education and Training for awarding me this scholarship, and for the department of physical education for trusting me on this journey.

Finally, to all my friends who kept in touch with me, supported me, believed in me, and encouraged me to achieve this accomplishment.

## ABSTRACT

This research is testing for a new technology (Dartfish) against the traditional proprioceptive coach-assisted feedback and simple video feedback. Also, it is testing for the differences between the traditional proprioceptive feedback and imitation learning. Three groups participated in this study; traditional proprioceptive feedback (TRD), simple video feedback (VID), and Dartfish (DRF). Four tests were conducted; Pretest, Post-test-1, Post-test-2, and Retention. The task was Pommel Horse Circles (PHC), and training lasted for four weeks. Six certified gymnastics judges evaluated the performance. The results of the study indicated that the DRF group performed and retained the performance better than the TRD and VID groups. On the other hand, the results indicated that the VID group is better than the TRD group during the performance phase, but not on the retention of the skill. Imitation learning using simple video feedback is not different than the traditional coach-assisted feedback technique in regards to retaining a gymnastics skill.

## TABLE OF CONTENTS

ACKNOWLEDGMENTS.....	i
ABSTRACT.....	iii
TABLE OF CONTENTS.....	iv
LIST OF TABLES.....	vii
LIST OF FIGURES.....	viii
CHAPTER ONE.....	1
INTRODUCTION.....	1
<i>Research Question/Problem</i> .....	4
<i>Hypothesis of the study</i> .....	4
CHAPTER TWO.....	5
LITERATURE REVIEW.....	5
<i>Imitation is a life long process</i> .....	6
<i>Imitation Learning</i> .....	9
<i>Augmented feedback and motivation</i> .....	12
<i>Mirror Neurons</i> .....	13
<i>Internal Models</i> .....	19
<i>Direct Perception</i> .....	21
<i>Development of Technology</i> .....	24
<i>Video Modeling</i> .....	28
CHAPTER THREE.....	33
METHODOLOGY.....	33

<i>Participants</i> .....	33
<i>Apparatus</i> .....	34
<i>Procedure</i> .....	34
<i>Training Protocol</i> .....	38
Judges.....	39
Analysis.....	41
CHAPTER FOUR.....	42
RESULTS AND DISCUSSION.....	42
RESULTS.....	42
<i>Pretest</i> .....	44
<i>Post-test-1</i> .....	44
<i>Post-test-2</i> .....	45
<i>Retention test</i> .....	46
Pretest-Retention.....	48
(Post-test-2)-Retention.....	48
DISCUSSION.....	49
Research Question 1.....	52
Research Question 2.....	53
Retention.....	55
Discovery Learning.....	58
CHAPTER FIVE.....	62
CONCLUSIONS AND RECOMMENDATION.....	62
Limitations.....	62

<i>Conclusions</i> .....	63
<i>Future Research</i> .....	64
References.....	66
Appendices.....	71
Appendix A.....	72
Institutional Review Board (IRB) Approval, and the approval to conduct the experiment on the gymnastics halls and athletes in Kuwait.....	72
Appendix B.....	76
Summary of the multiple comparisons.....	76
Appendix C.....	78
Summary Figure indicating p-values for the whole tests sessions.....	78
Appendix D.....	80
A real drawing of the experiment setting during the Dartfish overlap technique and simple video feedbacks.....	80



LIST OF TABLES

Table 1 Mean age for participants in the groups.....33

Table 2 Mean and standard deviation judging scores for  
testing sessions and feedback conditions.....43

LIST OF FIGURES

*Figure 1* a coach making corrections (right picture) to a deficit in the gymnast's performance (left).....35

*Figure 2* a gymnast performing a pommel horse circle, while the video camera is connected to a laptop. The gymnast then have the ability to watch his performance on the screen..... 36

*Figure 3* a gymnast performing a pommel horse circle overlapped with another gymnast performing the same skill.....37

*Figure 4* Pommel Horse Circle..... 37

*Figure 5* Judging setting..... 40

*Figure 6* Mean Score over the tests intervals..... 45

*Figure 7* Mean score for groups on the retention test .....46

*Figure 8* Pre-test to Retention comparision.....47

## CHAPTER ONE

### INTRODUCTION

Learning is one of the most important fundamental aspects in life, and we strive daily just to figure out new and better ways to learn. Many researchers have tried to search for feedback techniques that will enhance and optimize the process of learning, and many more have sought to contradict existing findings and submit their own new feedback techniques. Janelle, et. al. (1997) in the experiment on maximizing the performance feedback effectiveness, they involved imitation learning through looking at a ball throw performed by a high-level left-handed thrower. The findings clearly noted that throwing form improved during the acquisition phase.

The issue on the research conducted by Janelle et. al (1997) is that the performers in that experiment never actually compared their own performance with the optimal performance they wanted to achieve. We know it is difficult for the performers to detect the discrepancy

between their performance and an optimal performance. The present study proposes a new technique that exploits an optimal performance by overlapping the performance of an actual gymnastic performer with an image of a target optimal performance of the same skill. To date, research addressing the difference between coach-assisted proprioceptive feedback and standard visual feedback in gymnastics is limited. The current study addresses this issue.

Each one has a different view of the visual feedback presented in front of him/her. For example, one person might think that he is too close to the optimal performance; another would observe that he is perhaps too far away from the optimal performance. In the traditional proprioceptive coaching format, the performers' have little appreciation of their body position relative to an optimal performance; the same is true of standard video feedback. The present study, investigate the effects on learning using direct visual comparison of the athlete's own performance with the optimal target performance, using the overlap technique.

Many years ago before the introduction of the video technology, gymnasts were spotted and supported by a coach. Coach-assisted proprioceptive was the only kind of feedback available. The athlete was unable to view, in real-time, an optimal performance, and had to depend on the sensory information received from his body. For example, if the correct position of the gymnast's arm should be at 180 degrees of extension, and the gymnast attained only 90 degrees angle, the coach would hold his arm and position it at the correct extension.

With the development of technology, video feedback has been introduced and used in sports. The development of video cameras and computer software has positively influenced the coaching experience and the athletes' performance (Wilson, 2008).

## Research Question/Problem

This study sought to answer two questions:

1. Is Dartfish overlapping technique more effective than using the standard video feedback?
2. Does imitation learning yield better results than the traditional proprioceptive feedback learning?

The hypothesis of this study:

1. The overlapping technique (DRF) will enhance gymnasts learning more effectively than the standard video feedback (VID).
2. Both modes of imitation learning (DRF and VID) will be more effective way than the traditional proprioceptive feedback (TRD) for learning a gymnastics skill.

## CHAPTER TWO

### LITERATURE REVIEW

The following view of the literature will cover various aspects regarding imitation learning, augmented feedback, how humans control their movement, and how we perceive movements in the environment. Augmented feedback has been argued to have a motivational effect to reach the desired goal. Mirror Neurons were argued to facilitate action understanding, where they fire when we observe a model in intention to imitate it. Likewise, they fire when we go through that observed action. Internal models were argued to use sense received from the environment to update the models available to control movement. Updating these models was argued to involve calculations, where, for example, the actual sensory outcome of a movement is subtracted from the desired movement. This subtraction will yield error signals, and these error signals are the way to update our Internal Models. On the other hand, the Direct Perception by Gibson (1966, 1979) argued that we perceive the coordination dynamics of movements without the need of prior mediation of separate coded data. Direct Perception contradicted the view that there are

calculations during perceiving objects. For example, people believed that in order to pick up a cup, we have to figure out how big it is, and how far away it is, and what shape it is, and then put all these elements together and say this is a cup that is pickable. Gibson was trying to say that the kind of visual information we get, doesn't have to go through all those separate elements and then put them together, but the information, if we look at the right aspect of the stimulation, is whether this cup is pickable or not; we don't have to integrate a lot of separate elements to perceive.

### **Imitation is a life long process**

Imitation is a life long process. Many studies confirmed that imitation starts at early infancy (Barr, Dowden, & Hayne, 1996; Fontaine, 1984; Jones, 2007), other research shows that imitation starts even before the first 72 hours of the newborn's life. Metlzoff and Moore (1983) tested newborns to determine if they could imitate adult facial gestures. The enrollment criteria required that



infants should be less than 72 hours old, full-term (i.e. over 36 weeks' gestation), and normal birth weight (5.5-10 pounds). Forty newborns participated in this study, and were tested to determine whether they could imitate two adult facial gestures (mouth opening and tongue protrusion). The results of the study showed that newborn infants could imitate these gestures, which means that imitation takes place in a very early stage of the human life. Barr, et. al. (1996) did an experiment on infants aged between 6 to 24 months old, and they found that infants are able to imitate as early as this age. Likewise, Fontaine (1984) tested the infant's imitative skills between birth and six months, and have found that imitation in infants increases considerably during the second month of the infant's life.

With respect to children, it has been shown that 9-to-10 year old subjects imitated more than 15- to-16 year old subjects, which suggests that children might have enhanced imitation capabilities (Shwartz, 1956). Rosenblith (1959) did an interesting study on kindergarten and children aged between 3 and 11 years old

and also on 12-to-14 years old with adults. The study answered four important questions in regards to imitation learning, but the most important question was "does having a model lead to significantly greater improvement in learning than additional experience only?" The answer to this question through the results of the study was yes. Wilson (1958) conducted an experiment on preschool children to test the imitation and the learning of incidental cues. The age of the subjects ranged between 3 years, 7 months, to 4 years, 10 months. The results of the study clearly showed that imitation has a very important role in learning.

