DECISION MAKING IN SPORTS: AN INVESTIGATION OF 12- TO 19-YEAR-OLD BASKETBALL PLAYERS IN SINGAPORE

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NATIONAL UNIVERSITY OF SINGAPORE

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This thesis is dedicated to my aunt who passed away on 11 September 2013. Thank you for taking care of me for the past 28 years. I will always remember how you loved, encouraged and supported me all these years. No words can express how much I miss you.

DECLARATION

I hereby declare that the thesis is my original work and it has been written by me in its entirety. I have duly acknowledged all the sources of information which have been used in the thesis.

This thesis has also not been submitted for any degree in any university previously.

Ng Yuwen Stella

1 August 2014

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SUMMARY

Decision making has been a popular research topic across many disciplines. Decision research originated from the mathematical perspective, commonly known as the classical theory of decision making. Yet, it was later realised that the classical theory does not explain human decision making behaviour. This led to the rise of the psychological perspective of decision research, where researchers focused on the contexts and factors that affect human decision making processes.

The main aim of this thesis was to investigate human decision making behaviour in sports scenarios. A rating sheet and a computerized cognitive test were developed for this research study to measure the cognitive fitness of teenage basketball players in Singapore. The five main cognitive components required for decision making in basketball were competitive anxiety, short-term spatial memory, situation awareness, domain knowledge, and learning ability. The participants' basketball performance statistics from their first and last matches of their competitive leagues were also collected and coaches were engaged to provide expert judgement on the participants' decision making performance during basketball games. Results from the rating sheet and computerized cognitive test, as well as the basketball performance statistics were compared with that of the coaches' judgements. In addition, measures of the participants' physical fitness were also obtained. The participants' results during their annual National Physical Fitness Award (NAPFA) test were collected and used as measures of their physical fitness in this research study.

Thus, the effects of physical fitness, cognitive abilities, and experience on actual basketball performance were also evaluated in this thesis.

Our findings showed that the rating sheet for coaches was best able to predict the coaches' selection of the better and poorer decision makers in their teams. Although the computerized cognitive test provided objective assessments of the participants' cognitive abilities, the tools used in the test lacked the sensitivity to distinguish between the junior experts and novices in this experiment. Analysis of the participants' performance statistics showed that the better decision makers had significantly more playing time, attempted points per minute of playing time, and points scored per minute of playing time for both matches.

In recent years, the Direct School Admission (DSA) programme led many schools to conduct trials for the selection of potential athletes for various sports. The task of talent selection has never been easy, especially when the coaches only have a few hours to observe their prospective players. Coaches explained that it would be most useful to be able to identify players with superior cognitive abilities as it is easier to train physical fitness and sports skills. As such, three methods of diagnosing decision making abilities of basketball players were compared in this thesis. It was hoped that this work would be useful for practitioners in identifying youths with good decision making capability and provide insights on diagnosing human decision making performance.

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LIST OF ACRONYMS AND BASKETBALL TERMS

ANOVA:	Analysis of Variance
CSAI-2:	Competitive State Anxiety Inventory-2
DESSY:	Dynamic Environment Simulation System
DSA:	Direct School Admission
GPAI:	Game Performance Assessment Instrument
IRB:	Institutional Review Board
IZOF:	Individual Zone of Optimal Functioning
MLR:	Multiple Linear Regression
NAPFA:	National Physical Fitness Awards
NDM:	Naturalistic Decision Making
SAGAT:	Situation Awareness Global Assessment Technique
SPSS:	Statistical Package for the Social Sciences

Assist:	A pass that leads directly to a basket.
Box-out:	Using one's body to stay between an opponent and the basket and get into a better position for rebound.
Double-team:	The defensive tactic of two players guarding one.
Fast-break:	A play in which a team gains possession and then pushes the ball downcourt quickly, hoping to get a good shot off before the other team has a chance to get back and set up on defense.
Key:	The painted area between the end line and the free-throw line near each basket, outside which players line up for free throws. In the early years, it was key-shaped and has since widened twice to its present rectangular shape.
Lay-up:	A shot with one hand from a point close to the basket, in which a player shoots the ball toward the basket, often off the backboard.
Personal foul:	A violation that is usually due to an illegal contact between two players.
Rebound:	Gather in and gain control of a missed shot; a missed shot that is retrieved.
Shot-clock:	The 24-second clock used to time possessions. A team must attempt a shot that hits the rim within 24 seconds or else it loses possession of the ball.
Steal:	To take the ball away from the opposing team, either off the dribble or by picking off a pass.
Turnover:	Loss of ball, either through an errant pass or dribble or an offensive foul.

(Dictionary.com; NBA.com, 2001)

1 INTRODUCTION

1.1 Research Motivation

In the Oxford Dictionaries (2011), decision is defined as “a conclusion or resolution reached after consideration”, with the focus being on the “action or process” by which the conclusion is reached. Despite this definition, most people tend to judge a decision based on its outcome. However, to study decisions and judge if a decision is indeed ‘good’ or ‘bad’, the nature of the decision making task has to be studied in detail. This should be judged based on the information available and the uncertainties at that point in time, and not on the consequence of the decision (Wickens, 1992a). Therefore, a ‘good’ decision with the highest probability of success can still lead to a ‘bad’ consequence, and likewise, a ‘bad’ decision with the lowest probability of success can still lead to a ‘good’ consequence.

There are two main theoretical perspectives in decision making research and both hold differing assumptions (Mascarenhas & Smith, 2011). Decision research first started from the mathematical perspective where theorists explain decision biases with statistical analysis. As such, researchers in this area believe that statistical modelling can help decision makers to select the optimal choices. This perspective is commonly known as the classical theory of decision making (G. Klein, Orasanu, Calderwood, & Zsambok, 1993). However, it was later realized that the classical theory of decision making does not explain human decision making behaviour. Even in situations where decision makers were taught the classical theory of decision making, it was observed that they rarely apply the knowledge (Mascarenhas & Smith, 2011). Therefore, researchers began to investigate and understand human decision making from a psychological perspective, taking into account the context where the decision is made and the factors that affect decision making processes.

