Master's Thesis of Physical Education

Effect of Visual Stimuli Training on Reaction Time, Decision Making and Performance Accuracy of Table Tennis Player

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Seoul National University

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Amir Kamandi

Effect of Visual Stimuli Training on Reaction Time, Decision Making and Performance Accuracy of Table Tennis Player

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Supervisor: SeonJin Kim

Confirming the master's thesis written by:

Amir Kamandi

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Chair _____(Seal)

Vice Chair _____(Seal)

Examiner _____(Seal)

Graduate School of Physical Education

Seoul National University

Abstract

Objective: In sports it may be necessary for an athlete to make a decision and execute a movement towards a specific direction with high temporal accuracy. Previous study shows, by reducing or increasing the amount of time between what and how decisions via manipulating ball speed or training to change between different targets in time and movement constrain we can have a major impact on performance. The aim of this study was first to develop visual stimuli training device that able player to change between different targets and different movement training. Second, to investigate whether this training system can actually improve accuracy, reaction time and decision making of athlete after an intervention of five weeks by comparing to a control group with no specific visual stimuli training.

Methods: Eighteen semi-experience table tennis players were randomly divided into 2 groups (control group, n = 8; experiment group, n = 10) and underwent pre-test, intervention, post-test and retention test. The test consisted of accuracy test, decision making test, choice reaction time test and three different level of accuracy together with decision making test.

Results: The result shows significant improvement in choice reaction time test and accuracy test just for the group that use visual stimuli training system and not for control group. But no significant improvement was found in decision making test for either group. However, there was a significant improvement in all three level of

accuracy together with decision making test for only experiment group though the effect size were getting smaller by level of test difficulty.

Conclusion: By training to limit the available time for table tennis player to change the direction of sending ball into a different specific area in response to different visual stimuli, we can improve visual reaction time, performance accuracy but not decision making of table tennis player. However, the performance which require both decision making and accuracy together might improve even if the decision making part of the performance remain the same and this result shows that improving accuracy might be a guaranty for performance superiority that require decision making as well.

Keywords: Reaction time, Interactive training, Decision making, Accuracy, Table tennis

TABLE OF CONTENT

LIST OF FIGURES

LIST OF TABLE

I. Introduction

The popularity of table tennis has been growing considerably since it's origination in the late 19th century in England. Table tennis has begun as a recreational physical activity and social diversion during the 1880's when adherents of lawn tennis adapted their sports recreation be played indoors during the winter season (Lees, 2003). Today, it is an accepted fact that table tennis is one of the most popular racket sports in the world and the second most probably played sport (Purashwani, 2010).

Table tennis is one of the fastest racket sports game in the world, which required a very short time for planning and performing movements. As well as the player, needs to have a high temporal and spatial accuracy in the racket position for interception of the ball coming and also a good target response accuracy to send the ball to the proper point of the opponent side of the table. When table tennis play at competitive levels, demands extreme levels of agility, accuracy, coordination, stamina and expert tactical maneuvering. For that reason, table tennis offers quite interesting context for sports scientists to explore complex phenomena (Lees 2003). To put it in an example, by analyzing elite athletes' reaction time, target response, and realistic stroke velocity, it might be possible to reveal their neuromuscular performance and cognitive strategies (Lapzo, 2002).

Sports such as baseball, tennis, squash, table tennis, and badminton require good execution of motor behavior and high perceptual ability (Mori, Ohtani, & Imanaka, 2002). Playing table tennis requires strong coincidence-anticipation timing skills for hitting the ball, as well as excellent reaction time. Reaction time is explained as being composed of four stages; include the start of eye movements, eye movement time, decision time and muscle contraction time (Singer, et al., 1993). Reaction time is also affected by factors such as gender, the number of simultaneous stimuli, age, nutrition, training and physical fitness and fatigue (Morehouse & Miller 1976; Spirdiso, 1975). Reaction time to a visual stimulus decreased with at least three weeks of practice, and the effects of the practice last for at least three weeks as well (Ando, et al., 2002). Research showed that experienced table tennis player had shorter reaction times than intermediate plyer (Vidja, et al., 2012) and also table tennis players have shown faster visual and auditory reaction time than healthy controls (Deepa & Sirdesai, 2016).

One of the perceptual abilities is decision-making which is within pre-operation and based on information processing model. Decision-making can be categorized as a part of reaction time and by putting the factors together, it can be said that decision making in sports possesses a certain number of characteristics. In table tennis, decisions are natural in essence, dynamic, and often made instantaneously or under conditions of moderate to high pressures.

Many skills in table tennis require the player to perform the movement with both speed and accuracy. In this situation, the accuracy requirement of the movement will influence the movement speed so that an emphasis on accuracy will reduce speed, and an emphasis on speed will reduce the accuracy. Hence, the choice of not limiting target areas on the table benefits the comparison between intermediate level and expert players because it equalizes task difficulty between groups. Because the trade-off between speed and spatial accuracy is related to the skill level and reaction time, intermediate players would have relatively more difficulty of responding to particular areas under high velocity situations. Visser et al. (2007) found that training on a complex task improved accuracy and shortened reaction time.

At the present time, table tennis coaches and players use a training machine to coach and train players. In this way, players are trained to improve their reaction time and overall responses time. The aim of designing fast speed and reaction training is to improve the performer's anticipation, attention, memory, concentration, and problem solving skills through the design of practices where visual cognition training is integrated with physical and technical training. However, there a deficiency in the current equipment that player cannot combine training such as changing between different targets and different angle of movements and ability to quickly change direction of sending ball in response to different visual stimuli.

The new smart table tennis trainer device provides interesting integrating training of ability to quickly react to visual stimuli from the different part of table sending balls to the different point of the opponent side of the table. Hence, by reducing the time interval between presenting visual stimulus and executing movement it is assumed that the reaction time and performance accuracy of table tennis player would be improved if they train with such a system. Therefore, it can be said that the total skill of table tennis player would be affected and improved. Previous studies showed that top-level athletes could have developed the best conditions of reacting and moving faster and more accurate than less skilled athletes due to their long-term training. More complex experimental tasks seem necessary to understand expertise in rapid racket sports.

This study will examine whether training to make a faster decision to where to send the ball by using visual stimuli can improve reaction time, decision making and accuracy of performance of table tennis player or not, as well as check the reliability of the new smart table tennis training device. Therefore, this study will use the latest smart table tennis trainer device which includes ping pong auto ball service machine integrated with a system to illuminate a specific points of the table before the ball is projected to the player and consequently the player needs to identify the dropped position and react as quickly as possible to send the ball to the target area. Illumination of the table by giving information to the system can indicate a random landing point of the returned ball by lightening the ping pong table using LED lights

at the same time that balls are thrown by the ping pong auto ball training machine, the LED lights indicate any of the target zones (1 to 8 targets).

1.1. Rational

There is few study has demonstrated the role of new technology in improving reaction time and decision making of human in which, skills and new strategies can be used flexibly across a range of tasks and contexts. One of the important concerns of table tennis coaches is how to train better table tennis player with quicker decision-making ability and how to train them to send the ball to the proper location of the table within a millisecond in different situation (Yoshida, 1995).

1.2. Significance

The result of this study would be beneficial for both players and coaches as it would provide information on how can improve the accuracy and reaction time of table tennis player base on visual stimuli training. This study will be carried out in an experimental procedure, by using athletes as subjects and new smart table tennis trainer device in repeatable and field conditions to detoxify some of the questions and needs of professional coaches and athletes as well as researchers. If the hypothesis of this study would be proven, the proposed method of training and the test procedure can play as a tool for measuring some aspects of table tennis players' skill.

1.3. Objective

This study will examine whether training to make a faster decision to where to send the ball by using visual stimuli can improve reaction time, decision making and accuracy of performance of table tennis player or not. This study would specifically peruse the following objectives:

- To determine the reliability and validity of the smart table tennis trainer device.
- To improve the accuracy of table tennis players.
- To improve reaction time and decision making of table tennis players.

1.4. Hypothesis

We hypothesized that the experimental group training visual stimuli for 5 weeks would perform better in all six post-tests of accuracy, decision making, reaction time and decision making together with accuracy than the control group which trained the same protocol for 5 weeks but without visual stimuli training.

1.5. Limitation

Although this study was carefully prepared, but it faced to some limitations and shortcomings. First, the research will be conducted using only eighteen semi-experienced participants for five weeks of training, which is not enough for

significant changes in reaction time. This is due to lack of financial and time, that is hard to get cooperation for more than five weeks and also subjects would not be enough motivated to follow training program properly. It would be better if the training period would be done in a longer period. Second, the population of the study is small; only 18 semi-experienced participants which might not represent the majority of the table tennis players. The replication of the study by different level of table tennis players would enable better generalizability of the findings of the study. That is due to lake of equipment, which we have only one prototype of the new smart table tennis trainer device and each player need to train with machine individually for at least 12 minutes per training day.

1.6. Definition

1.6.1. Reaction time

Table tennis is categorized as reaction sport that the incredible speed of the ball fly and the short distance it travels between the opponents allows a minimal amount of time to react and execute movement to response to the ball coming. Hence, reaction time in our study can be define as the time interval between the shooting of the ball from the machine and initiating the movement to send back the ball to the opponent side of table. So if the athlete can react faster to the ball coming he or she would

have enough time for repositioning his or her body in the proper position behind the ball and can execute the stoke movement with confidence.