In another study conducted by McGuigan, et. al. (2007), children aged 3 and 5 years old were tested on. The important result from this research was that children at the age of 3 or 5 years old actually used imitation through live feedback or through a video feedback. They did significantly better than the control group which did not know anything about the task and were going through the discovery learning instead of the imitation learning.

## **Imitation learning**

Imitation learning is one of the first and most important ways of learning. We would see toddlers at a very early age (around 2) be able to imitate people that an adult can't achieve in an instant try (Vogt & Thomaschke, 2007). We can define Imitation as following a certain pattern of others, or we might even go farther and define it as the copying of others' actions. When we talk about imitation learning, we are talking about observational learning (Vogt & Thomaschke, 2007). To imitate someone, we have to observe this person and then we will be able to imitate him/her.

There is a linkage between the Direct Matching concept and imitation learning. Direct matching is defined as the involvement of motor processing in action observation (Brass & Hayes, 2005; Wilson & Knoblich, 2005). This phenomenon can be found through the precise copying of behaviors that the children do throughout their lives. The Direct Matching concept states "we understand actions when we map the visual representation of the observed

action on our motor representation of the same action”(Rizzolatti, Fogassi, & Gallese, 2001).

Barbi & Craig (2009) conducted a study on observational learning in adult sports novices. The study indicated that independent sport novices (i.e. sports that are dependent on the athlete only like gymnastics, diving, and swimming) would employ more of the skill function than interactive sport novice (sports that are dependent on others like soccer, football, and basketball).

Esseily, R., et al. (2010) conducted a study on object retrieval through observational learning in 8- to 18-month-old infants. The aim of the research was to study “the development of observational learning in acquisition of a new manual skill required for indirect object retrieval”. The researchers concluded that there is an increase in performance after observation between 10-and-12 month-olds, and that we can benefit from observation learning by 12 months-old. This study indicated that human at an early age observe movements and functions.

The infants as early as 12-months were able to imitate actions and movements, such as raising a lid that was attached to a transparent box with one hand while grasping the object with the other hand. Also, they were able to make detours to grasp an object, which shows that they were observing even the movements, not only the functions.

Rodrigues, et. al. (2010) compared the learning process of a highly complex ballet skill following demonstrations of point-light and video models. The study compared two groups, where the first one contained participants who watched a model's pirouette performance on video, and then tried to copy the model's action using a point-lights display of a ballet player performing. A second group studied a point light group watched an edited version of the same video clip. The findings of the study didn't confirm the expected superiority of the point-light group's learning process, and in favor of a better motor learning, the findings suggested that the high task complexity and the absence of an explicit outcome goal did not alter the use of visual information contained in

point-light model. According to ballet experts' judgments, there was a significantly better performance by the video group over the point-light group. Even though that there was some information available through observing the point-light display of a ballet player, the whole picture of a ballet player performing the pirouette had a significant better results, because it had more information to show. So, in order to even increase these better results, one might try and enhance this whole picture experience and show more information to the subjects.

### **Augmented feedback and Motivation**

Information processing of the performer is affected by motivation, and motivational effects of feedback affect the performance (Kaisu, 2007). Augmented informational feedback was linked to the motivation of individuals (Adams 1987; Little & McGullagh 1989; Annesi 1998; Silverman et al. 1998). It was suggested that with augmented informational feedback, the task is more

interesting, and learners increased their effort to reach the desired learning goal. Magill (2007) indicated that *"visual augmented feedback has been shown to have motivational benefits for learning motor skills"*.

Subjects strive and work harder on the responses that are already in their repertoire, and with the augmented feedback, there is motivation through subjects striving to reach the goal (Adams, 1987). Subjects can discriminate differences between the goal, scores, and errors just as if error was presented to them directly.

### **Mirror neurons**

When we look at imitation learning, we would see that it is a learning process that engages mirror neurons in the implementation of its process (Rizzolatti & Craighero, 2004). Mirror neurons were identified first in monkeys, and particularly in the F5 area of the monkey's premotor cortex. Mirror neurons are visuomotor neurons that discharge when the monkey performs a particular action or

when it observes another individual (human or monkey) doing a similar action (Rizzolatti & Craighero, 2004). Direct evidence that mirror neurons exist for humans is not available, but we have a rich amount of data that indirectly support the existence of mirror neurons in human beings.

Rizzolatti & Craighero (2004) supported the idea of Mirror Neurons through neurophysiological and brain imaging experiments. On neurophysiological experiments, activation of the motor cortex was noticed, even in the absence of any overt motor activity. On brain imaging studies, when an individual observes an action done by others, a complex network formed by occipital, temporal, parietal visual areas, and two cortical regions were observed.

In a magnetic stimulation study conducted by Fadiga, et. al. (1995), Motor facilitation during action observation was examined. In this study, Transcranic Magnetic Stimulation (TMS) was performed during four different



conditions. The first condition was the observation of an experimenter grasping objects. A second condition was observation of an experimenter doing aimless movements in the air with his arm. A third condition was observation of objects, and the last condition was on detection of dimming of a small spot of light. The interesting result the researchers found was that there was an increment in the excitability (from the Motor evoked potentials (MEP)) was noticed in those muscles that subjects would use when actively performing the observed movements.

Gallase and Goldman (1998) commented on the previous study by saying that the work of Fadiga, et. al. (1995) provided the first evidence that we have a mirror system that is similar to monkeys. They also stated, "Every time we are looking at someone performing an action, the same motor circuits that are recruited when we ourselves perform that action are concurrently activated". So to make this clear, and apply it to this research, when a gymnast observes pommel horse circles from another gymnast, there are motor circuits that are recruited when the observing gymnast performs the (same) observed

movement.

Mirror neurons are linked to visual observation of goal-directed actions (Miall, 2003). Through looking at brain imaging studies, when the observer is going through the action-guided movement (execution of the movement) the mirror neurons fire. This is the unique observation of mirror neurons; they show similar responses during execution of the movement and observation of the same action (Miall, 2003). Mirror neurons do not fire to the object alone, they fire when there is an intention to do the action that we want to imitate (Umiltà, Kohler, Gallese, & Fogassi, 2001). So, when the gymnast just looks at the pommel horse, or just goes ahead and executes the required movement (i.e. pommel horse circles), without the intention to imitate any performance, the mirror neurons do not fire. They fire when there is an intention (i.e. goal-directed) to imitate, and in this research, it will be imitating the optimal performance required for the gymnast to reach.

Mirror neurons help us understand actions performed by

others (Rizzolatti & Craighero, 2004), and the indirect evidence of the existence of these neurons gives us a chance to engage these neurons through imitation learning. We can state that the mirror neurons discharge when we have a meaning of the movement. We have to have a notion identifying the purpose in order to engage the system. For example, if we want to say this is an error, how would we know it is an error if we don't have a goal or know what is right?

In a study conducted by Abernethy & Zawi (2007), the researchers stated, "the perception and the production of the same action involve common coding so that the task of perceiving and anticipating someone else's movement patterns triggers the perceivers' coded representation of their own production of the same action. There is neural evidence of the presence in the human brain of so-called mirror neurons discharge when a particular action is either produced or observed". So, mirror neurons fire when we code the action on our coded representation of the same action. Meaning, when we observe pommel horse circles, and we want to imitate that pommel horse

circles, these neurons fire only we want to do pommel horse circle and also when we execute pommel horse circles. They do not fire when we execute different action on pommel horse, likewise, they do not fire when we do not observe the pommel horse circles to imitate that action. Thus, with the new technology of the Dartfish program used in this research, the observed action is pommel horse circles, and the executed action is pommel horse circles. Thus, mirror neurons will play a role in this Dartfish methodology.

Human beings have a capacity with respect to imitation learning. Each one of us has a different understanding and capability to learn through imitation (Rizzolatti & Craighero, 2004). Humans have neurons that are called "Mirror Neurons." These neurons fire when there is an intent to imitate actions, which indicates that imitation is not an arbitrary reaction, but an organized type of learning that engages the neuron system in it

## **Internal Models**

One of the theoretical views in the field of motor control is the existence of Internal Models. The existence of internal models and the use of the Central Nervous System (CNS) have been debated for a long time. It was proposed that CNS internally stimulates the dynamic behavior of the motor system in learning. Internal models were argued to be a movement controller consisting of forward dynamic models, and inverse dynamic models. Forward dynamic models predict the next state (eg. position and velocity) given the current state or the motor command (Wolpert, Ghahramani, & Jordan, 1996; Wolpert, Miall, & Kawato, 1998). On the other hand, the inverse dynamic models estimate the motor command that caused a particular state transition (Wolpert, Ghahramani, & Jordan, 1996; Wolpert, Miall, & Kawato, 1998). The forward dynamic model has a reafference and efference copy, where the reafference is a mechanism that allows the CNS to process information from the environment, and helps it to act with it. It tries to provide us with a physiological mechanism that is capable

of differentiating between information from the periphery and the information we generate ourselves. The efference copy is an internal copy created with a motor command of its predicted movement and its resulting sensations. One role of the efference copy is to enable the brain to estimate the sensory feedback from movements.