The presence of stress has a large effect on decision making abilities. There are many different types of stressors and they often make decision making a challenge. Such stressors include lack of knowledge, limited time, or even risk to life and property (Field, 1987; G. Klein, Calderwood, & Clinton-Cirocco, 2010; Oppe, 1988). One significant stressor that is often found in decision making situations is time pressure. Decision making under time pressure often leads to other physical (e.g. degraded performance due to lack of sleep), physiological (e.g. increased heart rate or blood pressure) or psychological stressors (e.g. frustration and fear). (G. Klein et al., 1993)

The ability to make good decisions is important to everyone as every individual faces various decision making situations every day. Although most research in decision making focuses on applications with a greater impact, the "scientific study of decision making should have (and could have) applications to all areas of our society" (G. Klein, 1999). One of the possible applications could be in the area of decision making in sports games. In the world of sports, a wide range of cognitive processes associated with human judgment and decision making is involved and people start to make decisions in sports at a much younger age than in situations where there are more impactful outcomes. Thus, the sports arena is a potential laboratory that is appropriate for research in decision making. (M Bar-Eli & Raab, 2006)

Decision making under time stress is also evident in sports where players have very limited time to obtain, interpret, analyze information and decide on their course of action as the situation continuous develops. In most sports games such as basketball, tennis and football, players are faced with a dynamic environment that changes due to external factors or as a result of other players' actions. The results of their decisions can be seen almost immediately. Knowing the results of their action choices quickly is important in the study of decision making as feedback and learning plays a significant role in the human information process model (Bridger, 2009).

1.2 Scope and Flow of Research Work

In this section, the scope of the current work done for this research area is explained. Thereafter, a brief overview describing the organization of this research thesis is presented.

1.2.1 Scope of research work

The research begins with a literature review on human decision making behaviour and its applications in various areas. The literature review includes topics such as:

- Definition of decision making
- Types of research in decision making
- Decision making theories and methodologies
- Studies of the effects of stress in decision making process
- Industries where decision making have been studied

Based on the literature review and findings, a framework to study decision making in sports was proposed. This research framework was then used to investigate the decision making performance of 12 to 19 years old basketball players in Singapore. This study constitutes a main part of this research work.

Lastly, the research contribution, limitations, and recommendations for future work are summarized.

1.2.2 Flow of research work

This thesis consists of nine main chapters. Chapter 1 presents the introduction section which discusses the research motivation for decision making under time stress and the scope of this research work. Thereafter, Chapter 2 describes the literature review on human decision making theories and research applications. In Chapter 3, the research gaps, objectives and questions are explored, while Chapter 4 covers the preliminary case studies and their findings. Chapters 5 and 6 describe the development of the research instruments and the data collection process respectively. Next, Chapter 7 presents the results and analysis of the data collected. Finally, the last two chapters of this thesis cover the discussion (Chapter 8), and conclusion and recommendations (Chapter 9).

1.3 Brief Overview of Published and Submitted Work

Papers that have been published or submitted are summarized below.

- *Paper 1*: The preliminary studies for this research were published in the *Proceedings of the 3rd International Conference on Education and*

Sports Education, April 1-2, 2012, Macau, China. This paper corresponds to Chapter 4 of this thesis.

- *Paper 2*: A further analysis of the preliminary studies and its findings was published in the *Proceedings of the 2nd International Conference of The Southeast Asian Network of Ergonomics Societies (SEANES), July 9-12, 2012, Langkawi, Malaysia*. This paper corresponds to Chapter 4 of this thesis.

- *Paper 3*: An analysis of the effects of ageing on human physical performance using the World Masters Athletics records. This paper was published in the *Proceedings of the 4th International Conference on Applied Human Factors and Ergonomics (AHFE), July 21-25, 2012, San Francisco, United States of America*.

- *Paper 4*: Presents an application of the proposed framework to investigate the decision making performance in teenage basketball players. This paper was published in the *Proceedings of the 9th International Conference on Cognitive Sciences, August 27-30, 2013, Kuching, Malaysia* and in *Procedia – Social and Behavioural Sciences*, 2013, Vol. 97C, pp. 715-722. It corresponds to Chapters 4, 5, 6, 7, and 8 of this thesis.

- *Paper 5*: Describes a more comprehensive application of the complete framework with a partial analysis of the results, comparing the basketball players' cognitive and physical fitness with their basketball performance. This paper was published in the *Proceedings of the World Academy of Science, Engineering and Technology (WASET)*

2013 International Conference on Sport Science, November 28-29, 2013, Malaga, Spain, which corresponds to Chapters 4, 5, 6, 7, and 8 of this thesis.

1.4 Conclusion

Decision making is an important cognitive function as everyone faces various decision making situations every day. Early decision research focused on the mathematical aspect, resulting in the development of many statistical models and tools to help guide decision makers towards the optimal choices. However, it was observed that most people do not make use of these models and tools when making decisions. As such, researchers began to turn towards the study of human decision making behaviour, where the situational context is often a significant factor that affects decision making processes.

In particular, stress has a significant impact on human decision making. There are various types of stressors in a decision making situation such as time pressure. Sports provide a suitable ground for the study of human decision making behaviour as athletes face a dynamic environment that constantly evolves. Besides having to deal with various stressors, an athlete also faces many other distractions during the game. In considering situational factors, the concept of naturalistic decision making was proposed. This concept will be explained in Chapter 2.

2 LITERATURE REVIEW

This chapter starts with an introduction of decision making as the main theory of focus in this research proposal. It includes the definition of decision making, the different types of theories and research in decision making, the study of decision making in Ergonomics, decision making under stress, as well as the challenges in decision making research.

The next part discusses the types of research in sports science and a description of some of the cognitive studies that have been conducted in the area of sports. Thereafter, a summary of the literature review is given.

2.1 Decision Making

Decision making is most commonly defined as “the selection of one option from a set of two or more options” (G. Klein et al., 2010). As mentioned in Chapter 1, the decision is analyzed separately from its consequence in the study of decision making. With this, we shall first look at the different types of research being done in the study of decision making.

2.1.1 Different approaches of research in decision making

The study of decision making has been researched in many distinct yet interrelated disciplines (M Bar-Eli & Raab, 2006). A search of the keywords “decision making” in Google Scholar has revealed about 1.24 million articles in areas such as psychology, operational research, social science, management science, computer science, neurology, organizational behaviour and human performance.

G. Klein (1999) discussed the two themes in decision research that was developed by Cohen and Doherty – a formal, mathematical paradigm and a rationalist paradigm. The formal, mathematical paradigm is the classical theory of decision making that considers the probability and value of outcome, while the rationalist paradigm attempts to describe human behaviour in judgment and decision making. The mathematical theme has led to the development of methods that help in breaking down complex decisions and determine the optimal choice, while the rationalist theme has valuable contributions in the areas of training and support to aid the process of decision making. Both themes are complementary and important in the research of decision making. This is especially evident in situations whereby optimal choices are required in human-machine systems (Bridger, 2009).