1.6.2. Decision-making

To indicate how fast the table tennis player can respond the ball, it is important for them to decide what movement to execute, how to carry out the movement and where to send the ball to in a very short time. This research refers to decision making as the ability of the player to choose the location of the sending ball into opponent's side of table in a very short time continue with successful execution of his or her stroke to send the ball to that intended location of the table.

1.6.3. Accuracy

Table tennis requires player to have temporal and spatial accuracy to hit with reference to two different targets accuracy. The primary target accuracy is ball hitting which happens when ball-rack contact has to occur in a time that the racket is at an appropriate angle, resulting from a particular trajectory, with distinct levels of rotatory components to produce intended spin that this study would not refer to as a variable. The secondary target accuracy, which in this study concerned, is the area of the opposite side of the table where the ball is expected to contact.

1.6.4. Visual stimuli training

This study will use the new smart table tennis trainer device, which include the lighting system to indicate landing point of response ball. The illumination of the

table by lighting system provides, visual stimuli that the player require time for his or her brain to recognize the visual stimulus first and also it takes time to his or her respective part of the body to adequately respond to the stimulus. Training to shorten the available time for psychomotor to make a decision where to send the ball with such a lightning and training system in this study is defined as visual stimuli training.

II. Theoretical background and literature review

When table tennis plays at competitive level it requires player to have fast reaction time, decision making and accuracy as well as a luxury of visual ability for situation assessment to take the best action and send the ball as fast as possible to the location of another side of table where it is hard to cover by the opponent. Therefor this study concerns about reaction time, decision making, accuracy and visual ability.

2.1. Reaction time and decision making

To obtain a successful execution in sports, it is essential that athletes have high levels of perceptual abilities and be able to demonstrate motor skills in an efficient manner (Cagri Cetin et al., 2011). One of the perceptual abilities is reaction time (RT) that takes place pre-operation based on information processing model. RT is defined as the elapsed time between one sensory stimulus and the subsequent behavioral response, which is the time interval between the presentation of an unanticipated stimulus and the beginning of the response (Schmidt & Wrisburg, 2004).

In a situation that there is only one, signal which requires only one action in response, the RT situation known as simple RT. The other type of RT is choice RT where there is more than one signal to present and each signal has its own specific required action. RT would be divided into two part. The first part is the period of

time that onset of stimulus signal presented and the beginning of the movement called premotor time. The second component of RT, begin by increasing muscle activity until the actual observable limb movement that is called motor time (Magill, 2011). The common reason for measuring RT is to identify the environmental context information that a person can use like visual information while preparing to produce a required action.

Another use of RT is to assess the capability of a person to anticipate a required action and determine when and how to initiate it (Magill, 2011). For instance, a table tennis coach may want to know how long it takes a player to choose what movement to select and which part of the table he or she will send the ball to. When used in this way RT provide information about decision-making. Thus in addition to indicating how fast the person can react to a signal, RT also provides a window for examining how a person interacts with the performance environment while preparing to produce a required action (Magill, 2011). For that reason, decision training and reaction training is one of the priorities for table tennis coaches when they train the athletes preparing for competition (Yoshida, 1995).

By breaking down the RT into two parts, it is assumed that the premotor time is the period of receipting and transmission of information from environment through the nervous system to the muscle by itself. This time interval seems to be an indicator of perceptual and cognitive decision-making activity in which the person engaged

while preparing an action. The motor time interval indicates that there is muscle activity before observable limb movement occurs. Researchers assumed this activity indicates a time lag in the muscle that needs to order to overcome the inertia of the limb after the muscle receives the command to contract (Magill, 2011).

Therefore, decision-making will be defining as the ability to use information from the current situation and the knowledge possessed by it to plan, select and execute an appropriate goal directed action or set of actions (Williams and Ford, 2013). By putting the aforementioned factors together, it can be say that decision making in sports possesses a certain number of characteristics. Sports decisions are natural in essence, dynamic, and often made instantaneously or under conditions of moderate to high pressures. The emphasis on the "available time" two types of decision makings are discussed when considering various types. First, the analytic decision-making, where the player has enough time to assess the situation, reviewing different options and acts. Second, is the instinctive decision making which is made when a quick response is required and there is no time for reasoning (Benjamin, et al., 2004).

During real-world sports performances, athletes not only have to perform motor tasks but they also need to make decisions about when, where, and in what direction to perform the tasks. Traditionally, RT measures have been used to indicate athletes' information processing capabilities in terms of decision-making (Lees, 2003).

Table tennis is a typical sport in which players have to decide what movement to perform and how to carry out the movement and where to send the ball to within a very short time is an important concern. Roth (1989) showed, in laboratory-based pre-cueing experiments, that to make corrections to stroke parameters in table tennis ('how' decisions) participants require a response window of at least 399 MS prior to execution. 'What' decisions, however, require 556 MS, based on movement durations of about 370 MS (from start of swing to bat-ball contact). These time windows indicate that the selection and execution of sequential table tennis movements are performed, to some degree, in parallel. Hence due to the speed of the ball, forces performers to use advanced cues to decide 'what' response is required and 'how' that movement should be carried out (Abernethy, 1991).

In 1953 a study by Singleton suggested that RT decrease significantly when the task is complicated rather than simple. Decision training and effects of complex instruction, variable practice will reduce delayed feedback on the acquisition and transfer of a complex motor skill (Vickers et al., 1999). The complexity of tasks can have an acute effect on both execution and selection of responses (Fits & Posner, 1967). Reducing or increasing the amount of time between 'what' and 'how' decisions by manipulating ball speed or altering the size or weight of the ball (Xiaopeng, 1998) can have a major impact on performance. Increasing the number of possible stimuli and responses can also affect shot quality by introducing uncertainty.

The RT can be considered a decisive factor in the win during a match. In table tennis, the incredible speed of the ball fly and the short distance it travels between the opponents allows a minimal amount of time to react and execute shots. Thus, the table tennis player barely has time to react to the visual stimulus of the ball before the ball has arrived to be hit. Rodrigues studied table tennis forehand drives in 2002 showed that a minimum amount of time of about 300-ms is required to predict ball flight and to initiate a movement to intercept it. Loureiro and Freitas analyzed the neuromuscular performance of expert and intermediate badminton players in a target-pointing task. Their results showed no effect of group (expert and intermediate badminton players) on movement time and radial error, but simple and choice RT were shorter for experts. Regardless of definitions, it is clear that deciding on what to do and how to execute it are important components of elite performance in sports (Raab et al., 2005).

Decision training is designed to improve the performer's attention, anticipation, concentration, memory, and problem-solving skills through the design of practices where cognitive training is integrated with physical and technical training. Szymanski (1997) found in a laboratory experiment that post-test performance (accuracy) was superior for groups that learned to change between different targets and different movements compared to a uniform group (both same target, same movement), supporting the idea that decision training leads to superior performance.

2.2. Accuracy

Accuracy can be involved in either spatial accuracy, temporal accuracy or both of the types. The situation that involves space dimensions, such as distance called spatial accuracy and the situation involved in time dimensions called temporal accuracy. For both types of accuracy, error measure allows researchers to evaluate skills performance for which accuracy is the action goal (Magill, 2011). As the accuracy demands for a movement increase, the amount of time for preparation of the movement also increase. The need for additional time for action preparation in this type of situation is due to the additional preparation of the athlete to constrain his or her limb to move within spatial constraints imposed by smaller target (Sidaway, 1995).

2.3. Vision and reaction time

The reaction is a voluntary response to different stimuli and visual stimuli is not an exception. Visual information is critical in perceiving hazards and initiating plan to avoid them such as responding to an unexpected stimulus while driving (Deery 1999) therefore visual information enable human to respond accurately to a stimulus. In addition, visual information is so critical for stimulus accuracy that the brain initiates the response by moving the eye in the predicted location of stimulus (Saunders and Knill 2003). Ghuntla and his colleagues in 2014 shows that visual

reaction training and practice can improve simple and choice reaction time. Fast-paced activities, such as table tennis place great demands on human vision and reaction time.

Actions and reactions are dependent on receiving accurate and reliable information from the environment. Table tennis is characterized by perceptual uncertainty and time pressure, hence as a dynamic sport it involves an incessantly depends on varying visual environment. In order to react and respond properly to such a variable stimulus, the player must have a superior acquisition of visual information about the impending object.

The use of visual information and the features of motor control of table tennis techniques have been strongly debated. Bootsma and van Wieringen showed that elite table tennis players did not completely rely on a consistent movement production strategy, which was interpreted as a compensatory variability between perception and action. Experts performing a forehand drive are capable of having very short visuo-motor delays, around 100<200-ms, a measure comparable to reaction times. Bootsma and van Wieringen found visuo-motor delays between 105 and 156-ms and noticed that two of their five players had visuo-motor delays of 50 to 60-ms shorter than the duration of the movement, in principle allowing online corrections to be made. (Bootsma & Wieringe, 1990; Soset & Beek, 2010).