There are many fundamental benefits of forward dynamic models (Wolpert, Ghahramani, & Jordan, 1996). The first one is that it overcomes the large delays in sensorimotor loops by estimating the outcome of an action and its usage before the sensory feedback is available. On the other hand, a forward model provides appropriate signals for motor learning, by transforming the desired and actual sensory outcome of a movement into corresponding errors in the motor command. Finally, when the model prediction's of the next state combine with a reafferent sensory correction, it can be used for state estimation (Goodwin & Sin, 2009). We can train these models by updating our sensory information (Vercher, Sares, Blouin, Bourdin, & Gauthier, 2003), and this will be through

providing error signals to the model itself (Wolpert, Miall, & Kawato, 1998).

After-effect can be one of the explanations that support the existence of inverse models in mammals, thus it supports internal models. If we don't have an after-effect, then there wouldn't have been learning. After-effect tell us that learning took place, then the notion of generalizability of that learning tells us something about a rule base learning (that we have acquired a rule). Internal models are nothing more than sets of rules that connect certain input and generate a fix output based on that input. It does not prove that we have inverse dynamic models, but it's consistent with its notion.

### **Direct perception**

Direct Perception Theory of Gibson (1966, 1979) is a view that questions the existence of internal models. Direct

perception has been interpreted by Alva & Thompson (2002) as "*the seeing of an environment by an observer existing in that environment is direct in that it is not mediated by visual sensations or sense data*". By looking at studies conducted using point-light displays, it has been argued on the way humans perceive these point-light displays without having prior experience or memory of how to interpret these points and set them together to yield the observed function. Bertenthal, et. al. (1984) tested the perception of biomechanical motions of infants. Infants aged between 3-to-5 months old were recruited for this study: A point-light display of a person walking was presented to these infants in upright and inverted positions. Two kinds of walking were presented; rigid (constant distance between the point-lights), and non-rigid (the distance between the point-lights was not constant). In the upright position, infants were able to discriminate between rigid and non-rigid displays. Rodrigues, et. al. (2010) compared the learning process of a highly complex ballet skill following demonstrations of a point-light display and video model. The study compared two groups, where the first one contained participants who watched a model's pirouette performance



on video, and then tried to copy the model's action. The point light group watched an edited version of the same video clip, but it displayed a point lights version of the activity against a black background. This group copied the model's action. The results of the study showed a superior performance favoring the video group. On the other hand, Scully (1986) reported no difference between the point-light display, and the observation of the whole image display.

Kozlowski and Cutting (1977) tested whether subjects were able to recognize the sex of a walker from a dynamic point-light display. In this research, there were no familiarity cues available from a full body picture. All that subjects could see were dynamic point-light displays of a moving walker. In this study, the subjects were able to recognize the sex of the point-light display walker and differentiated if it were a man or a woman walking. The activity in this study was the same, that is walking, but how did they differentiate the sex of the point-light display walker? The subjects differentiated the sex from the movement. The movement characteristics of a human

walker of a man are different than those of a woman. We can find, for example, the wide movement of the arms, knee movement, and stroke of the feet on the ground that is unique to men.

The take home message here is not whether the whole image observation is better than the point-light display or the other way around. Subjects are able to perceive and discriminate the movement of a human body without prior experience to it (i.e. no engagement/chance of update to the internal model), which favors Gibson's theory of direct perception suggesting that prior mediation of internal models is unnecessary, as direct perception is not based on the having of sensations (Alva & Thompson, 2002).

### **Development of Technology**

Technology affected positively the imitation learning experience. Wilson (2008), in his article regarding the

"Development in video technology for coaching", briefly described the technologies used in sports. By the use of the old video tape recording cameras, athletes in the past used to wait for next day or hours after training to watch their own performance on screen. This is considered as delayed feedback, because the gymnast didn't get an immediate visual feedback but after hours of the end of performance, as the cassette used in the video cameras had to be ejected, and viewed on TV through a video player. The old Video Home System (VHS) cassette usage in sports in the past has many disadvantages. For example, it was time consuming, as the coach has to go through the whole recording session (through the fast-forward or fast-rewind) to find the performance needed to be viewed. Also, slow motion wasn't an option available on all video players, and even if it were available, the image quality was blurry when the performance of the athlete was viewed in slow motion. Other disadvantages like the delayed feedback, the poor image quality, the lost of quality of the cassette, lack of ability to draw on certain spots on the performance to be viewed in more focus and better ways also existed.

With time, digital video cameras and computer software were introduced in the sport settings. The digital video cameras have better quality of images and more options to help the video feedback experience for the athletes. The digital video cameras have many advantages, such as, the ability to search through different clips without the need of going through the whole recording, the video is stored digitally so the image quality does not deteriorate, and the slow motion experience is enormously improved. The slow motion happens when the frames per second (fps) playing is reduced from the normal speed of play, which is 25 Hz (25 fps), to 10 Hz. Now, digital video camera has the ability to record of up to 7500 frames per second (fps) compared to the old 25 fps recording. Which gives it stunning stop-action replays. Stop-action is when the coach freezes the video at a certain point, and a clear picture is displayed.

Computer software emerged into the field of sports, which can enhance the learning experience of athletes. Now, coaches have the ability to draw on the stop-action

images, view biomechanical properties of the performance, view multiple screens side by side, highlight key frames, overlay video images, and many more. When a digital video camera is hooked to the computer, the athletes have the ability to get immediate feedback through the delayed feedback of recording. For example, the coach can set up the delayed feedback option for 10 seconds, so whatever the camera is recording, it will not be displayed on screen until after 10 seconds. By this means, an athlete performs a certain skill, and by the time he's done with his performance and looks at the screen immediately, he would get an immediate view of his performance on the screen. The overlapping video images option is one of the advantages of computer software. With this technology the performance of an athlete is overlapped with the performance of another athlete or even with athlete's own different trials. The advantages of the use of digital videos and computer software are many, such as, the athlete can view his/her own performance, the performance can be easily repeated to detect errors more thoroughly, and the performance can be viewed from different angles with the use of more than one camera.

## **Video Modeling**

Video modeling is another term for using imitation learning via video. There have been many studies conducted in sports in regards to video modeling. One of these studies were conducted by Atienza et. al. (1998) on the effect of video modeling on tennis service placement and technique in 9-to-12-year-old children. The purpose of the study was to "analyze the effects of complementing the physical training for tennis service with the observation of video models and imagery training on tennis service by a group of 9- to 12-year-old tennis players". Twelve female tennis players participated in that study with mean age of 10.6 years and a standard deviation of 1.3 year-old, and they were recruited from Valencian Community in Spain. Participants were divided into three training groups. Group one participants trained verbally by a coach. Group two participants received verbal coaching and video model observation. Group three participants received verbal coaching, video observation, and imagery of the selected skill. The

dependent variables were the service placement test and the judges' rating of the tennis service technique. There were no significant differences between the groups at the beginning of the study, and there was a significant agreement between the judges ( $p=0.02$ ). The results of the study indicated that the group trained through verbal coaching did not show any significant differences over time in technique or service placement. On the other hand, the group who received verbal coaching with video observation showed significant differences in service placement and in technique. Finally, group three who received verbal coaching, video observation, and imagery showed differences in technique but not on service placement. The group who received verbal coaching with video observation had higher mean technique scores than the verbal coaching group (5.33 vs. 4.63). The researchers concluded that the addition of video-model observation created improvement on the technique of the skill performed (i.e. tennis service).

Baudry, et. al (2006) conducted research on the effect of combining self- and expert-modeling on the performance of

a Pommel horse circle (double leg circle). The purpose of the study was to assess the influence of the combination of self- and expert modeling using short- and medium-term retention tests. The second purpose was to assess the improvement in performance of each of the four circle phases (i.e. back phase, entry phase, front phase, and exit phase) during acquisition.

The hypothesis of the study was that video modeling would be beneficial to performance over the short and medium terms, and that gymnasts in the expert modeling condition were expected to show greater improvements than gymnasts in the traditional training in regard to body segmental alignment during circle.

Sixteen gymnasts were assigned to a control group or a modeling group (n=8 in each group). For the control group, the mean age of participants was  $15.1 \pm 2.2$  year old. On the other hand, the mean age of participants on the modeling group was  $14.3 \pm 1.8$  year old. Subjects were required to perform two sequences of eight pommel horse



circles. In the modeling group, the gymnasts were able to observe their own performance with an optimal performance on a side-by-side screen (i.e. the gymnast performance on half side of the screen, and the other half of the screen is showing an optimal performance of a pommel horse circles). In the traditional group the gymnasts didn't receive observation of a model, or feedback from the coach. The dependent variable in this study was the body segmental alignment. Three tests were conducted; pretest, post-test, and retention.

The results of the study indicated a main effect for groups ( $p < 0.05$ ), and tests ( $p < 0.05$ ). There was a significant interaction between tests and groups ( $p < 0.05$ ). In the retention, ANOVA test performed on the modeling group showed an effect for tests ( $p < 0.05$ ). The researchers concluded that immediate video modeling could facilitate correcting complex sports movements.

Given the current literature just reviewed, this study is not testing or supporting the Internal Models, Mirror

Neurons, or the Direct Perception Theory. This study is going to compare three conditions of training (i.e. traditional coach-assisted feedback, standard video feedback, and a new technology called Dartfish).