2.1.2 Decision making and ergonomics

Focusing mainly on human judgment and information processing, the ergonomics perspective of decision making can be classified under the rationalist paradigm as discussed by G. Klein (1999). In the field of ergonomics, decision making is seen as "a complex process…(that) involves seeking information relevant to the decision at hand, estimating probabilities of various outcomes, and attaching values to the anticipated outcomes". Thus, decision making "is at the heart of information processing" (Sanders & McCormick, 1992).

Wickens (1992a) explained why people may not make the best decision with the information that they have on hand by studying the features of the decision making task. When a person is tasked to make a decision, he starts by obtaining some cues from the environment and forms his own perception of this information. Thereafter, he develops his diagnosis of the situation using both his long-term memory and working memory. With this initial diagnosis, the decision maker may then decide to hold back and search for more information or proceed with his choice of action. Figure 2.1 below illustrates how decision making interacts with the other functions of the human information process. From this figure, it can be noted that limitations in any aspect of the human information processing capabilities, such as one's memory or attention span, can affect decision making. Wickens (1992a) also mentioned that limitations in human biases affect one's perceptions and inferences of statistical estimation, which leads to a less than perfect choice of action.

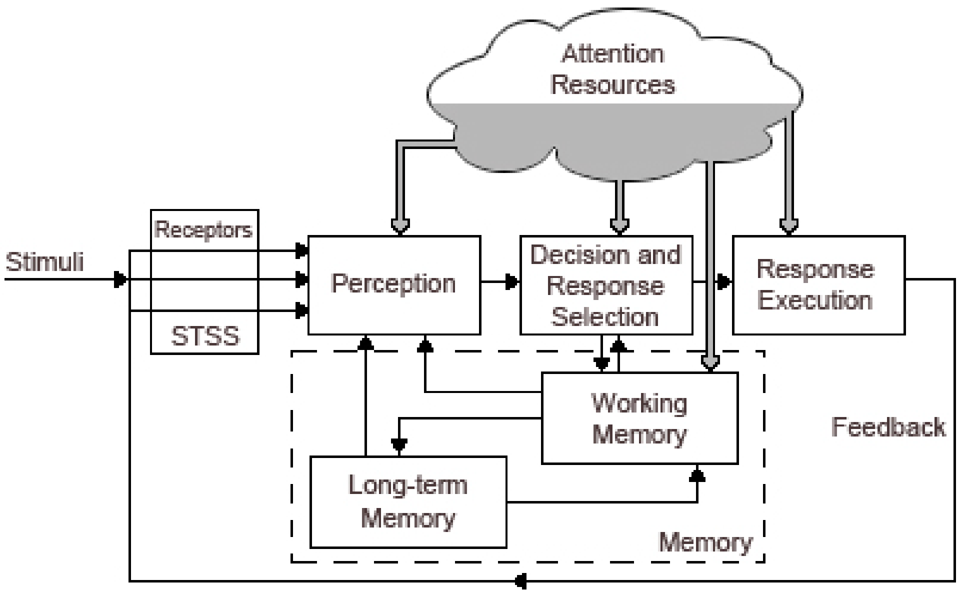

Figure 2.1 A model of human information processing (Wickens 1992, p17)

The information processing model for decision making can be summarized into four broad stages (Bridger, 2009). The first stage is known as the information acquisition stage where the decision maker searches for information and specifies the alternatives. Next, he goes on to evaluate the alternative courses of action. This stage has been greatly researched and there are many models and decision strategies developed for this stage of the decision making process. Once the course of action is decided, he proceeds to the execution stage. Lastly, he reaches the stage of obtaining feedback after the action has been executed. This stage is important as it allows the decision maker to learn and gain expertise in decision making skills. As one gains more experience in decision making, this increase in expertise can affect future decision making processes. There are various benefits and limitations of expert decision making. Wickens (1992a) listed some of the main benefits and biases as shown below.

Benefits

- *Cue sampling*: Due to their huge amount of experience, experts are able to identify and perceive new information more efficiently. Thus, reducing the amount of time needed to understand the situation and decide on their choice of action.

- *Hypothesis and action generation*: With a huge database of possible hypotheses and actions already stored in their long term memory, expert decision makers are able to recognize the patterns and diagnose the problems with less time and effort.

- *Risk and probability calibration*: The increased domain knowledge allows experts to have a better grasp of the actual probabilities of the states and outcomes. As such, they are able to calibrate and make the necessary adjustments to their diagnosis and choices by considering the current risks.

Biases

- *Misleading feedback*: As 'wrong' decision strategies may still lead to good outcomes, and vice versa, experts may be misled by previous experience. Therefore, it is more difficult for an expert to 'unlearn' an inappropriate strategy that was correct by chance.

- *Limited attention to delayed feedback*: Fischhoff observed that experts tended to be overconfident in their forecasting and attributed it to a lack of attention to feedback. He labelled the phenomenon as cognitive conceit.

- *Selective perception of feedback*: In Einhorn and Hogarth's experiment, it was observed that decision makers tend to focus on the number of successes, rather than the probability. Due to a host of factors, this leads to a bias of attention against failures that causes experts to be overconfident of their decision strategies.

- *Selective influence on outcome*: Following on the selective perception of feedback, Einhorn and Hogarth further noted that most decision makers have a vested interest in the success of their decision rules.

In summary, many ergonomics textbooks focus on heuristics and biases in the study of human decision making (Bridger, 2009; Sanders & McCormick, 1992; Wickens, 1992a). By understanding and considering human capabilities and limitations, ergonomists contribute to the study of decision making and suggest methods to assist the decision making process and improve the quality of decisions made. These methods can help to present information in a better way or even pre-processing information to facilitate the decision making process.

2.1.3 Decision making under stress

Stress is a critical influencing factor in the human decision making process. Kowalski-Trakofler, Vaught, and Scharf (2003) defined stress as "a process by which certain work demands evoke an appraisal process in which perceived demands exceed resources and result in undesirable physiological, emotional, cognitive and social changes". There are various stressors in our everyday life and every individual behaves differently in response to similar stressful situations (Lundberg, 1993).

In the paper by Kowalski-Trakofler et al. (2003), some assumptions and key issues regarding the interaction between stress and human decision making were addressed.

- *Stress is affected by perception*: As defined earlier, stress is determined by each individual's perceived demands of the work or situation. However, there are general scenarios which tend to invoke higher stress in most people. For example, uncontrollable events, major disasters, or the unavailability of critical information places a greater stress than minor life events.