The process of reaction time by professional players occurs within milliseconds and if the player can react faster, they can take the best action to hit the ball sending it to the best location of the table where it is hard or impossible for the opponent to cover. Such an ability to hit the ball properly to the best location of the table, it requires continuous eyes convergence of the opponent position on another side of the table, as well as assessing the speed of the ball and predicting its path, which flies rapidly in space without any spatial clue. Forehand strokes of expert table tennis player towards a target area are the result of speed coupling process, means that they would apply lower arm velocity to the faster-approaching ball condition or reverse (Marinovic, 2004).

Subsequent when a player trying to intercept an approaching object, he or she has to deal with the time latency essential to alter the motor commands relying on the sensory visual information. So if the visual system is not receiving information accurately or quickly enough, performance may suffer due to longer reaction time. As a result, if a subject's visual system is functioning at a higher level, then the overall performance will be at the higher level as well and it can be defined as a limiting factor in the differentiation between elite athletes and recreational sports participation (Bahill & La Ritz, 1984).

In table tennis serve, time of ball flight is approximately 800ms, which the opponent has to select an appropriate trajectory for the racquet based on the information

available early in ball flight (Rodrigues et al., 2002). As a result, it is essential for visual systems to function at advanced level because player's performance depends on the information that he or she received from the environment.

Visual location assessment can be pertaining to perceptual skills, for instance detecting the presence of a ball in briefly presented sport scenes (Allard & Starkes, 1980), making efficient search for relevant and informative parts of the opponent's body and fields (Abernethy & Russell, 1987; Goulet et al., 1989; Williams et al., 1994), or anticipating the ball direction and the opponent's action from advance information (Abernethy, 1990; Jones & Miles, 1978; Williams & Aavids, 1998). As such a table tennis player with advanced sensory visual ability has the luxury of increased time to react to the visual stimulus before it has occurred thereby reducing the overall reaction as well as movement time during the game.

III. Materials and Methods

3.1. Participants

The statistical samples are included 18 semi-experienced table tennis players (18 to 30 years old) from Seoul National University table tennis club and Nukdu Gari club were volunteer to serve as subjects. Samples are state and university level table tennis players of different states in South Korea, free of lower extremity injuries. Subjects was randomly assign to two groups, experimental and control group.

3.2. Task

In order to perform the experiment, this study used a smart table tennis device for experiment group, which includes the ping pong auto ball service machine integrated with a system to illuminate a specific area of the table before the ball is projected to the player and consequently the player needs to identify the dropped position and react as quickly as possible to send the ball to the target area. In this method, there is eight targets area of 40x40 squares and in every sequence of ball projection, one of these targets (1 to 8) will be shown randomly before the ball projected to the player. The training method includes six sets of two minutes trial for each player at every training season in which the player should try to send the ball to the shown target areas for two continues minutes using forehand and backhand stroke. Control group using the same training protocol but without target

illumination system by using only ping-pong auto ball service machine. Therefore, subjects in control group, do not need to make a decision to where to send the ball to and they are free to choose the area of other side of table to send the ball. The ball

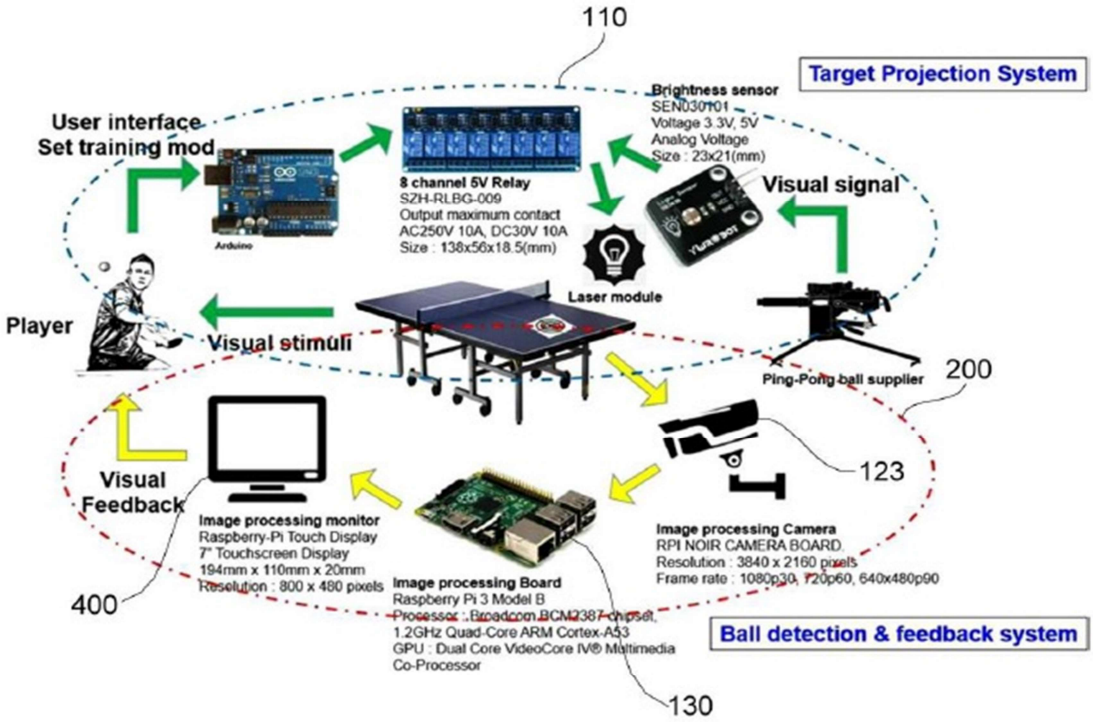

Figure 1.The smart table tennis trainer device and it components

service machine discharged 40+mm balls at frequency of 60 balls per minute during training and test of both control and experiment group.

3.3. Apparatus

The experiment will be performed on a standard table tennis table (Champion S33). For experimental group a smart table tennis trainer device installed which is

consists of piezo vibration sensor on one side of the ping pong table will be able to trace the landing points of ball including an electrical training board which guides the LED lights to point out the intended landing points of the returned ball. Illumination of the table by giving information to the system can indicate the landing point of returned ball by lightening the ping-pong table using LED lights. Before balls are thrown by the pingpong auto ball training machine, the LED lights indicate any of the target zones (1 to 8) randomly. And for control group only using auto ball training machine, model Y & T 989.

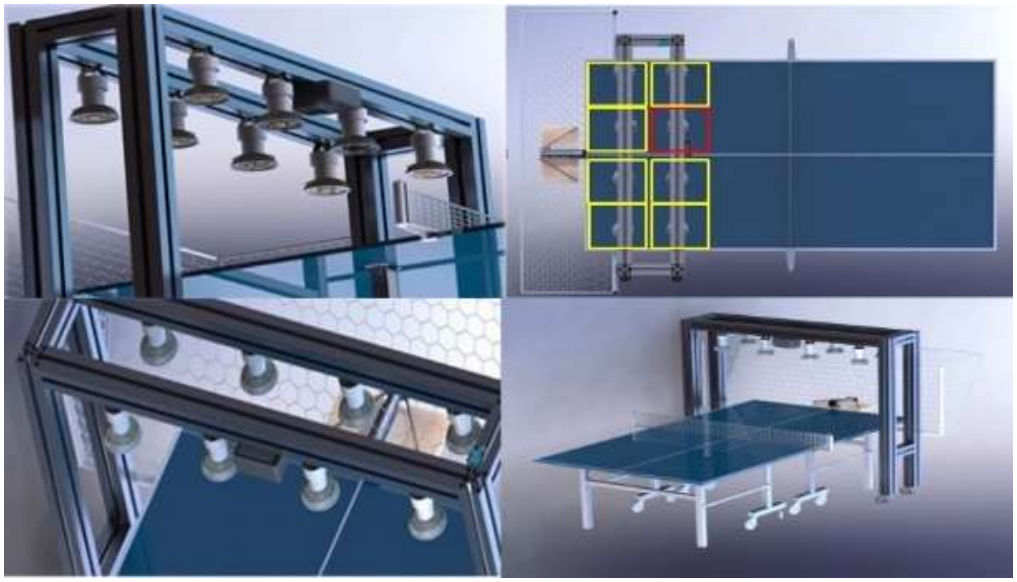

Figure 2. Smart table tennis trainer device 3D design and target area

3.4. Assessment

Pre-test, post-test and retention-test data from following parameters was collected to indicate the improvement level of reaction time, decision making, performance accuracy and three different level of decision making together with accuracy of table tennis players. The retention-test was conducted 7 days after the post-test for every subject.

3.4.1. Reaction Time Test

The choice reaction time was measured using Reaction Timer F3, A1 for dominant side. The distance from the stimulating light to the subject's eyes was fixed to about 55-cm. In this study, the subjects pressed a button from three different buttons (yellow, green, red) as soon as one of the pair color light randomly turns on with the index finger of their dominant hand.

Figure 3. Reaction timer, model F3-1A.