## CHAPTER THREE

### METHODOLOGY

#### Participants:

Thirty Volunteer male gymnasts participated in the study. Only male gymnasts were recruited because access was limited as the activity under study was the Pommel Horse, which is a gymnastics specialty limited to male gymnasts. The gymnasts ranged in age from 10 to 16 years old with mean age 12.13 and S.D of (1.46) (Table1). Participants

	Traditional	Video	Dartfish
Age	M= 12.1 SD= 1.2	M= 12.3 SD= 1.64	M= 12 SD= 1.63

Table1. Mean age for participants in the groups.

were recruited from both the national team of Kuwait and from various gymnastics clubs.

Participants were assigned at random to one of three groups. Group one comprised gymnasts exposed to a traditional coach-assisted proprioceptive feedback coaching (TRD). Group Two (VID) comprised gymnasts exposed to visual feedback via video observation. Group three (DRF) comprised gymnasts who used visual feedback via the Dartfish program (overlap observation). The

inclusion criteria were gymnasts who were not experts in pommel horse, or had a performance deficit in the circles (score between 7 and 8). The exclusion criteria were gymnasts who suffered from past injuries that might affect their hip flexion, and gymnasts who were expert in Pommel Horse Circles (PHC).

**Apparatus:**

The Federation of International Gymnastics (FIG) approved pommel horse was used in this study. The software used in this study was the Dartfish (Dartfish Inc., Fribourg, Switzerland). The recording of the exercise was used through a digital Canon video camera. The computer used to run the software was a Macbook pro 8 GB 1333 MHz DDR3 with 2.3 GHz Intel Core i7 processor, with a bootcamp running Windows 7.

**Procedure:**

Participants were assigned to one of three groups. Group one (TRD) included gymnasts who were exposed to

traditional coach assisted proprioceptive feedback coaching technique. For the TRD group, the coach supported the gymnast's body, and made corrections in order to achieve the desired position if performance errors were present (Figure 1).



Figure 1. a coach making corrections (right picture) to a deficit in the gymnast's performance (left)

The VID group included gymnasts exposed to standard video feedback. The video recording was delayed for 15 seconds to allow gymnasts to view their performance after completion of the activity. Performers in the VID group could also compare their performance to an image of an

optimal performance of a PHC via an image display on the same screen (Figure 2) without verbal input from a coach.

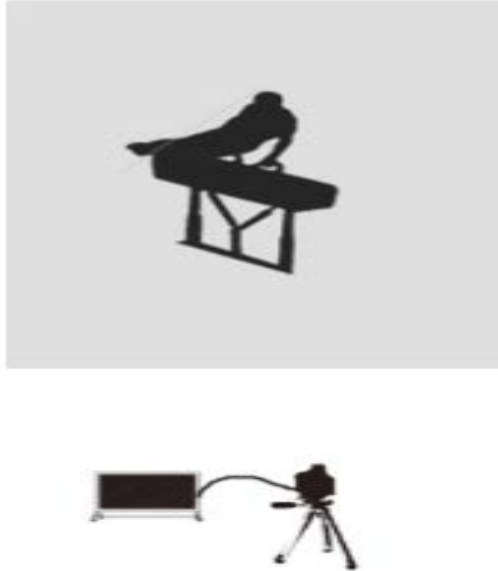


Figure 2. a gymnast performing a pommel horse circle, while the video camera is connected to a laptop. The gymnast then have the ability to watch his performance on the screen, with a follow up show of a target optimal performance.

First, they viewed their own performance, then, they viewed an optimal performance of a PHC. The DRF group included gymnasts who used the Dartfish recording system, which presented the gymnast's, own performance overlapped with an optimal performance of a PHC (Figure 3). There was a 10 to 15 second post-performance delay in order to allow the experimenter to overlap each gymnasts performance with the optimal performance of a PHC.



Figure 3. a gymnast performing a pommel horse circle overlapped with another gymnast performing the same skill.

Each Gymnast performed five circles on the pommel horse, and each performance was evaluated by six gymnastics judges. A PHC stunt (Figure 4) is performed by the gymnast supported by both arms, with the legs positioned out and away from the body. Ideally legs should be fully extended and closed.



Figure 4. A pommel Horse circle

The gymnast alternates arm support as the hips and legs swing in a circular rotational motion. The gymnast's body moves in a full circle, always supported by one arm. To perform a perfect PHC, the gymnast must achieve 180 degrees of hip angle or more (the body will be in a straight or fully extended position). The selection of five circles was designed to overcome the easiness of the task. For example, if the gymnast performed only one circle, he could use the ground forces when he pushed to perform the first circle, which might make it easy to put the body in an extended position.

### **Training Protocol**

The intervention-training program was scheduled to last four weeks. Each week comprised six days of training. Each day participants completed 20 trials, yielding a total of 120 trials per week, and 480 trials for the complete four weeks training session. There were four evaluation sessions. The first, at the beginning of the



study (pre-test); the second (post-test-1) after two weeks; the third (post-test-2) was 4 weeks from the start of the training program. The last evaluation session was a retention test at week 5. For the retention session, gymnasts were not exposed to any practice.

### **Judges:**

Performance scores were generated by qualified gymnastics judges. Gymnastics judging in general is divided into two sections. Section one is the D-Jury, and section two is the E-Jury. The E-jury are judges who deduct points when deficits are observed in the overall gymnast performance. The D-jury are judges who score the difficulty of the different skills on the gymnasts routine (i.e. difficulties are ranged gradually from A to F, where F is the most difficult skill level). In this study, the experimenter only used the E-Jury to evaluate the participants. A perfect score is 10 (i.e. no deductions). The optimal performance presented in the VID and DRF groups of the PHC conducted by the gymnast was evaluated

by the judges, and scored 9.9 on a scale of 10, before being used in the present study.



Figure 5. Judging setting.

All judges' scored performance using the International Gymnastics Code of Points to evaluate each gymnast's performance. The International Gymnastics Code of Points is governed by the *Federation Internationale de Gymnastique* (FIG), and it is a rulebook that defines the scoring system. Six scores were taken from the six judges; the highest and lowest score was deleted; the four remaining scores were averaged to generate the final score (Figure 5).

## **Analysis**

Data were analyzed using SPSS (SPSS Inc, Chicago, IL,USA) with linear mixed effects (repeated measure) Tests x Groups (3x3) design where conducted to test the performance phase. Also, Tests x Groups (2X3) repeated measure design were conducted to test for the differences on the Pretest in relation to the Retention. Likewise, the same test design was conducted on Post-test-2 in relation to Retention. Tukey HSD post-hoc analysis was used to detect significant differences between the groups over the tests intervals. Main effects for groups, tests, and interaction were yielded from the linear mixed effects statistical method.

CHAPTER FOUR  
RESULTS AND DISCUSSION

**Results**

The two research questions for this study were:

1. Is Dartfish overlapping technique more effective than using the standard video feedback?
2. Does imitation learning yield better results than the traditional proprioceptive feedback learning?

The data tested two hypotheses:

1. The overlapping technique (DRF) will enhance gymnasts learning than the standard video feedback (VID).
2. Both modes of imitation learning (DRF and VID) will be more effective than the traditional

proprioceptive feedback (TRD) for learning a gymnastics skill.

Table 2 summarizes the study results. For the pre-test; the TRD group mean score was 7.51 with a standard deviation of 0.13; the Video group mean score was 7.49 with a standard deviation of 0.18, and for the Dartfish group the mean was 7.49 with a standard deviation of 0.13. For the three feedback conditions, the post-test-1 mean

	Traditional	Video	Dartfish	Grand $\bar{X}$
PreTest	M= 7.51 (0.13)	M= 7.49 (0.18)	M= 7.49 (0.13)	M= 7.50 (0.15)
Post-Test-1	M= 7.52 (0.13)	M=7.60 (0.16)	M=8.02 (0.31)	M= 7.71 (0.20)
Post-Test-2	M=7.46 (0.13)	M= 7.74 (0.28)	M=8.21 (0.29)	M= 7.80 (0.23)
<b>Grand <math>\bar{X}</math></b>	<b>7.50 (0.13)</b>	<b>7.61 (0.21)</b>	<b>7.90 (0.24)</b>	<b>7.67 (0.19)</b>

Table2. Mean and standard deviation judging scores for testing sessions and feedback conditions.

Scores were 7.52 for the TRD group, 7.60 for VID group, and 8.02 for DRT group. Post-test-2 mean scores were 7.46 for the TRD group, 7.74 for the VID group, and 8.21 for

the DRF group. These mean changes are presented for clarity in Figure 6.

### Pretest

There was no significant group effect for the pretest.

### Post-test-1

For the Post-test-1, there was a significant group effect [ $F(2,27) = 15.55, p < 0.001$ ]. A Tukey Honestly Significant Difference (HSD) post-hoc analysis was conducted to determine which group significant different from the other. The difference between TRD group and VID group on post-test-1 was -0.08, and was not significant. A -0.5 between the TRD group and DRF group was significant ( $p < 0.001$ ). Likewise, the difference of -0.42 between the VID and DRF groups was also significant ( $p < 0.001$ ).

### Post-test-2

For the Post-test-2, there was a significant group effect [ $F(2,27)= 23.983, p<0.001$ ]. A Tukey HSD post-hoc analysis determined which group contributed to this effect. The mean difference between the TRD group and VID group on post-test-2 was  $-0.28$ , and this difference was significant ( $p<0.05$ ). The mean difference of  $-0.75$  between the TRD group and the DRF group was also significant ( $p<0.001$ ). Likewise there was a mean difference of  $-0.47$  between the VID group and DRF group, and this difference was significant ( $p<0.05$ ).