- *Competence in judgment is always compromised under stress*: It was noted that increased stress can lead to improved or degraded performance as described by the Yerkes-Dodson law (see Figure 2.2). Various experiments have showed that decision makers under high and low levels of stress use different strategies, but these strategies may not necessarily lower their competence.

- *Stress is related to information*: Poor quality, unclear, and incomplete information often leads to increased stress levels in a decision making situation. This poor information access may be due to technology, communication or even leadership issues.

- *Stress narrows the focus of attention*: It was observed that decision makers tend to focus on the critical issues and display more risk-avoiding behaviour when placed in a situation with high levels of stress. They also offer solutions quicker, without considering all alternatives.

- *Dynamic environments impact on decision making*: Uncertainties in a dynamic environment have significant impact on human decision making behaviour. In dealing with these uncertainties, one has to weigh the costs and benefits of action and non-action. An experiment conducted by Kerstholt shows that decision strategies in a dynamic environment are less adaptive to the ever-changing conditions than what was inferred from the studies of static tasks.

- *Stress affects behaviour in emergencies*: In a study of miners tasked to escape from an underground mine, researchers observed several factors that affect one's ability to solve problems under time pressure. These factors include one's psychomotor skills, knowledge and attitude, quality and completeness of information, stress level experienced, and the complexity of the situation.

- *Laboratory studies versus real-world experiences*: Due to the extent of the life-threatening and dangerous situations in the real-world, it is difficult to simulate a laboratory study that reflects such extreme stress. Therefore, research in extreme stress conditions need to be followed up by assessments of real-life experiences.

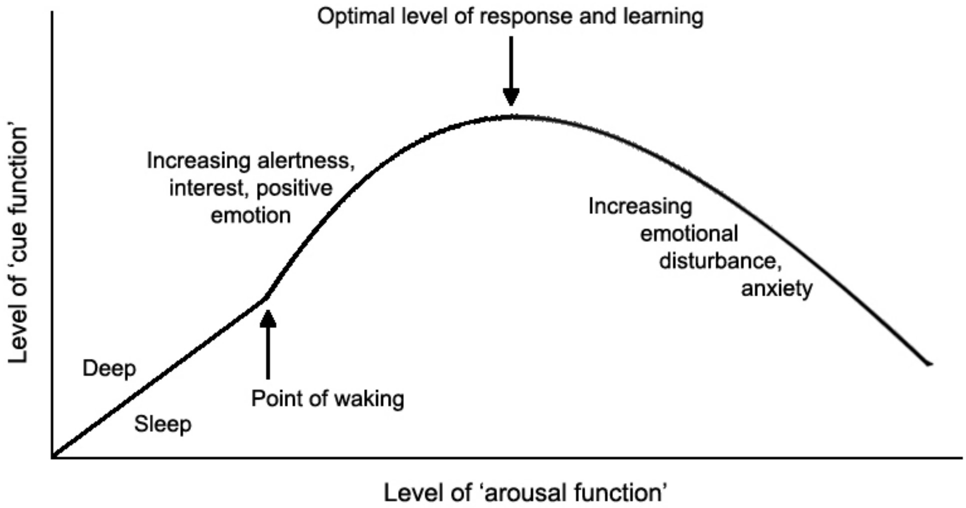

Figure 2.2 Graphical description of the relationship between arousal and performance developed by Hebb in 1955 (Teigen 1994, p533)

G. Klein et al. (1993) introduced the concept of naturalistic decision making (NDM) to understand decision making in the real-world environment. They listed the eight characteristics of NDM as follows:

- ill-structured problems
- uncertain dynamic environments
- shifting/ill-defined/competing goals
- action/feedback loops
- time stress
- high stakes
- multiple players
- organizational goals and norms

Decision makers under stress will experience fatigue and reduced alertness. As such, they tend to look for less complicated strategies to aid their decision making (Orasanu & Connolly, 1993). Mathematical strategies such as the multi-attribute utility analysis are seen as compensatory decision strategies, which are generally very time-consuming. Therefore, in most real life situations, non-compensatory strategies like the dominance structuring strategy or elimination by aspects strategy are used (Svenson & Maule, 1993).

Mascarenhas and Smith (2011) added that the concept of NDM is largely used to distinguish the differences between expert and novice decision makers. They cited the findings of Simon and Chase that “experts perceived the structured display (of chessboard patterns) in terms of highly familiar patterns made up of meaningful chunks of information” in their investigation of chess players. The organized structure of knowledge in experts’ memories enables them to access and retrieve information rapidly under time stress (Tenenbaum, 2003). Besides the ability to structure information more effectively, expert behaviour also showed that the complex interaction between their perception, attention and domain knowledge allowed them to perform better in time-constrained situations.

For a decision to be considered naturalistic, it does not have to feature all eight characteristics of NDM (Orasanu & Connolly, 1993). As such, a naturalistic decision can also be simple. In the investigation of decision making processes of fire fighters (detailed in Chapter 2.2.1.1), G. Klein et al. (2010) explained the recognition-primed model (RPM) which they derived through the study in 1989. Zsambok and Klein (1997) later clarified that this RPM deals more with simple, routine decisions that can be made rapidly and are less conscious to the decision maker. Such decisions can also be explained by Rasmussen’s (1983) model of the three levels of human performance (see

Figure 2.3). In simple, routine decisions, decision makers display skill-based behaviours as they are able to recognize the cues and make the decision without conscious effort. Wickens (1992b) described skill-based behaviours as being the most automated level. He then gave the example of a sufficiently experienced driver intuitively applying the brake in the car when he sees the red light. Therefore, in this simple, routine situation, the driver is able to rapidly make the decision to stop the car and move his leg to depress brake pedal without conscious effort.