3.4.2. Accuracy Test

Accuracy test using a 30-trials drill by smart table tennis device, which requiredthe participants to direct balls using forehand top spin which is classical stroke (Mala, al. 2014) in the modern offensive game, in the same order to the target areas from one to eight. Every target (40x40) was shown to the subjects by the LED light in sequence, start from one to eight. Each successful attempt awarded one point and because the test comprised of 30 attempts, the participants awarded a maximum

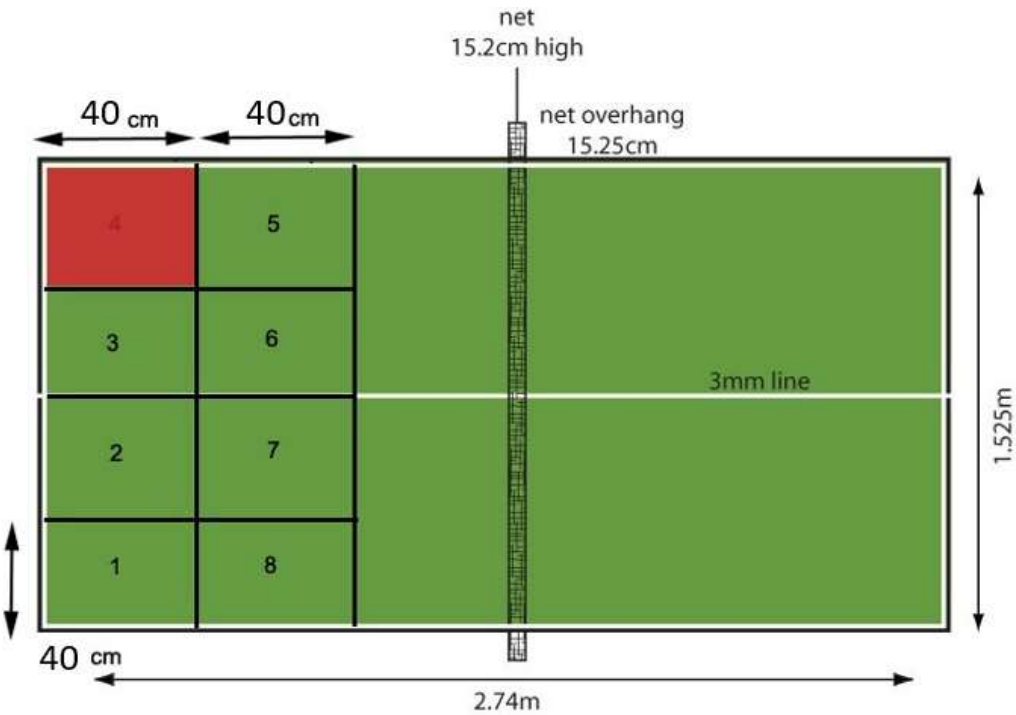

Figure 4. Accuracy test and targets order, subjects should hit the target from one to eight in sequence order.

score of 30 points in the test. In addition, the smart table tennis device demonstrated the result of missing and successful execution.

3.4.3. Decision Making Test

In order to perform the assessment, two square targets (40cm× 40cm) on the left and right end of one side of table was randomly shows to the player on the same side as the ball server. During the test subjects aimed to send the ball to either right or left squares on the table depending on which square shows at the time that the ball is sent to them. A 20- trials stroke, participants required to direct the balls to the right hand target or to the left hand target (square 2). The test of every subject was recorded by Sony full HD 1080 camera and the intention of the subjects were scored by observer. The test was assessed by totaling the number of correct

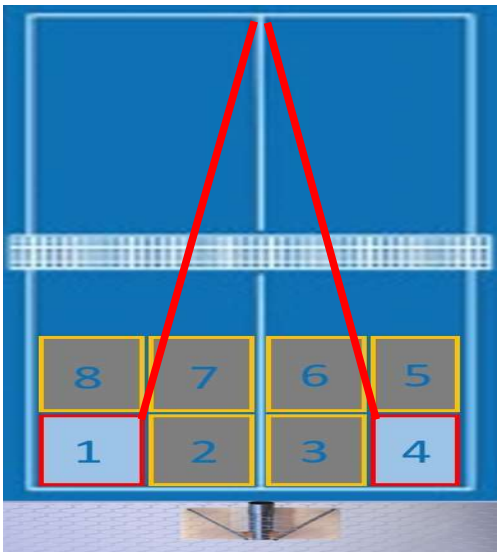

Figure 5. Two lines were applied by Premier Adobe to the video record to make it easier for the rater to score the subjects according to the ball fly direction.

intention of sending ball despite position of landing point in response to visual signal of right or left side of the table which selected in random order. Each

successful attempt in terms of intention of ball direction awarded one point and because the test comprised of 20 attempts, the participants awarded a maximum score of 20 points in the test.

3.4.4. Decision Making and Accuracy Test

1. Decision Making and Accuracy Level one

In order to perform the assessment similar to the decision making test two square targets of (40cm× 40cm) on the left and right end of one side of table was randomly shown to the participants on the same side as the ball server. During the test, subjects aimed to send the ball to the right or left squares on the table depending on which square shown at the time that the ball is sent to subject.

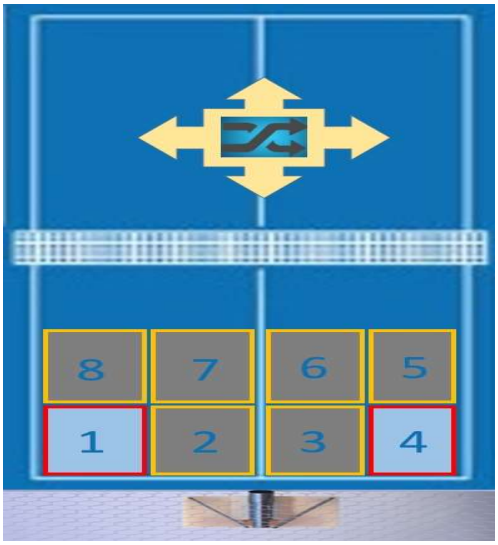

Figure 6. Decision making together with accuracy level one marked area on the side of the table opposing the subjects. The two sides on the right and left used in the test.

In 20-trials stroke, participants required to direct the balls to the right target (square 1) or left target (square 2). Each successful execution of hitting the target which was dedicated by the smart table tennis machine was awarded one point and because the test comprised of 20 attempts, the participants would be awarded a maximum score of 20 points in the test.

2. Decision Making and Accuracy Level two

Second test using a 30-trials drill by smart table tennis device, which require the participants to direct balls using forehand stroke in a totally random order to one of the eight target areas. Each successful attempt awarded one point and because the test comprised of 30 attempts, the participants awarded a maximum score of 30 points in the test. At the end of each trial, the smart table tennis device demonstrated the result of missing and successful execution.

3. Decision Making and Accuracy Level three

The third test used Y & T 989 ping pong auto ball service machine on one side of the table which discharged 40+mm balls at frequency of 60 balls/min. 100 balls (50 white and 50 yellow balls) placed in the ball storage hopper and prior to each experiment, the balls would be mixed thoroughly to ensure random discharge. A Sony full HD 1080 video camera recorded participant's performances and to determine ball landing points.

Figure 8. Sony full HD 1080

Figure 7. Auto ball training machine model Y & T 989.

In order to perform the assessment, six large squares (50 cm× 50 cm) was marked in two rows on the same side as the server. The left and right side square in the row nearest to the table tennis ball server device housed a smaller square (25 cm × 25

Figure 9. The decision-making test setting. Marked area on the side of the table opposing the subjects. The targets number one and two sides on the right and left used in the test.

cm) to indicate the optimum landing point. During the practice for experiment group, subjects aimed to send the ball to the right or left smaller squares on the table depending on the type of decision-making involved (white-right and orange-left). A 20-trials stroke, participants required to direct white balls to the right-hand target (square 2) and yellow balls to the left-hand target (square 1). Between 0 to 3 points awarded according to the landing point of the ball. For example, if a ball had to be directed to the number 1 target earned 3 points and 2 points awarded if it landed into another part of square number 3.

Only 1 point awarded if it landed on squares 5, 6 or 7. Zero scores would be awarded to balls landing outside the designated areas. Because a test comprised of 20 attempts, the participants awarded the maximum score of 60 points in each test.

The research method is semi-experimental. Each participant assigned to either the visual stimuli training condition (experiment group) or the control training condition(control group), using random sampling. The experiment was a 3 (measuring point) x 2 (group) design. These three different measuring points consisted of pre-test, post-test and retention-test at intervals of five weeks. The reaction time, decision making and accuracy of performance result assessments was administered prior to training and immediately after the final training session and again 7 days after the post-test time.

All subjects usher, not to do any lower extremity agility and reaction time programs during the period of the five weeks study and ushering to do only performing activities of normal daily training. The five weeks table tennis apparatus training program developed using two training sessions per week and each season 60 minutes.

Table 1. Training program for each group.

Mode	Type	Time	Frequency
Warm-up	Stretching	10 min	
Experiment group (Smart table tennis trainer device)	• Forehand • Backhand • Forehand & backhand topspin	40min (Each participant train for 6 trials of 2 minutes with device and the rest, each subject train normal backhand & Forehand training with his partner)	2 times/week

Control group (Auto ball training machine)	• Forehand • Backhand • Forehand & backhand topspin	40min (Each participant train for 6 trials of 2 minutes with device and the rest, each subject train normal backhand & Forehand training with his partner)	
Cool-down	Stretching	10 min	

3.5. Data analysis

Statistical analyses were performed with SPSS 16.0 (SPSS Inc. Chicago, IL). Descriptive statistics were mean, standard deviation (± SD) and variability. Before each statistical analysis, the normal distribution of the population was tested with Shapiro–Wilk test and the homogeneity of variances was verified with Bartlett's test. A repeated measures ANOVA was used to determine if there was a learning factor associated with the repeated fractionated among all the tests measurements.