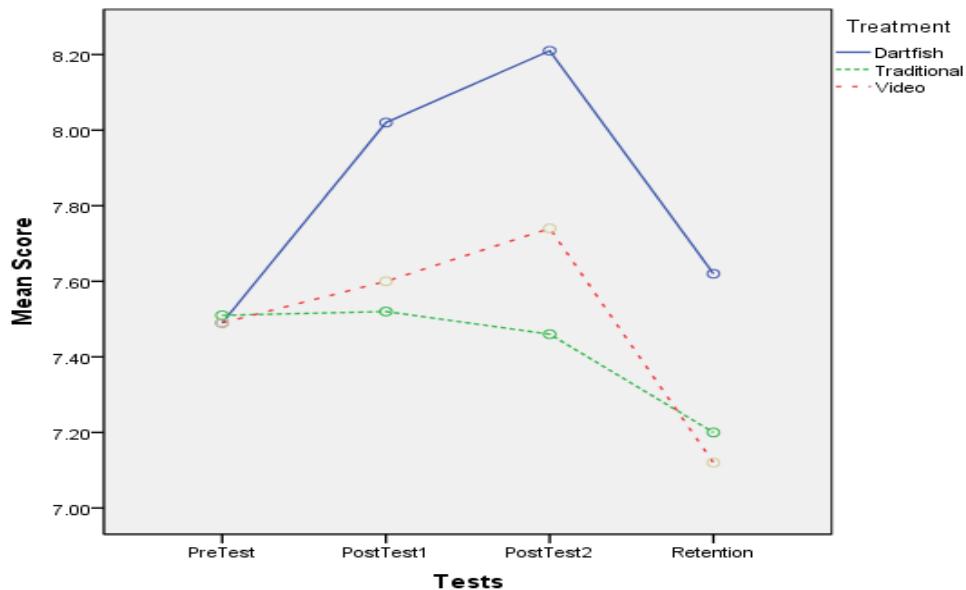


Figure 6. Mean Score over the tests intervals

Figure 6 also illustrates a significant main effect for groups [ $F(2,27)= 19.57, p<0.001$ ], a significant main effect for Tests [ $F(2,27)= 25.15, p<0.001$ ], and a significant interaction (Tests  $\times$  groups) [ $F(2,27)= 13.73, p<0.001$ ].

### Retention Test

For the retention test, the mean scores were 7.20 for TRD coach assisted feedback, 7.12 for the VID group, and 7.62 for DRF group (Figure 7).

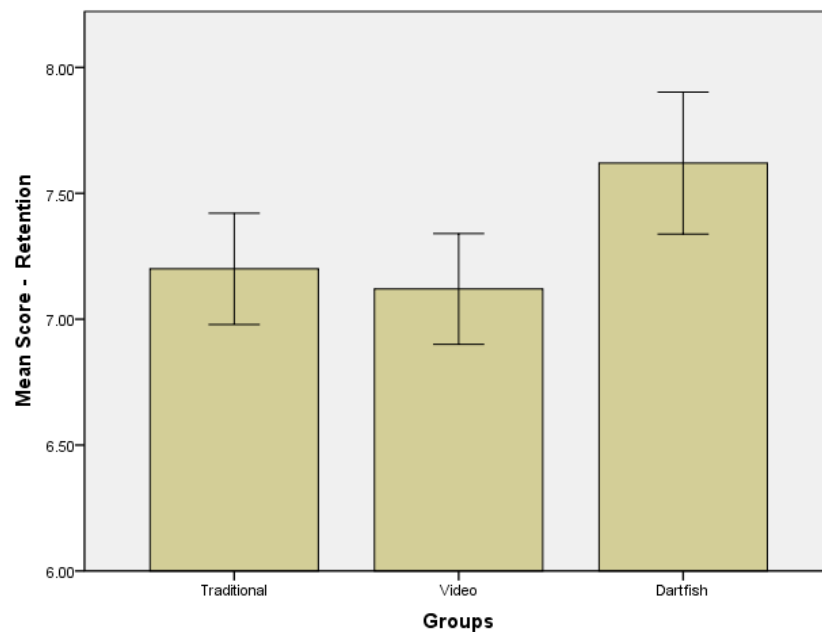


Figure 7. Mean score for groups on the retention test



There was a significant group effect [ $F(2,27)= 12.234$ ,  $p<0.001$ ]. A Tukey HSD post-hoc analysis tested which group was significantly different between groups. The mean difference between the TRD group and the VID group on the retention test was 0.08, and this was not significant. The mean difference -0.42 between the TRD group and DRF group was significant ( $p<0.05$ ). Likewise, the mean difference of -0.5 between the VID group and DRF group, and was also significant ( $p<0.001$ ).

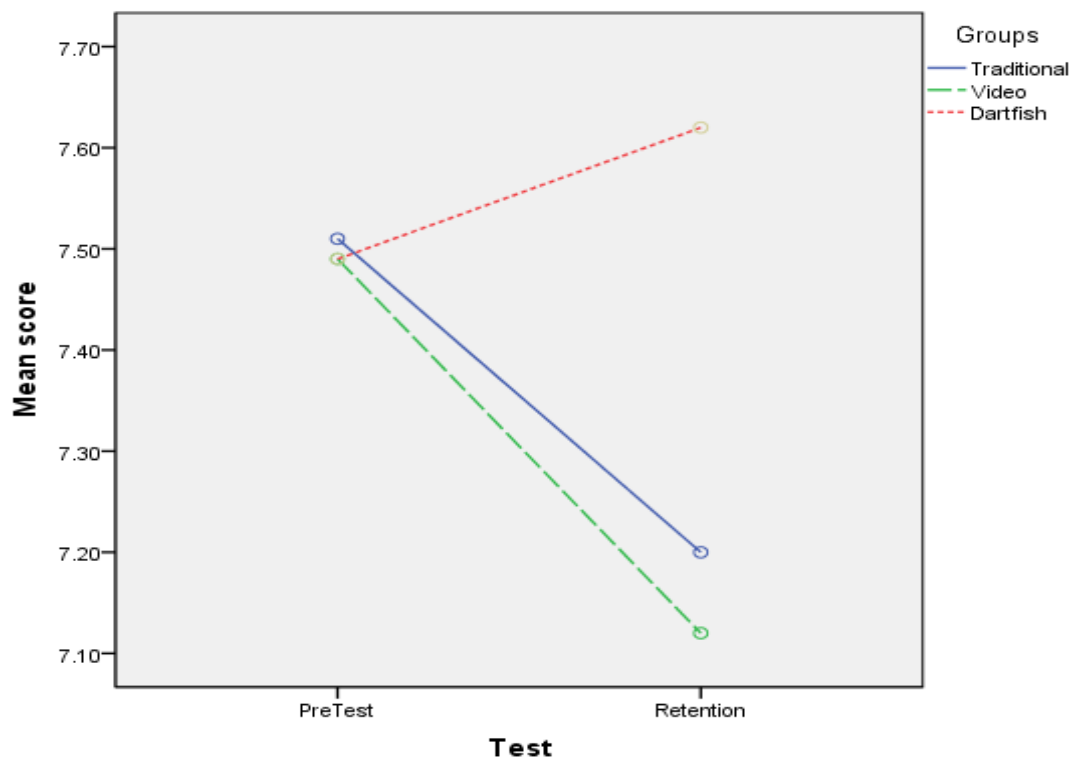


Figure 8. Pre-test to Retention comparison.

### Pretest-Retention

Figure 8 illustrates a significant group effect ( $p < 0.001$ ) and significant tests effect ( $p < 0.001$ ). There was no significant difference on the DRF group. There was a significant difference on the TRD group ( $P < 0.001$ ). Likewise, the difference between the Pretest and Retention yielded a significant difference on the VID group ( $p < 0.05$ ).

### (Post-test-2)-Retention

There was a significant difference on the TRD group ( $P < 0.05$ ). Likewise, the difference between the Pretest and Retention yielded a significant difference on the VID group ( $p < 0.001$ ). There was a significant difference on the DRF group ( $p < 0.001$ ).

## DISCUSSION

Learning accounts for both living and surviving. We learn to walk, for example, to engage in activities of daily living, and to acquire new skills to become better athletes, workers, etc. Finding a new more effective way of learning is always desirable. If a new method of learning is current today, tomorrow, for sure, there will be a new challenge to find an even better way. The traditional technique of learning a skill using coach assisted proprioceptive feedback in gymnastics has not proven to be less effective than the use of new technology with video cameras that provides visual feedback. Dartfish challenges this standard video camera recording by incorporating computer software, which has many advantages to facilitate the learning environment.

The subjects' were chosen based on the age at which they first started learning and performed a PHC. Typically gymnasts begin to perform PHC on the age of nine years, and they keep performing simple PHCs even as they attempt

more advanced routines, as PHC is the key skill to perform the other more complex skills on Pommel Horse. Groups were designed to test the new learning technique, the traditional learning technique, as well as the standard video feedback that previous research developed. The score range for the inclusion in this study was 7.0 to 8.0; it was chosen because this score is considered a low score but a score that should allow for improvement in performance. A baseline test was used so that athletes who scored below the score of 7.0 or above 8.0 would be excluded from the study. The researcher also excluded gymnasts with past injuries so that the injury would not contaminate the results of the study.