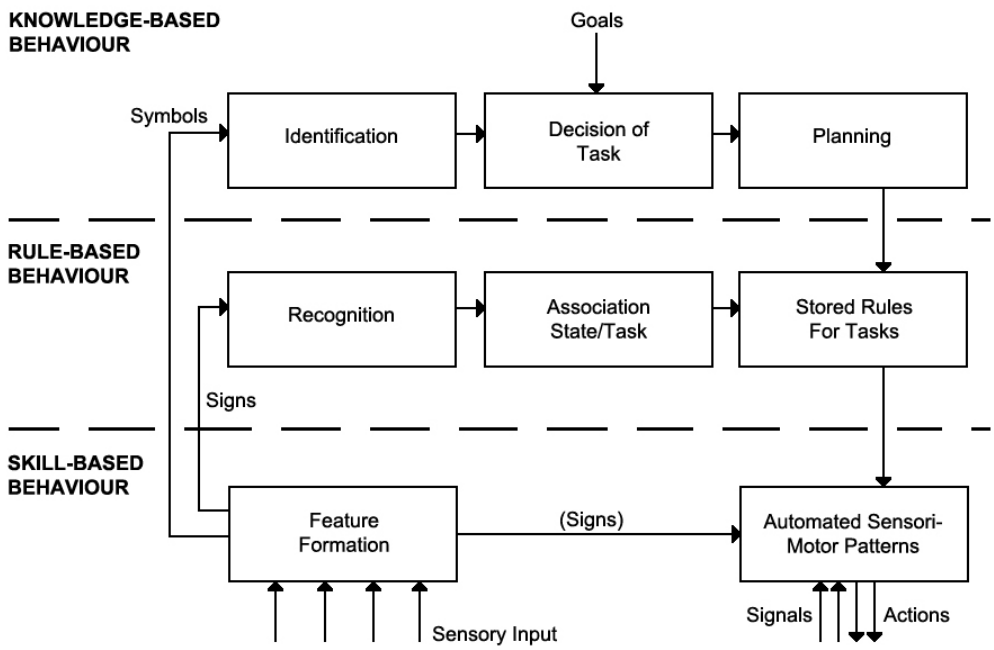

Figure 2.3 An illustration of the three levels of human performance (Rasmussen 1993, p258)

Svenson and Maule (1993) stated that most studies of decision making under pressure “use a ‘cold’ rather than a ‘hot cognition’ framework”, as they did not consider the arousal effect that one experiences under time stress. Thus, in the ‘hot cognition’ framework, emotional and psychobiological reactions to time pressure and their effects on decision making are considered. For example, time pressure tends to increase the level of arousal and psychological stress in the decision maker, causing him to decide before evaluating all alternatives. Also, with high levels of stress, decision makers are more inclined to stick with one problem-solving strategy and minimize their scanning for more information (Edland & Svenson, 1993). Tenenbaum (2003) also demonstrated that the cognitive, emotional and motivational states of expert athletes do have significant effects on their decision making process at high level competitions.

2.2 Sports

There are more than 8000 types of sports games played around the world (Liponski, 2003). Some of these sports are played exclusively by a small group of people while other sports are played by many around the globe. Sports play a significant role in today's world and it is estimated to represent about three per cent of the Gross Domestic Product (GDP) in the Organization for Economic Co-operation and Development (OECD) countries (Henry & Gratton, 2002a). The biggest international sporting event is the Olympics, which takes place once every four years. Currently, it comprises of 41 summer sports and 15 winter sport and 205 countries took part in the latest 2012 London Olympics (Olympic.org, 2013; Olympics, 2012). Due to its great economic benefits, there have been an increasing number of such major sporting events and many countries compete fiercely to host them (Dobson & Sinnamon, 2002). Therefore, there has been an increasing emphasis on sports over the years.

2.2.1 Research in sports

Humans have been participating in sports for hundreds of years and people with strong athletic abilities are often highly valued (Babu, 2009). Therefore, it is not surprising for researchers to be interested in studying sports. In the recent years, increasing research attention has been given to the area of sports. Figure 2.4 shows the number of research articles indexed by Scopus over the past 20 years. 139,206 articles were found using the keyword "sports". Most of these articles were in the area of medicine and health, followed by social sciences, engineering, psychology, genetics, and business management.

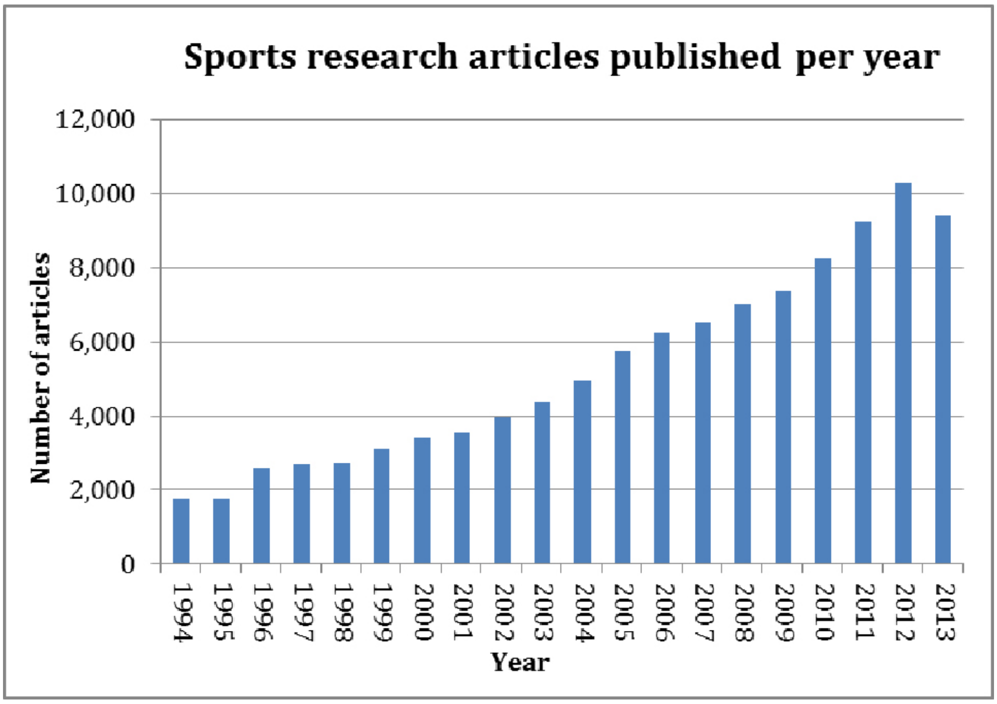

Figure 2.4 Number of sports related articles indexed by Scopus per year up to 28 December 2013

Research in the area of sports medicine and health is extensive as it covers a wide range of topics such as neurology, injury rehabilitation, biomechanics, nutrition, and many more. Most articles tend to focus on sports injuries and treatment processes (Medscape, 2013). On the other hand, social science research investigates the role of sports in society and the political-economic and socio-cultural interactions. Sports engineering and technology is a relatively new research area as the two main research organizations, Sports Engineering Research Group and International Sports Engineering Association, were founded less than 20 years ago. Research in sports engineering and technology uses the application of mathematical knowledge and physics to solve problems in sports, which may include the development of training tools and techniques for coaches and athletes or setting safety standards (ISEA, 2013; SERG, 2013). Sports psychology investigates the psychological factors that affect performance and participation in sports (Weinberg, Gould, & OverDrive, 1995). Major topics within sports psychology include imagery, motivation, and attention focus (Cherry). Sports genetics applies the biological study of genes in the area of sports. Like genetic studies in other areas, sports genetics uses the deoxyribonucleic acid (DNA) of athletes for research (Aschwanden, 2013). Sports business management involves the economic aspect of sports. Research in this area can cover a wide range, from sports tourism to organization management and events management (Henry & Gratton, 2002b).