A series of 6 two-factor univariate analysis of variance (ANOVA) with repeated measures on both within subject independent variables (group; measuring point) were run to examine the effects on accuracy, decision making, reaction time, and three different level of decision making together with accuracy tests. The Duncan--Waller post--hoc test was used for multiple comparisons amongst groups. The pair--wise comparisons were adjusted by Bonferroni correction. Significance level was set to $P< 0.05$ for all analyses.

IV. Result

4.1. Accuracy Test

In accuracy test maximum score of 30 points was taken as the dependent variable in the learning phase in response to different training program as independent variable. The test was assessed by totaling the number of correct response to the correct targets bounce which was provided by the machine.

Table 2. Descriptive statistics (Mean+ Standard Deviation) of accuracy test.

Intervention	Group	Mean± SD
Pre-Test	**Control**	7.88 ±3.72
	Experiment	9.60 ± 5.6
Post-Test	**Control**	9.75 ±4.56
	Experiment	18.30±5.72
Retention-Test	**Control**	10.25±4.60
	Experiment	16.50±5.60

A 3 measuring point (Pre, post, retention test) x 2 groups (Experiment and Control) ANOVA on accuracy revealed a significant interaction effect between measuring point and group $F(2, 16) = 13.280$, $p < 0.000$, a significant main effect on

measuring point $F(2, 16) = 36.633$, $p < 0.000$, and a significant main effect on group $F(1, 16) = 5.760$, $p < 0.029$.

Table 3. The data presented represents accuracy, Two-way measure ANOVA test.

Source	df	F-Value	P-value
Intercept	1	110.184	.000
Group	1	5.760	.029
Measuring Point	2	36.633	.000
Measuring Point X Group	2	13.282	.000

P < .05*

Follow-up pairwise t-test on accuracy the intervention group showed a significant improvement from pretest to posttest $p < 0.000$ and from pretest to retention test $p < 0.000$. The participants in experiment group improved their accuracy at sending the ball to correct part of table in comparison to the baseline measurement (pretest). A pairwise t-test on accuracy of the control group showed no significant differences from pretest to posttest $p = 0.447$ and from pretest to retention test $p = 0.299$. The participants in control group didn't have significant changes in regards to accuracy test.

Table 4. Accuracy post hoc test

Control group				Experiment group	
(I)Sequence	**(J)Sequence**	**Mean change**	**P-value**	**Mean change**	**P-value**
Pre-test	Post-test	1.87	0.447	8.7	.000*
	Retention-test	2.37	0.299	6.9	.000*
Post-test	Pre-test	1.87	0.447	8.7	.000*
	Retention-test	0.5	.948	-1.8	.106

P < .05

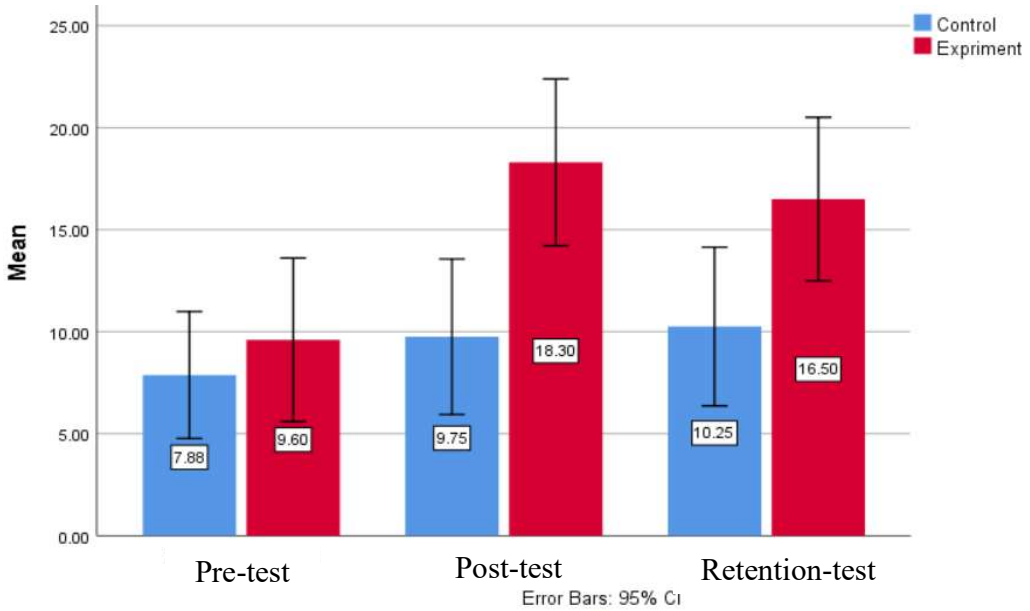

Figure 10. Accuracy test during all three measuring points of both groups.

4.2. Decision Making Test

In decision making test maximum score of 20 points was taken as the dependent variable in the test in response to different training program as independent variable. The test was assessed by totaling the number of correct intention of sending ball despite of accuracy of landing point in response to random visual signal of right or left side of the table.

Table 5. Descriptive statistics (Mean+ Standard Deviation) of decision making.

Intervention	Group	Mean± SD
Pre-Test	**Control**	14. **1** ±3.4
	Experiment	14.0 ±3.4
Post-Test	**Control**	14.4±3.2
	Experiment	15.3±3.2
Retention-Test	**Control**	14.4±3.6
	Experiment	14.9 ±3.5

A 3 measuring point (Pre, post, retention test) x 2 groups (Experiment and Control) ANOVA on accuracy revealed a no significant interaction effect between measuring point and group $F(2, 16) = .471$, $p = 0.629$, not significant main effect

on measuring point F(2, 16) = 1.086, p = 0.350, and not significant main effect on group F(1, 16) = .090, p = 0.769.

Table 6. The data presented represents decision making, Two-way measure ANOVA test.

Source	df	F-Value	P-value
Intercept	1	386.646	.000
Group	1	0.090	.769
Measuring Point	2	1.086	.350
Measuring Point X Group	2	.471	.629

P < .05*

Follow-up pairwise t-test on decision making the intervention group showed no significant improvement from pretest to posttest p < 0.640 and from pretest to retention test p < 1.000 The participants in experiment group couldn't improve their decision making. A pairwise t-test on decision making of the control group showed no significant differences from pretest to posttest p = 1.000 and from pretest to retention test p = 1.000. The participants in control group also remained similar across all three measuring points with regard to the reaction time.

Table 7. Decision making post hoc test

Control group				Experiment group	
(I)Sequence	**(J)Sequence**	**Mean change**	**P-value**	**Mean change**	**P-value**
Pre-test	Post-test	0.25	1.000	1.30	.604
	Retention-test	0.25	1.000	1.9	1.000
Post-test	Pre-test	0.25	1.000	1.30	.604
	Retention-test	0.00	1.000	-0.52	.928

P < .05*

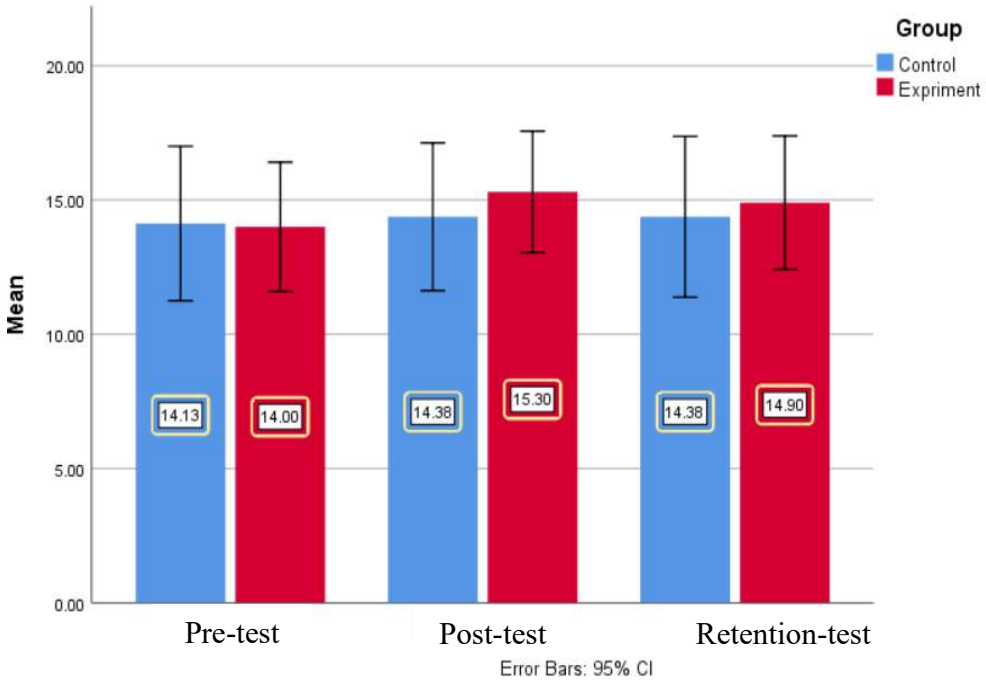

Figure 11.Decission making test during all three measuring points of both groups.