Two other tests (Post-test-1 and Post-test-2) were conducted to determine the gradual development over a period of a fixed time. Bandura (1969) in his research regarding Social-Learning Theory of Identificatory Processes stated,

"In evaluation theories of identification or modeling phenomena, it is essential to distinguish between acquisition and spontaneous performance of matching behavior because these events are

determined by different sets of variables" (Bandura, 1969, p.219).

Retention processes have been linked to observational learning in Bandura's research, where long-term retention of coded modeling events was argued. Thus, a retention test determined if the learning effect was still present after one week. By this the researcher is testing if the learning is a somewhat permanent change.

The TRD group in the current study consisted of gymnasts exposed only to proprioceptive feedback (i.e. no observation of an optimal performance was provided). In the Video group (VID), gymnasts were exposed to a standard video feedback, and were able to watch their own performance immediately following their performance, with a follow-up video image of the optimal target performance. The Dartfish Group (DRF) consisted of gymnasts exposed to the overlapping technique of their own performance with the optimal target performance.

### Research Question 1

*Is Dartfish overlapping technique more effective than using the standard video feedback?*

The hypothesis was that the overlapping technique (DRF) would enhance gymnasts learning more effectively than the standard video feedback (VID), because the discrepancy between the performer's actions and the optimal performers action is clearly observable.

Prior to the beginning of the study, all groups where tested performing the PHCs (Pre-test); no significant differences were present between groups. Post test was carried out two weeks after Pretest; the pretest significant difference between groups were present [ $F(2,27)= 15.556, p<0.001$ ]. A Tukey HSD's post-hoc analysis showed a significant difference between VID and DRF ( $p<0.001$ ). These data indicated that performers who practiced using the DRF overlap technique for the first

two weeks of practice, scored higher than using the standard video feedback technique.

At Post-test-2, this significant group difference between the VID and DRF groups was continued ( $p < 0.05$ ).

On the retention test, the DRF group continued to be superior to the other two groups. There was a significant difference between the DRF and VID ( $p < 0.001$ ). These results indicate that the new Dartfish overlap technique is more effective than the standard video feedback for both performance, and also for the retention of the learned skill.

### Research Question 2

*Does imitation learning yield better results than the traditional proprioceptive feedback learning?*

The hypothesis testing the question was that both modes of imitation learning (DRF and VID) would be more effective way than the traditional proprioceptive feedback (TRD) for learning a gymnastics skill. The results of the study indicated that imitation learning yielded better results than the traditional proprioceptive feedback. These results are broken into two parts. Part one the imitation learning using the Dartfish overlapping technique, which resulted in a significant improvement over the traditional proprioceptive feedback. Part two, the standard video feedback took four weeks to yield a significant difference between the VID group and the traditional TRD group. This might be because it takes longer period of time to yield positive effects from video usage in practice (Guadagnoli et. al. 2002).

Lack of significant difference on post-test-1 between TRD and VID was consistent with the conclusion of Guadagnoli, et. al. (2002) that the benefits of video feedback are time dependent and results typically take time. This contradicts the data reported by Whiting, Bijlard, &



DenBrinker (1987) regarding the immediate benefits of imitation learning using video feedback of an optimal performance, and Boyer, et. al's (2009) results of the quick benefits of video modeling coupled with video feedback; the subjects in Boyer's study practiced only three days a week.

After four weeks of practice, there was a significant difference between TRD and VID ( $p < 0.05$ ). These data are consistent with Guadagnoli et. al. (2002) suggesting it does take time to yield positive effects from video usage in practice. It took four weeks to yield a significant difference between the TRD group and the VID group. Performers presumably, over the four-week practice passed were able to detect the differences between their performance and the model. The significant difference between the TRD group and DRF group was not unexpected.

### Retention

The lack of significant difference between the TRD and the VID groups on the retention test contradicts Horn et. al. (2002), who only gave the performers in his study

three cycles of observing the model followed by practice. Then, a retention test was conducted two days later. Horn et. al (2002) concluded that skills learned through observation of a model via video are better retained than skills without a demonstration of a model. The results of the present study might be due to the fact that the training period was insufficient to detect significant differences. It might require a longer period training of this task using the video feedback to detect significant differences on the retention test. On the other hand, there was a significant difference between the DRF and the TRD groups ( $p < 0.05$ ), which indicates that imitation learning using the overlap technique was a more effective method than merely relying on the traditional proprioceptive feedback.

Comparing Pretest to Retention showed that the Dartfish group, even though they did not significantly improved, there was a slight increment relative to the Pretest. On the other hand, both the Traditional Proprioceptive Feedback Group and Video Groups dropped significantly on Retention relative to Pretest. The significant drop for

the DRF, VID, and DRF groups during the Retention test in relative to Post-test-2 was due to the detraining effect, and this detraining effect significantly affected the scores.

DRF group was superior to the other groups. It could be that when gymnasts used the overlapping technique, they were motivated to reach the optimal performance, and that every time they got closer visually, they might get more motivated to reach the optimal performance. Video recording and display through, for example, a computer monitor had been linked to augmented feedback (Magill, 2007). The role of augmented feedback was argued to be as follows:

1. To facilitate achievement of the action goal of the skill
2. To motivate the learner to continue to strive toward the achievement of a goal (Magill, 2007, p. 364)"

It could be that gymnasts evaluated their performance deficits easier when compared directly and more visibly with the optimal performance needed to be achieved through the overlapping technique. When comparing to the difference that the standard video feedback delivers, and from passed experience of my own, I find it difficult to

distinguish between the optimal (target) performance and my own performance. Even though the coach kept telling me that there is a difference between me and the optimal performance, by the time my own video feedback disappears, and the video of the optimal performance appears, it was hard to remember where my body position was relative to the optimal performance body position.

In this study, imitation learning is a more effective way of learning than proprioceptive feedback. With older modeling techniques (i.e. standard video feedback) it may take some time to notice positive effects, and with the new modeling techniques (Dartfish overlapping technique), it takes less time to achieve positive effects.

### Discovery Learning

Whiting, Bijlard, & DenBrinker (1987) conducted an experiment in which participants performed on a ski simulator. Participants in this study were exposed to two

conditions of learning. The first was discovery learning, where participants had no view of a model; in a second learning condition, participants observed a video model of a skilled performer as they performed the ski simulator. The results of this study showed that participants who observed a model of the skilled performer, were more fluent and consistent in their movement than participants who engaged only in discovery learning. In a later paper, Vereijken and Whiting (1990) defended the discovery learning. Presumably Vereijken and Whiting (1990) showed that the availability of a model was not superior to discovery learning. They stated that discovery learning forces the learner to explore the dynamics of the system, which exploits the learner's sensitivity to the kinematic properties of the activity.

The present study compared a group that received only proprioceptive feedback (TRD) to VID and DRF groups, who were able to observe and compare their performance to an optimal (target) performance. Thus, comparable differences between the effects of proprioceptive feedback and video feedback were possible. Research

addressing the differences between traditional coaching using standard proprioceptive feedback (TRD), and learning via imitation in gymnastics is not addressed in the current research literature.

Discovery learning is not separate from modeling in a motor task, as modeling can compliment the discovery of a skill. The data from this study showed that modeling in a complex skill such as a PHC is better than only going through the discovery of the required technique of the skill without observing a model. This suggests that the usage of modeling in addition to discovery learning, enhances the learning and resulted in higher score in a four weeks period.

The ability to learn involves the task, the performer, and the environment (Walter & Allen, 1991). The results of Vereijken and Whiting (1990) study were based on a slalom ski-type movement. The current study used a different complex task, the PHC. The environment is also different between these two studies. The addition of the Dartfish overlapping technique enhanced the modeling of

an optimal performance than merely the standard video feedback, and resulted in better scores, which suggests that one way to enhance our ability to learn, is to find a more effective way of displaying the targeted performance of a model. This suggests, the more information showing the discrepancy between the athlete's performance and a target optimal performance, the more effective the ability to learn will be.

## CHAPTER FIVE

### CONCLUSIONS AND RECOMMENDATIONS

#### **Conclusion**

Based upon the findings and with the limitations of this study, following conclusions could be reached. The following limitation associated with this study was:

1. The study was conducted only on one sport, which is gymnastics.
2. This study included only male gymnasts, due to the nature of the skill and because the researcher only had access to male gymnasts.
3. The age of participants in this study ranged between 10 and 16 years old only, due to the fact that this is the age range is where gymnasts start to learn PHCs.
4. Although the subjects in this study were beginners and somewhat less skilled with the PHC, they were not totally beginners to gymnastics as a sport.



5. The study was based on a simple gymnastics skill only, and not on very complex high speed skill.
6. This study was conducted on one apparatus, which is the Pommel Horse.
7. The study did not include elite athletes comparing their performance to another optimal performance technique.
8. On the retention test, subjects did not receive any practice. This detraining effect significantly affected the results on the retention test and resulted in a significant drop on scores.

Considering the limitations of this study, the following conclusions can be made:

1. Dartfish overlapping technique not only enhances the performance during the acquisition phase, but also enhances the retention of the learned skill.

2. Standard video feedback is an effective way of coaching during the acquisition phase, but not during the retention of the skill.
3. It takes more time to yield positive effects from Standard video feedback than it takes with the new Dartfish overlapping technique.
4. Both Dartfish overlapping technique and standard video feedback are better than the traditional proprioceptive coach-assisted feedback during the acquisition phase.
5. Standard video feedback is not different than the traditional coach-assisted feedback in regard to the retention of the skill.