2.2.2 Decision making in sports

Good decision making skills are required in many sports. Central to the human information processing system, an athlete's decision making performance relies on his or her individual cognitive abilities (Tenenbaum, 2003). The terms 'cognition' and 'psychology' are sometimes confused.

According to the American Psychological Association (APA, 2013), cognition is defined as the "processes of knowing, including attending, remembering, and reasoning; also the content of the processes, such as concepts and memories", while psychology is defined as "the scientific study of the behavior of individuals and their mental processes". Thus, cognitive psychology can be defined as the "study of higher mental processes such as attention, language use, memory, perception, problem solving, and thinking". The study of the human decision making process is a part of cognitive psychology as decision making is an important function of the human information processing system (Wickens, 1992a).

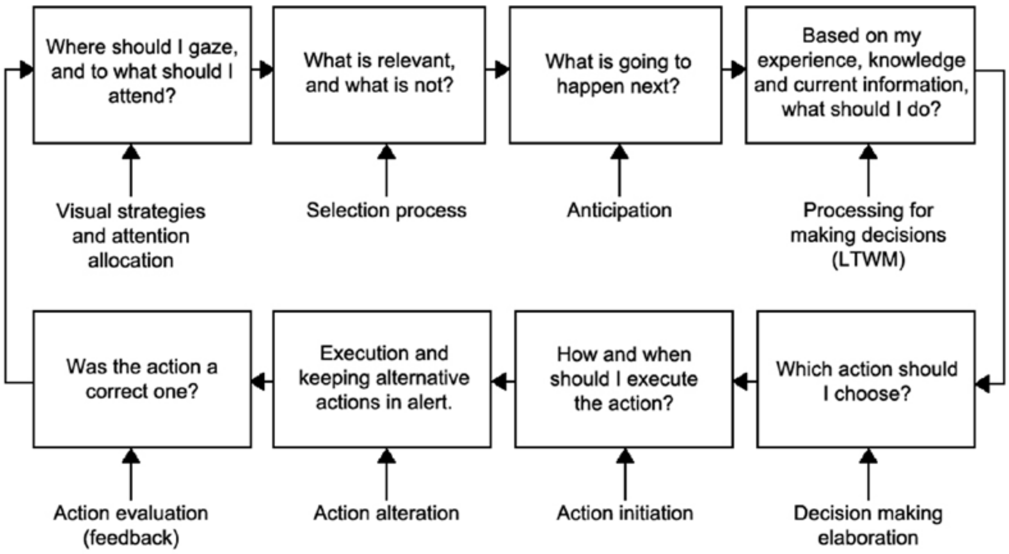

Figure 2.5 A model of the decision making process of athletes developed by Tenenbaum (2003, p195)

Figure 2.5 shows the model developed by Tenenbaum in 2003 to depict the different cognitive functions required in the various stages of the decision making process of athletes in open skill sports. Open skill sports are "performed in an environment which is rapidly changing and in which both perceptual uncertainty and time-constrained decision making are critical features" (Helsen & Starkes, 1999). According to this model, an athlete needs to have good visual strategies, attention allocation, selection process, anticipation, memory, and the ability to elaborate and evaluate in order to make good decisions in sports situations.

Tenenbaum (2003) explained that there are two types of visual strategies – target- and context-oriented. Researchers found that novices tend to use target control strategy where they search the visual field until a target is detected. Thus, only the target and the near areas are attended to. On the other hand, experts who are familiar with the context tend to search with the help of memory representations and are not particularly sensitive to individual objects in the visual field. Therefore, experts who use context control strategy direct their attention to cues in a larger area around their visual fixation point. As such, they shift attention on the basis of the context rather than targets and this allows them to identify the stimulus more quickly. It was also noted that the capacity to allocate attention simultaneously to different locations in the visual field helps to optimize performance. A. M. Williams and Davids (1998) conducted a visual search experiment with 12 experienced and 12 novice soccer players. Using an eye movement registration system, the authors found that the experienced soccer players had higher search rates and better anticipatory skills than the novice soccer players. It was also noted that experienced soccer players spent less time attending to the ball and the ball player and more time on the other areas on display, thus looking more at the "big picture". Singer, Cauraugh, Chen, Steinberg, and Frehlich (1996) also obtained similar results when they tested the visual search patterns, anticipation, reaction, and movement of tennis players using simulated tennis situations in a laboratory setting. In the visual search testing, the novice players were found to have focused more on the head region of the tennis player than the expert players.

The first three steps of Tenenbaum's model are similar to the three levels of situation awareness model developed by Endsley (2000b). Situation awareness is defined as the ability of a person to perceive and understand information surrounding his situation. It comprises of three levels – perception, comprehension, and anticipation – and is a critical factor in decision making (Endsley, 2000b). Therefore, how well an athlete perceives his or her environment depends on his or her visual search strategies and attention allocation, while comprehension of the sport and decision making situation affects his or her selection process.

Besides situation awareness, researchers also found that experts have a memory advantage. K. Anders Ericsson and Kintsch (1995) observed that with domain-specific practice, experts are able to use their long term memory as an extension of their short term memory system. This is done through the creation of efficient retrieval routes that allows the short term memory system to access the long term memory storage with minimal effort. Investigations of tennis players showed that experts are able to focus attention on several cues in the early stages of observing their opponents' actions while novices typically focused only on one cue. However, one study that used an intermediate skill level revealed that players in the intermediate and expert groups made similar anticipatory judgments. It seems to imply that differences between intermediate- and expert-level players may be due to variables other than anticipatory capabilities. In addition, with more experience, expert athletes are more likely to have encountered a similar decision making situation before and thus, are better able to identify information that are more relevant and predict the next scenario more accurately. It was also noted that experts are able to recognize situations that are similar to their prior experience quickly. They are also alert to the changes in the situation and are able to alter their actions even after they have decided.

The ability to attend to several cues at once also allows the experts to be aware of changes in the surroundings even when they are selecting their responses. Therefore, experts' responses tend to be more affected by external factors such as the actions of other players. With this attention advantage in being able to shift attention to valid cues faster, experts require shorter response time and are able to alter their responses very quickly. This provides expert athletes with an edge in open skill competitions as their actions are less predictable and opponents have a shorter time to react to their actions.