4.3. Decision Making and Accuracy Level one test

In decision making and accuracy level (1) test maximum score of 20 points was taken as the dependent variable in the learning phase in response to different training program as independent variable. The test was assessed by totaling the number of correct response to the accurate right or left targets bounce which was in response to random visual signal of right or left side of the table. The score of every subject was provided by the device feedback system.

Table 8. Descriptive statistics (Mean+ Standard Deviation) of decision making and accuracy level one.

Intervention	Group	Mean± SD
Pre-Test	**Control**	3.4±.5
	Experiment	3.3 ±1.4
Post-Test	**Control**	3.8±1.4
	Experiment	6.8±1.7
Retention-Test	**Control**	4.2±1.0
	Experiment	6.4 ±1.7

A 3 measuring point (Pre, post, retention test) x 2 groups (Experiment and Control) ANOVA on decision making and accuracy level (1) revealed a significant interaction effect between measuring point and group $F(2, 16) = 17.673$, $p < 0.000$,

a significant main effect on measuring point $F(2, 16) = 38.634$, $p < 0.000$, and a significant main effect on group $F(1, 16) = 9.140$, $p < 0.008$.

Table 9. The data presented represents decision making and accuracy level one, Two-way measure ANOVA test.

Source	df	F-Value	P-value
Intercept	1	286.556	.000
Group	1	9.140	.008
Measuring Point	2	38.624	.000
Measuring Point X Group	2	17.673	.000

P < .05*

Follow-up pairwise t-test on the test intervention group showed a significant improvement from pretest to posttest $p < 0.000$ and from pretest to retention test $p < 0.000$. The participants in experiment group improved at making decision on where to send the ball between right or left targets (2 targets) compare to the baseline measurement (pretest). A pairwise t-test on accuracy of the control group showed no significant differences from pretest to posttest $p = 0.682$ and from pretest to retention test $p = 0.123$. The participants in control group didn't have significant changes in regards to decision making and accuracy level (1).

Table 10. Decision making and accuracy level one post hoc test

Control group				**Experiment group**	
(I)Sequence	**(J)Sequence**	**Mean change**	**P-value**	**Mean change**	**P-value**
Pre-test	Post-test	0.5	.682	3.5	.000*
	Retention-test	0.37	.123	3.1	.000*
Post-test	Pre-test	0.5	.682	3.5	.000*
	Retention-test	0.87	1.000	-0.4	.504

P < .05*

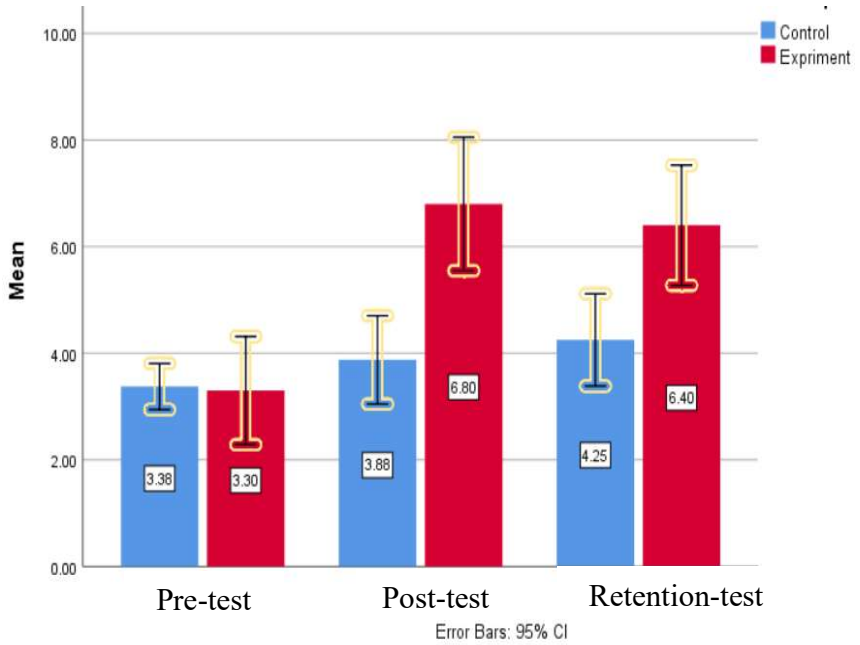

Figure 12. Decision making together with accuracy level one test during all three measuring points of both groups.

4.4. Decision Making and Accuracy Level two test

In decision making and accuracy level (2) test maximum score of 30 points was taken as the dependent variable in the learning phase in response to different training program as independent variable. The test was assessed by totaling the number of correct response to the accurate target bounce which was in response to visual signal of 8 different targets of the table. The score of every player was provided by the device feedback system.

Table 11. Descriptive statistics (Mean+ Standard Deviation) of decision making and accuracy level two.

Intervention	Group	Mean± SD
Pre-Test	**Control**	6.5±2.3
	Experiment	6.5 ±1.3
Post-Test	**Control**	7.1±1.8
	Experiment	9.8±2.7
Retention-Test	**Control**	6.6±2.7
	Experiment	9.6 ±2.5

A 3 measuring point (Pre, post, retention test) x 2 groups (Experiment and Control) ANOVA on decision making and accuracy level (2) revealed a significant interaction effect between measuring point and group $F(2, 16) = 13.282$, $p < 0.024$,

a significant main effect on measuring point $F(2, 16) = 36.633$, $p < 0.003$, and no significant main effect on group $F(1, 16) = 5.760$, $p = 0.051$.

Table 12. The data presented represents decision making and accuracy level two, Two-way measure ANOVA test.

Source	df	F-Value	P-value
Intercept	1	110.184	.000
Group	1	5.760	.051
Measuring Point	2	36.633	.003*
Measuring Point X Group	2	13.282	.024*

P < .05*

Follow-up pairwise t-test on the test intervention group showed a significant improvement from pretest to posttest $p < 0.020$ and from pretest to retention test $p < 0.037$. The participants in experiment group improved at making decision on where to send the ball among 8 different targets compare to the baseline measurement (pretest). A pairwise t-test on accuracy of the control group showed no significant differences from pretest to posttest $p = 0.837$ and from pretest to retention test $p = 1.00$. The participants in control group didn't have significant changes in regards to decision making and accuracy level (2) test.

Table 13. Decision making and accuracy level two post hoc test

Control group				**Experiment group**	
(I)Sequence	**(J)Sequence**	**Mean change**	**P-value**	**Mean change**	**P-value**
Pre-test	Post-test	0.63	.837	3.3	.020*
	Retention-test	0.13	1.000	3.1	.037*
Post-test	Pre-test	0.63	.837	3.3	.020*
	Retention-test	-0.5	1.000	-0.2	1.000

P < .05*

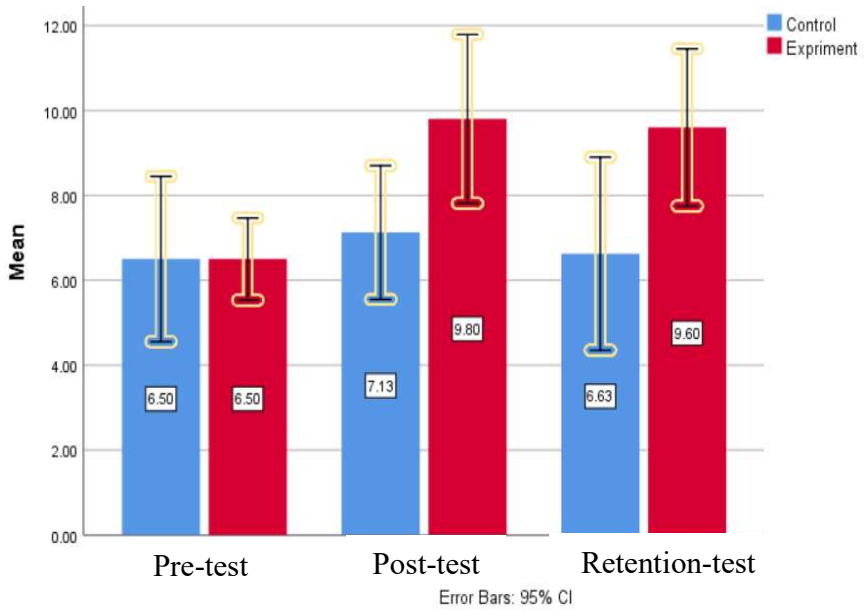

Figure 13. Decision making together with accuracy level two test during all three measuring points of both groups.

4.5. Decision Making and Accuracy Level three test

In decision making and accuracy level (3) test maximum score of 60 points was taken as the dependent variable in the learning phase in response to different training program as independent variable. The test was assessed by totaling the number of correct response to the accurate target bounce which was in response to two different color of ball sending it to the right or left targets. The score of each player was calculated by calculator.

Table 14. Descriptive statistics (Mean+ Standard Deviation) of decision making and accuracy level three.