### **Future Research**

This work should be tested also on females. It would also be interesting to know if we can apply this method on subjects that had never been exposed to gymnastics. Future research is suggested to test if this method also applies to a more complex skills with different apparatus

such as the High Bar, Floor Exercise, Parallel Bars, Rings, and Jumping Vault. Retention tests where subjects continue practicing pommel horse but without any feedback technique is recommended. The generalizeability of this method has not been tested. Would this method be beneficial on different sports, or even any different task?

## References

- Abernethy, B., & Zawi, K. (2007). Pickup of Essential Kinematics Underpins Expert Perception of Movement Patterns. *Journal of Motor Behavior* , 39 (5), 353-367.
- Adams, J. (1987). Historical review and appraisal of research on the motor learning, retention, and transfer of human motor skill . *Psychological Bulletin* , 101, 41-74.
- Alva, N., Thompson, E. (2002). *Vision and Mind: Selected Readings in the Philosophy of Perception* Cambridge, MA: MIT Press.
- Annesi, J. (1998). Effects of computer feedback on adherence to exercise. *Perceptual and Motor Skills* , 87, 723-730.
- Atienza, F., Balaguer, I., & Garcia-Merita, M. (1998). Video Modeling and Imaging Training on Performance of Tennis Service of 9- to 12-year-old Children. *Perceptual and Motor Skills* , 87, 519-529.
- Bandura, A. (1969). Social-Learning Theory Of Identificatory Processes. In D. Goslin, *Handbook of Socialization Theory and Research* (pp. 213-262). Chicago: Rand McNally & Company.
- Barbi, L., Craig, H. (2009). Observational learning use and self-efficacy beliefs in adult sport novices. *Psychology of sport and exercise*, 10 (2), 263-270.
- Barr, R., Dowden, A., & Hayne, H. (1996). Developmental Changes in Deferred Imitation by 6- to 24-Month-Old Infants. *Infant Behavior and Development* , 19, 159-170.
- Baudry, L., Leroy, D., & Chollet, D. (2006). The effect of combined self- and expert-modelling on the performance of the double leg circle on the pommel horse. *Journal of Sports Sciences* , 24 (10), 1055-1063.

- Bertenthal, B., Proffitt, D., & Cutting, J. (1984). Infant Sensitivity to Figural Coherence in Biomechanical Motions. *Journal Of experimental Child Psychology* , 37, 213-230.
- Boyer, E., Miltenberger, R., Batsche, C., & Fogel, V. (2009). VIDEO MODELING BY EXPERTS WITH VIDEO FEEDBACK TO ENHANCE GYMNASTICS SKILLS. *Journal of Applied Behavior Analysis* , 42 (2), 855-860.
- Brass, M., & Hayes, C. (2005). Imitation: Is cognitive neuroscience solving the correspondence problem? *Trends in Cognitive Sciences* , 9, 489 - 495.
- Esseily, R., Nadel, J., Fagard, J. (2010). Object retrieval through observational learning in 8- to 18-month-old infants. *Infant Behavior and Development* , 33 (4), 695-699.
- Fadiga, L., Fogassi, L., Pavesi, G., & Rizzolatti, G. (1995). Motor facilitation during action observation: a magnetic stimulation study. *Journal of Neurophysiology* , 73 (6), 2608-2611.
- Fontaine, R. (1984). Imitative Skills Between Birth and Six Months. *Infant Behavior and Development* , 7, 323-333.
- Gallese, V., & Goldman, A. (1998). Mirror neurons and the simulation theory of mind-reading. *Trends in Cognitive Sciences* , 2 (12), 493-501.
- Gibson J. J. (1966) *The senses considered as perceptual systems*. Boston, MA: Houghton Mifflin.
- Gibson, J. J. (1972). Outline of a theory of direct visual perception. In J. R. Royce & W. W. Rozeboom (Eds.), *The psychology of knowing*. New York: Gordon & Breach.
- Gibson J. J. (1979) *The Ecological Approach to Visual Perception*. Boston, MA: Houghton Mifflin.
- Goodwin, G., & Sin, K. S. (2009). *Adaptive Filtering Prediction and Control*. New York: Dover Publications.

- Guadagnoli, M., Holcomb, W., & Davis, M. (2002). The efficacy of video feedback for learning the golf swing. *Journal of Sports Sciences* , 20 (8), 2002.
- Horn, R., Williams, M., & Scott, M. (2002). Learning from demonstrations: the role of visual search during observational learning from video and point-light models . *Journal of Sports Sciences* , 20 (3), 253-269.
- Janell, C., Barba, D., Frehlich, S., Tennant, K., & Cauraugh, J. (1997). Maximizing Performance Feedback Effectiveness Through Videotape Replay and Self-Controlled Learning Environment. *Research Quarterly for Exercise and Sport* , 68 (4), 269-279.
- Jones, S. (2007). Imitation in Infancy: The Development of Mimicry. *Psychological Science* , 18 (7), 593-599.
- Kaisu, M. (2007). The effects of augmented feedback on motor skill learning in shooting: A feedback training intervention among inexperienced rifle shooters. *Studies in Sport, Physical Education and Health*, Jyväskylä: University of Jyväskylä, 63 p.
- Kozlowski, L., & Cutting, J. (1977). Recognizing the sex of a walker from a dynamic point-light display. *Perception & Psychophysics* , 21 (6), 575-580.
- Little, W., & McGullagh, P. (1989). Motivation orientation and modelled instruction strategies: The effects of form and accuracy . *Journal of Sport and Exercise Psychology* , 11, 41-53.
- Magill, R. (2007). *Motor Learning and Control* (Vol. Eighth Edition). New York: McGraw-Hill.
- McGuigan, N., Whiten, A., Flynn, E., & Horner, V. (2007). Imitation of causally opaque versus causally transparent tool use by 3-and 5-year-old children. *Cognitive Development* , 22 (3), 353-364.
- Meltzoff, A., & Moore, M. K. (1983). Newborn Infants Imitate Adult Facial Gestures. *Child Development* , 54 (3), 702-709.

- Miall, R. (2003). Connecting mirror neurons and forward models. *NEUROREPORT* , 14 (17), 2135-2137.
- Rizzolatti, G., & Craighero, L. (2004). The Mirror-Neuron System. *Annual Review of Neuroscience* , 27, 169-192.
- Rizzolatti, G., Fogassi, L., & Gallese, V. (2001). Neurophysiological mechanisms underlying the understanding and imitation of action. *Nature Reviews Neuroscience* , 2, 661-670.
- Rosenblith, J. (1959). Learning by Imitation in Kindergarten Children. *Child Development* , 30 (1), 69-80.
- Rodrigues, S., Ferraciolo, M., & Denardi, R. (2010). Learning a complex motor skill from video and point-light demonstration. *Perceptual and Motors Skills* , 111 (2), 307-323.
- Scully, D. (1986). Visual perception of technical execution and aesthetic quality in biological motion . *Human Movement Science* , 5 (2), 185-206.
- Shwartz, H. (1956). An experimental study of imitation. The effects of reward and age. *Senior honors thesis, Radcliffe College* .
- Silverman, S., Woods, A., & Subramaniam, P. (1998). Task structures, feedback to individual students, and student skill level in physical education . *Research Quarterly for Exercise and Sport* , 69, 420-424.
- Umiltà, M., Kohler, E., Gallese, V., & Fogassi, L. (2001). I know what you are doing. A neurophysiological study. *Neuron* , 31, 155-164.
- Vercher, J.-L., Sares, F., Blouin, J., Bourdin, C., & Gauthier, G. (2003). Role of sensory information in updating internal models of the effector during arm tracking. *Progress in brain research* , 142, 203-222.
- Vereijken, B., & Whiting, H. (1990). In defence of discovery learning. *Canadian Journal of Sport Science* , 15, 99 - 106.

Vogt, S., & Thomaschke, R. (2007). From visuo-motor interactions to imitation learning: Behavioural and brain imaging studies. *Journal of Sports Sciences* , 25 (5), 497 - 517.

Walter, D., Allen B. (1991). *Ecological task analysis: Translating movement behavior theory into practice*. Adapted Physical Activity Quarterly, Vol 8(2), 154-177

Whiting, H., M., B., & Den Brinker, B. (1987). The effect of the availability of a dynamic model on the acquisition of a complex cyclical action. *The Quarterly journal of experimental psychology* , 39 (1), 43-59.

Wilson, B. (2008). Development in video technology for coaching. *Sports Technology* , 1 (1), 34-40.

Wilson, M., & Knoblich, G. (2005). The Case for Motor Involvement in Perceiving Conspecifics. *Psychological Bulletin* , 131 (3), 460 - 473.

Wilson, W. (1958). Imitation and the Learning of Incidental Cues by Preschool Children. *Child Development* , 29 (3), 393-397.

Wolpert, D., Ghahramani, Z., & Jordan, M. (1996). An Internal Model for Sensorimotor Integration. *Science* , 269 (5232), 1880-1882.

Wolpert, D., Miall, C., & Kawato, M. (1998). Internal models in the cerebellum. *Trends in Cognitive Sciences* , 2 (9), 338-347.



## Appendices

## Appendix A

Institutional Review Board (IRB) Approval, and the approval to conduct the experiment on the gymnastics halls and athletes in Kuwait.