Most researchers in human decision research observe that individuals experience arousal when faced with a decision task. Depending on the context, these arousal effects may be physical, psychological or emotional and it is generally agreed that arousal leads to narrowed attention. Abernethy (1993) found that with more practice and greater exposure to stressful, competitive situations, experts have greater tolerance to changes in arousal level. This increased tolerance allows experts to concentrate better and leads to better decision making and response selection. Moreover, Y. Hanin (2003) argued that there exists an emotional zone of optimal performance in sports as athletes psychologically regulate themselves so as to experience the emotions that optimizes their performances. He termed this framework the Individual Zone of Optimal Functioning (IZOF) as “each athlete has (his or) her own optimal anxiety and zones of intensity”. In this sports-specific conceptual framework, Hanin identified five performance-related basic dimensions – form, content, intensity, time, and context. He suggests that this framework offers a complete description of an athlete’s emotional state for better data collection and analysis. However, the IZOF has not been tested in the context of decision making and it will be interesting to note how one’s emotional state affects his or her decision making behaviour (Tenenbaum, 2003).

Lastly, Tenenbaum (2003) discussed how individual motivational and emotional states affects decision making behaviour. Tenenbaum explained that one’s motivational state is a result of his or her self-efficacy, which can facilitate or inhibit performance. Many researchers have conducted various experiments and found self-confidence to be positively correlated with sports performance (Craft, Magyar, Becker, & Feltz, 2003; Parfitt & Pates, 1999; J. Taylor, 1987; Thomas, 1994; Woodman & Hardy, 2003). As experts tend to perceive that they are more competent, they are also more likely to select ‘riskier’ moves as they are more confident of being able to execute them. Besides self-confidence, Janelle (2002) found that increased anxiety alters one’s gaze behaviour and affects one’s visual search strategies. After conducting an experiment to study the relationship between anxiety and the execution of a far aiming task, Behan and Wilson (2008) found that the specific visuomotor strategy needed for skilled and accurate performance, which they termed as the "quiet eye", is sensitive to changes in anxiety and adversely affects accuracy.

In most decision research, decision makers are studied in a controlled, laboratory environment, which may be very different from the decision maker's natural environment. As such, the decision maker's behaviour may differ greatly during the experiment and in an actual situation. G. Klein et al. (2010) first developed the concept of NDM when they observed fire fighters in the field to study their decision making processes in their natural environment. However, Zsambok and Klein (1997) also explained that field studies is not the only methodology for research in NDM. Laboratory experiments that mimic the real-world factors with participants, who take the tests as serious as they do in reality, can also be considered as NDM research.

In a dynamic environment, the decision situation constantly changes. Hence, time pressure can also be experienced due to the constantly evolving situation. Many laboratory experiments that study the effects of time pressure on decision making impose a time limit or deadline for the decision to be made (Edland, 1993; MacGregor, 1993; Stiensmeier-Pelster & Schürmann, 1993; Svenson & Lehman Benson, 1993). These time limits can restrict just the time participants have to obtain information (Edland, 1993) or the total time until the choice of action. In the investigation of time pressure effects, there is usually a control group where participants evaluate the same situations without a time limit. The results of both groups are then compared. Participants were also asked to indicate their perceived stress levels using a scale of 0 (no stress) to 10 (much stress) before and after the experimental session. Kerstholt (1993) explored a different way of simulating a constantly changing environment by developing a computerized test that continuously changes the decision making situation as time passes. The situation surrounding the decision may change by itself or as a result of the decision maker's action. In this experiment, a graph is used to depict the changes in an athlete's fitness level and participants are supposed to prevent the fitness level from reaching zero. Throughout the experiment, the participant can request for more objective or subjective information to determine if a decline in fitness level is a false alarm, or use the information to diagnose the cause of the decline. Then, they can administer the correct treatment to improve the fitness level if necessary. Kerstholt (1993) set different incentive schemes for the participants and studied the difference how they allocated their time between the different decision phases and behavioural indices such as their information requests and treatments chosen.

Macquet and Fleurance (2007) also used the concept of NDM to study the decision making process of badminton players. The research study was conducted using data recorded from competitions and self-confrontation interviews with four badminton players. The interviews were conducted as soon as possible after their game and the players had to explain the decisions behind their actions during the game. From this experiment, it was found that the badminton players continuously assess the environment, even in the midst of making a decision. The players also explained some of the factors of consideration during decision making, which includes time-based factors and competencies of opponent. In instances with high time pressure, the players used more knowledge-based decision making to overcome their lack of understanding and help them to make the most appropriate decision. The study also revealed that players can choose the same action for different intentions. For example, a player may choose a cross-court drop shot to win the game, or to surprise the opponent and influence his decision, or to tire the opponent, or just to learn more about the opponent's competencies. Macquet and Fleurance (2007) explained that the results of this study helped coaches to better understand the cognitive functioning of players during competition and how they can better plan their training to enhance the players' decision making abilities.

2.2.3 Challenges in the research of decision making in sports

Despite being a topic of interest in many disciplines, the study of decision making has always been challenging. Some of the challenges of investigating decision making in dynamic sports situations are discussed below:

- Limitations of research methods

G. Klein et al. (2010) studied the decision making processes of fire fighters by observing them in the field and conducting interviews with them. In this way, they are able to study the fire fighters in their most naturalistic conditions. Yet, it is also understood that there are limitations with observational studies and interviews. One such issue lies with the ability of human subjects in verbalizing their thought processes. Especially when interviews are conducted after the incident, it is expected that some details might have been forgotten.

Zsambok and Klein (1997) also mentioned that field studies is not the only method of research for NDM. Laboratory experiments can also be considered under NDM research if it fulfills the criteria:

- Model simulates the naturalistic environment
- Participants consider the decisions as seriously as they do in the real-world

However, it is not easy to fulfill these two requirements in a laboratory setting. In particular, it is difficult to create decision situations where lives or assets are at stake (G. Klein et al., 2010) as these situations often lead to high levels of arousal in the decision makers. This heightened arousal has a significant effect on one's cognitive functions. (Svenson & Maule, 1993)

Also, there is no standard, objective method of measuring the performance of opponent-based sports such as badminton, football, netball, and taekwondo (Lames & McGarry, 2007). Although there is a standard scoring system in place for these sports, the amount of scores or point obtained in a match is largely dependent on the strength of the opponent. A higher score does not necessarily imply a better performance as it may be due to a weaker opponent. As such, it is difficult to compare performance across games or even amongst the players within the same team (Hughes & Bartlett, 2002). This is especially so in team sports such as basketball. In team sports, players usually specialize in certain roles or positions. For example, the point guard who is a three-point shooter may score the most points, while the forwards who usually run for fast-breaks may have the highest shooting percentage and assists, and the centers may have the most rebounds. Hence, various sports researchers have used formulas that combine several performance measures into a single index to compare players' performances (Barker & Jones, 2008; Sonstroem & Bernard, 1982). Yet, these formulas still lack reliability due to the dynamic nature of these sports (Lames & McGarry, 2007).