Intervention	Group	Mean± SD
Pre-Test	**Control**	27.7±7.1
	Experiment	27.2 ±5.5
Post-Test	**Control**	32.4±8.1
	Experiment	40.9±7.8
Retention-Test	**Control**	30.8±6.9
	Experiment	38.1±6.6

A 3 measuring point (Pre, post, retention test) x 2 groups (Experiment and Control) ANOVA on decision making and accuracy level (3) revealed a significant interaction effect between measuring point and group $F(2, 16) = 10.68$, $p < 0.000$,

a significant main effect on measuring point $F(2, 16) = 40.75$, $p < 0.000$, and no significant main effect on group $F(1, 16) = 2.691$, $p = 0.120$.

Table 15. The data presented represents decision making and accuracy level three, Two-way measure ANOVA test.

Source	df	F-Value	P-value
Intercept	1	452.922	.000*
Group	1	2.691	.120
Measuring Point	2	40.75	.000*
Measuring Point X Group	2	10.68	.000*

P < .05*

Follow-up pairwise t-test on the test intervention group showed a significant improvement from pretest to posttest $p < 0.000$ and from pretest to retention test $p < 0.000$. The participants in experiment group improved at making decision on where to send the ball among two different targets in response to different ball color compare to the baseline measurement (pretest). A pairwise t-test on accuracy of the control group showed no significant differences from pretest to posttest $p = 0.116$ and from pretest to retention test $p = 0.366$. The participants in control group didn't have significant improvement in regards to decision making and accuracy level (3) test.

Table 16. Decision making and accuracy level three post hoc test

	Control group			Experiment group	
(I)Sequence	**(J)Sequence**	**Mean change**	**P-value**	**Mean change**	**P-value**
Pre-test	Post-test	4.63	.116	13.7	.000*
	Retention-test	3.13	.366	10.9	.000*
Post-test	Pre-test	4.63	.116	13.7	.000*
	Retention-test	-1.5	1.000	-2.8	.096

P < .05*

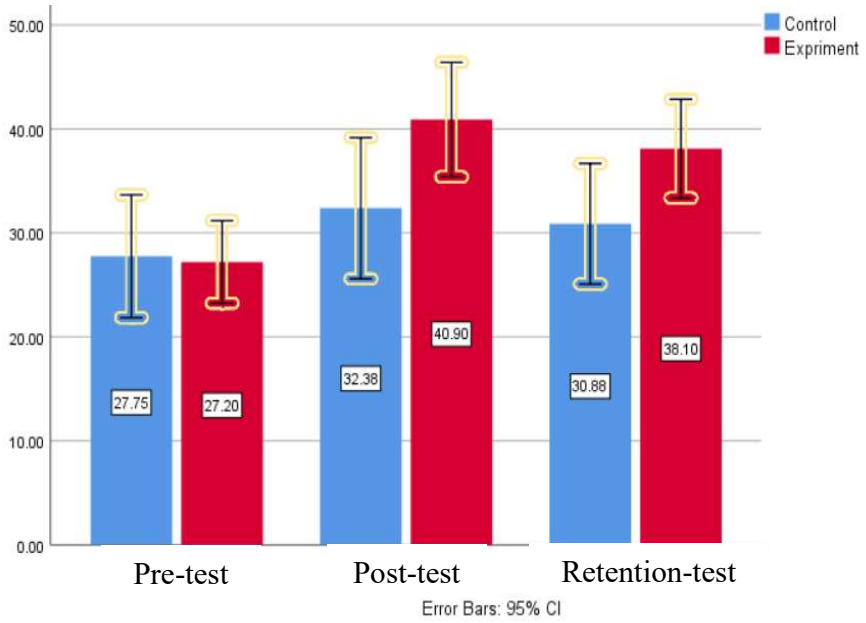

Figure 14. Decision making together with accuracy level three test during all three measuring points of both groups.

4.6. Reaction Time Test

The choice reaction time in milliseconds was taken as the dependent variable in the test in response to different training program as independent variable.

Table 17. Descriptive statistics (Mean+ Standard Deviation) of reaction time test descriptive mean ± SD.

Intervention	Group	Mean± SD
Pre-Test	**Control**	512.6±42.7
	Experiment	534.4 ±89.9
Post-Test	**Control**	490.4±40.3
	Experiment	448.2±55.1
Retention-Test	**Control**	478.9±43.4
	Experiment	448.9 ±56.3

A 3 measuring point (Pre, post, retention test) x 2 groups (Experiment and Control) ANOVA on choice reaction time test revealed the result of very close to significant interaction effect between measuring point and group $F(2, 16) = 3.3$, $p = 0.52$, significant main effect on measuring point $F(2, 16) = 12.25$, $p < 0.000$, and not significant main effect on group $F(1, 16) = .521$, $p = 0.481$.

Table 18. The data presented represents reaction time two-way measure ANOVA test.

Source	df	F-Value	P-value
Intercept	1	19332.3	.000
Group	1	.521	.481
Measuring Point	2	12.25	.000
Measuring Point X Group	2	3.3	.052

P < .05*

Follow-up pairwise t-test on decision making the intervention group showed significant improvement from pretest to posttest $p < 0.037$ and from pretest to retention test $p < .019$ The participants in experiment group improve their choice reaction time in response to the training. A pairwise t-test on decision making of the control group showed no significant differences from pretest to posttest $p = .0460$ and from pretest to retention test $p = .090$. The participants in control group didn't have significant improvement in regards to reaction time test.

Table 19. Reaction time post hoc test

	Control group			Experiment group	
(I)Sequence	**(J)Sequence**	**Mean change**	**P-value**	**Mean change**	**P-value**
Pre-test	Post-test	-22.25	.460	-86.2	.037*
	Retention-test	_33.76	.098	-85.5	.019*
Post-test	Pre-test	-22.25	.460	-86.2	.037*
	Retention-test	-11.51	1.000	0.7	1.000

P < .05*

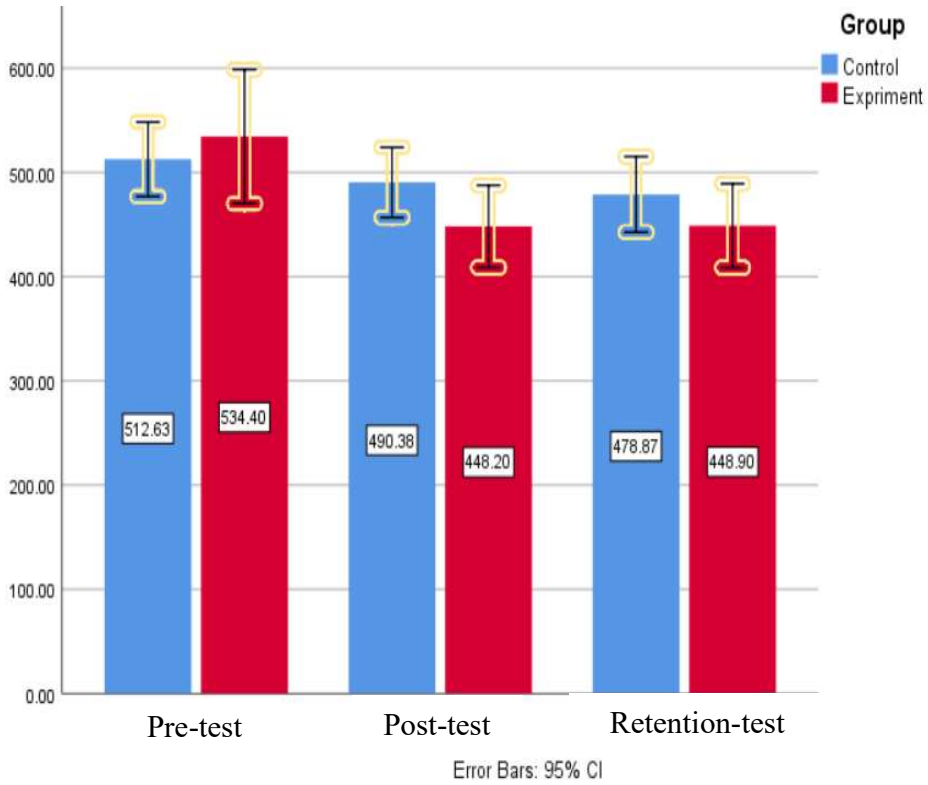

Figure 15. Reaction time test during all three measuring points of both groups.

I. Discussion

This study was a novel attempt to determine if visual stimuli training can improve the performance of table tennis player or not as well as to find out which component of the motor skills leads to the execution improvement. The result indicates not all components of the performance are trainable at least for five weeks of visual stimuli training. It was seen that the mean choice reaction time and accuracy improved significantly in visual stimuli training group but not in control group. Despite that there was no significant difference in mean decision making test between pre-test, post-test and retention-test for either group. However, significant improvement in mean accuracy together with decision making test of all three level tests was also seen only in visual stimuli training group but not for control group although the effect size getting smaller by number and different type of visual stimuli. Finally, this study found that the improvement effect last at least for seven days after the visual stimuli training stopped. The frequency of the ball throwing machine was set during the test procedure and training according to the previous literature that found optimal time for table tennis player's decision making was one ball per second (Moradi et al., 2014). The length of the training was similar with the study that train reactive agility each session lasted approximately 15 minutes per player (Serpell et al., 2011).