## UNIVERSITY OF MINNESOTA

Twin Cities Campus

Human Research Protection Program  
Office of the Vice President for Research

D528 Mayo Memorial Building  
420 Delaware Street S.E.  
MMC 820  
Minneapolis, MN 55455

Office: 612-626-5654  
Fax: 612-626-6061  
E-mail: [irb@umn.edu](mailto:irb@umn.edu) or [ibc@umn.edu](mailto:ibc@umn.edu)  
Website: <http://research.umn.edu/subjects/>

July 11, 2011

Saqer G Almulla  
808 Berry Street Apt 275  
Saint Paul, MN 55114-1391

RE: "Imitation learning in gymnastics using a new overlapping technique"  
IRB Code Number: **1106P01083**

Dear Mr. Almulla

### Notification of Institutional Review Board (IRB) Action

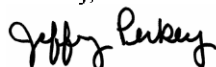
The IRB received your application entitled "Imitation learning in gymnastics using a new overlapping technique." Upon review of your application, the IRB determined these activities do not meet the regulatory definition of research with human subjects and do not fall under the IRB's purview.

*(i.e., Although the activities described in your application are considered research, the proposed activities are a) not a systematic investigation and/or b) not designed to develop or contribute to generalizable knowledge [45CFR46.102(d)].*

Please do not hesitate to contact the IRB office at 612-626-5654 if you have any questions. Thank you for allowing the IRB to make the determination about whether or not review is required.

If you have questions concerning this specific correspondence, contact Bri Warner at 612-624-5142.

Sincerely,



Jeffery Perkey, MLS, CIP  
Research Compliance Supervisor  
JP/bw

CC: Michael Wade

**Driven to Discover<sup>SM</sup>**

**KUWAIT GYMNASTIC FEDERATION**

Tel. : 22634497 - Fax : 22634496  
Cable : GYMNASTIC - Telex : 23192 Committee  
P.O.Box : 2020 Safat - Code No. 13021 Kuwait  
E-mail : kgf-gymnastic@hotmail.com



**الاتحاد الكويتي للجماز**

تلفون : ٢٢٦٣٤٤٩٧ - فاكس : ٢٢٦٣٤٤٩٦  
برقيا : جمناستك - تللكس : ٢٣١٩٢ كوميتي  
ص.ب : ٢٠٢٠ الصفاة الرمز البريدي 13021 الكويت  
البريد الالكتروني : kgf-gymnastic@hotmail.com

Ref. No. : \_\_\_\_\_ : الاشارة

Date : ٢٧-١١-٢٠٠٩ التاريخ

**TO WHOM IT CONCERN**

We would like to let you know that we are happy to cooperate with university of Minnesota student / *Mr. Saqer Ghanim Almulla* in any way to help him conduct his research at **Kazma Club Gymnastics Hall**.

We will provide him with Gymnastics as subjects, and also we give him the permission to conduct his experiments in the Gymnastics Hall .

Sincerely regards  
General Secretary  
SAIF ABUEDEL





Date : 16 - 11 - 2009  
Ref. : 1265

التاريخ :  
الإشارة :

### To Whom It Concern

We would like to let you know that we are happy to cooperate with university of Minnesota student / Mr. **Saqr Ghanim Almulla** in any way to help him conduct his research at kazma Club Gymnastics Hall. We will provide him with Gymnastics as subjects, and also we give him the permission to conduct his experiments in the Gymnastics Hall.

Sincerely regards,  
Kazma Club

Copy to file

*abdelwhab*

Appendix B

Summary of the multiple comparisons

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Treatment	(J) Treatment	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
PreTest	Dartfish	Old	-.0200	.06594	.951	-.1835	.1435
		Video	.0000	.06594	1.000	-.1635	.1635
	Old	Dartfish	.0200	.06594	.951	-.1435	.1835
		Video	.0200	.06594	.951	-.1435	.1835
	Video	Dartfish	.0000	.06594	1.000	-.1635	.1635
		Old	-.0200	.06594	.951	-.1835	.1435
PostTest_1	Dartfish	Old	.5000*	.09630	.000	.2612	.7388
		Video	.4200*	.09630	.000	.1812	.6588
	Old	Dartfish	-.5000*	.09630	.000	-.7388	-.2612
		Video	-.0800	.09630	.688	-.3188	.1588
	Video	Dartfish	-.4200*	.09630	.000	-.6588	-.1812
		Old	.0800	.09630	.688	-.1588	.3188
PostTest_2	Dartfish	Old	.7500*	.10944	.000	.4786	1.0214
		Video	.4700*	.10944	.001	.1986	.7414
	Old	Dartfish	-.7500*	.10944	.000	-1.0214	-.4786
		Video	-.2800*	.10944	.042	-.5514	-.0086
	Video	Dartfish	-.4700*	.10944	.001	-.7414	-.1986
		Old	.2800*	.10944	.042	.0086	.5514
Retention	Dartfish	Old	.4200*	.10859	.002	.1508	.6892
		Video	.5000*	.10859	.000	.2308	.7692
	Old	Dartfish	-.4200*	.10859	.002	-.6892	-.1508
		Video	.0800	.10859	.744	-.1892	.3492
	Video	Dartfish	-.5000*	.10859	.000	-.7692	-.2308
		Old	-.0800	.10859	.744	-.3492	.1892

Based on observed means.

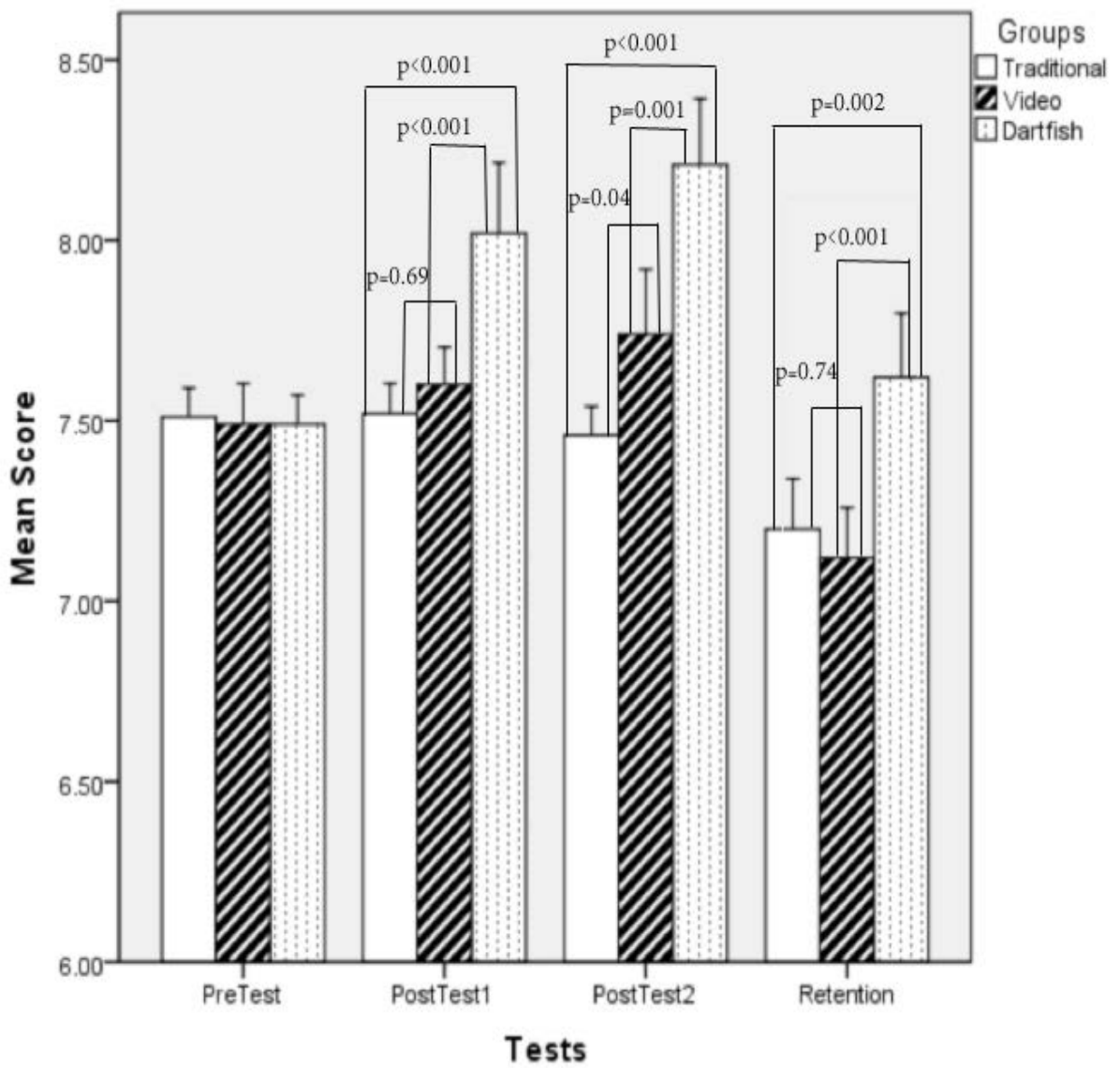
The error term is Mean Square(Error) = .059.

\*. The mean difference is significant at the .05 level.

## Appendix C

Summary Figure indicating p-values for the whole tests sessions.





## Appendix D

A real drawing of the experiment setting during the Dartfish overlap technique and standard video feedbacks.