Previous literatures found that the accuracy demand of a response affects both response programming and response execution. Moreover, reaction time and pre motor time will increase as constraints on movement increased (Chen & Cauraugh. 1989; Sidaway, 1991; Sidaway et al. 1990). And in another study Szymanski (1997) found in an experiment that accuracy was improved in the groups that trained to change between different targets and different movements compared to a control group (both same target and same movement). Therefore, it is reasonable to assume that by training to limiting the available time for table tennis player to change the direction of sending ball into a different specific area in response to different visual stimuli in a random order leads to performance improvement. This type of training will reduce the performance cost associated with the need for additional time for action preparation of the athlete to constrain his or her limb to move within spatial constraints imposed by small target while making decisions. This notion is supported by Sidway et al., 1995 who found in an experiment that trying to hit relatively smaller target increased programming time because the person has produced a more constrained movement pathway throughout the response to achieve reaching to the target. Hence accuracy improvement might be a guaranty for performance superiority which require decision making as well. This experiment highlights the importance of considering the accuracy demands of the entire task in sport, especially, if the performer must make a decision that requires an immediate motor response.

Visual sensory input may account for up to 85-90% of the sensory input of an athlete during sport performance (Zupan et al., 2006). By being the first step of information processing, vision shape a critical component of successful performance in sports. The results of different studies also prove that visual skills training can have major impact on sport performance improvement (Kluka et al., 1996, Worrell, 1996). In an experiment in fencing the subjects try to improve their reaction time by visual stimuli training (Electronic Fencing Target Device) during 9 weeks by hitting five targets in random order with an epée after LED lights turned on in every target (Balco et al., 2017). The author reports a significant choice and simple reaction time improvement in the group which train with Electronic Fencing Target. Maman et., al in 2011, shows that five weeks of visual skill training of table tennis player could improve their movement time, choice reaction time and eye hand coordination which in turn are transferable into sports specific performance. Parallel to these claims the results of the present study indicated a significant improvement in visual choice reaction time for the experimental group that use visual stimuli training for 5 weeks. These improvements can be in relation to the hypothesis that frequent training of the visual system might lead to stronger muscle fibers and more efficient neuronal response (Zupan et al., 2006).

The reason why decision making was not improve in this study can be explain in a way that, the speed, difficulty, and effort involved in fast complex movement motor tasks can reduce the energy available for the cognitive component, negatively

impacting decision clarity, and in turn decision accuracy (Grehaigne, et al, 2002 and Henry, et al., 2012). In the other hand Benjamin et al in 2011 found in an experiment that the perceptual and decision making elements of agility can be trained at least in three weeks of training. However, if we would use more complex decision making test in this study it might shows different result in the decision-only test. In an experiment by Poolton et., al in 2006 to find the effect of analogy learning on decision-making in table tennis, participants made more correct decisions when the decision was low in complexity than when it was high in complexity. As a result, when the decisions were low in complexity, no motor performance differences were evident between the two conditions, whereas when the decisions were high in complexity, the performance of participants in the explicit condition deteriorated relative to participants in the Analogy condition. Low complexity test design in this study was used as our decision making and accuracy test level two test only. This test design was used frequently in previous literature as a tools to measure low complexity decision making (Poolton et al., 2006, Master et al., 2008, Moradi et al., 2014). However, this test cannot separate decision making component of the performance and accuracy of player, as the scoring system evaluate performance is based on the place where the ball landed on the table. However, our result in this test was in contrast and show significant different between experiment and control group.

Good eye hand coordination increases the player's ability to perform complex movement, respond effectively to external stimuli and create fluent movement. In relation to table tennis eye hand coordination helps the player in proper positioning of the racquet as well as control the arm velocity and direction of hit (Rodrigues et al., 2002). It has been explained that spatial and temporal depends on coupling of eye and hand as long as the motor reaction relies on visual information (Sailer et al., 2000). As such an individual who can process more visual information in a shorter period and make the proper response will have an advantage in competition (Adam & Wilberg, 1992). However, none of these study measured decision making and accuracy of table tennis player in a separate test to declare the reason of their results. This study therefore concluded a causal relationship between visual stimuli training and performance improvement of players. There may be several ways and reason of benefiting players by visual training program that used in this study. This study is a novel approach to visual stimuli training as we have developed the system for the first time in table tennis and consider accuracy element of performance in our experiment design but the previous research used only video recording or visual skill training in order to impact the perceptual or performance of table tennis player in vision context and also in their experimental design they could not separate the accuracy and decision making element of the performance.

A different explanation for the success of the visual stimuli condition in this experiment may be that athlete adopted a task-switching strategy in a way that

intentionally and selectively switching their attention from the decision making to the motor response to accurately hit the target. However, for task switching to be an effective strategy, the time period between tasks must be sufficient to allow successful processing of the decision, prior to processing of the movement. In the present experiment, the frequency of ball service (60 balls/min) and the time between ball release and ball strike (approximately 450 ms) are likely to have enforced temporal constraints that prevented task switching. Anyhow Moradi et., all also proved that best decisions are not necessarily occur on more available time and table tennis player can also disrupt the decisions with reduction of the ball speed.

It could be argued that improvements in test procedure for the experiment training group were related to the test familiarity. This argument does not account fully for the relative differences between the visual stimuli and control during pre, post and retention-test, as both conditions had the opportunity to adopt such a test procedure. And five out of six tests were different from training program of experiment group. However, random training mode used in training was similar in only one of the accuracy and decision making test level three. And all the other five tests were conducted differently with training procedure of experiment group and all participants were given a familiarization session before testing. This notion is supported by Abernethy et al. who used video clips to train decision making and

also the test procedure of his test was similar of using video clips as well and he argued that because a range of video clips were used and because the clips used in the test differed from those used in training, skills learned were generic and could not be related to test familiarity. Thus, it can be assumed that accuracy and reaction time, and subsequently accuracy together with decision making, improvements in this study were because of generic skill acquisition and not related to test familiarity.

II. Conclusion and Future study

In order to maximize performance, table tennis coaches and athletes alike need to be concerned with the principles that affect reaction time, decision making and accuracy. As mentioned earlier, table tennis would be classified as a reaction sport and players have to not waste any time in extra movements. Table tennis is dynamic and physical games based on speed and agility. Table tennis players can improve their reaction time and decision making which are very critical factors for them by practicing base on previous literature. This illustration would clarify the importance of factors, that decreasing reaction time as much as possible in order to decrease the time that will be required for reacting and maximize the time available to play the ball. Another concern of table tennis coaches is the accuracy of player that makes them able to send the ball to the location of another side of table where it is difficult to be cover by opponent. Based on these requirements of table tennis players, there is verity of equipment and training method have been designed for them to improve their performance. But there was a gap in the recent equipment and methods that player cannot train in combination with special training like changing between different targets and different movements, decision training and choice reaction time response training in order to improve the agility and accuracy of player.

This study developed equipment which concerns players' trained reactions by visual stimuli training. The equipment can illuminate the specific points of the table before balls sent to the player by ping-pong auto ball training machine. The present study examined whether the improvement of reaction time, decision making, and performance accuracy by using new technology could result by exploiting visual stimuli training method or not.

The result of this study shows training to limiting the available time for table tennis player to change the direction of sending ball into a different specific area in response to different visual stimuli, can improve visual reaction time, performance accuracy but not decision making of table tennis player. However, the performance which require both decision making together with accuracy would improve by visual stimuli training and this result shows that improving accuracy might be a guaranty for performance superiority which require decision making as well.

Identifying the mechanism that sets apart the treatment conditions in a totally different environment design is beyond the scope of this study experimental design. Also this study does not give any insight into ability of transferring the skills learnt in a laboratory setting to the field and competition. Identifying the extent to which this can be done is important as reaction time, decision making and accuracy can be influenced by many other factors such as playing conditions, age, sounds, color, level of experience, brightness, etc. Furthermore, as this study has shown that visual

stimuli training for accuracy and decision making is possible, future research should make identification of sources of improvement in kinematic constrain for furthered details into explanation of decision making and accuracy improvement and the cause of error.

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Abstract

Objective: In sports it may be necessary for an athlete to make a decision and execute a movement towards a specific direction with high temporal accuracy. Previous study shows, by reducing or increasing the amount of time between what and how decisions via manipulating ball speed or training to change between different targets in time and movement constrain we can have a major impact on performance. The aim of this study was first to develop visual stimuli training device that able player to change between different targets and different movement training. Second, to investigate whether this training system can actually improve accuracy, reaction time and decision making of athlete after an intervention of five weeks by comparing to a control group with no specific visual stimuli training.

Methods: Eighteen semi-experience table tennis players were randomly divided into 2 groups (control group, n = 8; experiment group, n = 10) and underwent pre-test, intervention, post-test and retention test. The test consisted of accuracy test, decision making test, choice reaction time test and three different level of accuracy together with decision making test.

Results: The result shows significant improvement in choice reaction time test and accuracy test just for the group that use visual stimuli training system and not for control group. But no significant improvement was found in decision making test for either group. However, there was a significant improvement in all three level of

accuracy together with decision making test for only experiment group though the effect size were getting smaller by level of test difficulty.

Conclusion: By training to limit the available time for table tennis player to change the direction of sending ball into a different specific area in response to different visual stimuli, we can improve visual reaction time, performance accuracy but not decision making of table tennis player. However, the performance which require both decision making and accuracy together might improve even if the decision making part of the performance remain the same and this result shows that improving accuracy might be a guaranty for performance superiority that require decision making as well.