– Naturalistic decision making environment is complex

Most real world decision situations are complex as they involve many different pieces of information (Raab, 2003) and not all information is relevant to the decision at hand. Thus, the decision maker has to sieve out the important information for further analysis and evaluation (Bucknall, 2000). For example, players in an actual game has to filter out the noise from the spectators, manage their emotions or emotions of the other players, deal with possible rogue players, and many other distracting sources of information (Mascarenhas & Smith, 2011). As mentioned in the previous point, it is difficult to simulate the actual decision making environment with all the kinds of stressors and information load due to its complexity.

– Exact nature of the interaction between stress and human decision making is unknown

There is no unifying theory that explains the effects of stress on human decision making (Svenson & Maule, 1993). The interaction between stress and the various aspects of human cognition is extremely complicated. Athletes experience different kinds and levels of stressors during competition and these stressors can have different effects on different cognitive functions. Therefore, the resulting variance in decision making performance may be confounded by other interacting factors. Researchers have also found that there are individual differences in the effects of stress in decision making (Rastegary & Landy, 1993). Thus, the same level of stress may cause some athletes to perform worse but enable other athletes to perform better.

In addition, there are different perspectives of time in decision research. Some researchers perceive time constraints as a stressor that decision makers have to overcome and adapt. This heightens their arousal level and increases their cognitive load, which leads to changes in their judgment and decision making. On the other hand, time may also be viewed as a resource. In this case, decision makers are seen as changing their strategies of allocating the limited time in the most effective way. As such, the time constraint can also be perceived as a distraction when decision makers waste precious time and attention on monitoring the remaining time. Therefore, these two perspectives lead to different understanding of how and why decision makers change their decision strategies when faced with varying levels of time pressure (Svenson & Maule, 1993).

2.3 Conclusion

In summary, there are generally two approaches in the study of decision making. The classical theory of decision making has been extensively researched and there are many methods developed to guide decision makers to an optimal choice. On the other hand, behavioural studies suggest that human decision making process differs from the classical theory. This leads to an increasing interest in NDM research (Mascarenhas & Smith, 2011) where researchers study decision makers in their natural setting. There has also been increasing interest in sports in the recent years, but there is still little research in the area of cognition in sports. Thus, it is believed that new insights can be gained by investigating the decision making behaviour of athletes.

3 RESEARCH GAPS, OBJECTIVES AND QUESTIONS

3.1 Research gaps

From the literature review, some research gaps have been identified. The research gaps are presented in this chapter, together with the hypotheses.

3.1.1 Gap 1: Lack of understanding in how the different cognitive components contribute to decision making

We have always been interested in how our brains work. Over the years, there has been extensive research in psychology, neuroscience, and cognitive science to map out the cognitive processes. Although we have gained a better understanding of the functions of our brain to date, the way a human brain works is still largely a 'black box'. Different researchers have developed different models and theories to explain how they think the brain works (Bridger, 2009; Endsley, 1997; K. Anders Ericsson & Kintsch, 1995; Glöckner, Heinen, Johnson, & Raab, 2011; Johnson, 2006; Kahneman, 2011; G. Klein et al., 1993; Peacock & Chai, 2012; Rasmussen, 1983; Sanders & McCormick, 1992; Stiensmeier-Pelster & Schürmann, 1993; Wickens, 1992a). Yet, most researchers do agree that there are various cognitive components that contribute to the human decision making process. These components include:

- Visual search strategies
- Attention allocation
- Selection process (selecting which cues are relevant)
- Anticipation (how the situation develops)

- Memory

It is unclear exactly how and how much each of these components integrate and contribute to the decision making process. To date, human decision research has focused mainly on studying the separate components or environmental contexts and their effects on decision making behaviour. Janelle (2002) and Behan and Wilson (2008) found that competitive anxiety affects visual search strategies and attention, which in turn affects the decision making process. Endsley (1997) demonstrated that situation awareness is important for good decision making. Decision makers who are more aware of their situation are better able to make use of the information available to make sound decisions. K. Anders Ericsson and Kintsch (1995) also described how one's memory and past knowledge and experiences play an important role in decision making. A person who had experienced a similar situation before is able to draw on that past experience and thus, reducing the amount of time needed to analyse the situation and make a decision. Brehmer and Allard (1991) found that experience improved decision making performance, feedback affects learning, and the ability to learn quickly is important in efficient and effective use of resources. Thus, there are many existing tools and methods to evaluate the different aspects of the human information processing system. Some of the existing cognitive tools and methods are listed in Table 3.1.

Table 3.1 Existing experimental tools and methods used to study decision making and its related cognitive components

Tool / Method	Description	Cognitive function studied	Source
Dynamic decision making task	In this computerised test, participants were tasked to control a system that continuously changes. System changes were presented in the form of graphs and participants could increase or decrease feedback. They had to apply the correct actions in time to control the changes and prevent system failure.	Decision making	Kerstholt (1993)
Static decision making task	Static images of decision making situations were shown to participants who were tasked to choose the action that is most suitable for the situation.	Decision making	McMorris and Graydon (1996)
Dynamic Environment Simulation System (DESSY)	Simulates decision making in real time by varying important characteristics of the task and assessing the effects of these variations. Participants were presented with a constantly changing fire-fighting scenario. Their commands throughout the experiment were recorded.	Decision making	Brehmer and Allard (1991)
Situational Awareness Global Assessment Technique (SAGAT)	Participants were presented with a simulated scenario. This scenario was paused at different times. During these pauses, participants were asked several predetermined questions about what they perceive, understand, and predict will happen in the given scenario.	Situation awareness (Perception, Comprehension, Anticipation)	Gawron (2000)
Secondary tasks	There were many forms of secondary tasks. In general, this technique required participants to perform a primary task within certain	Mental workload	Gawron (2000)

	requirements and use spare attention to perform a secondary task.		
Visual search test	Participants were presented with a display containing a number of items. They were tasked to determine if a specific target item is or is not present among the distractor items.	Visual search	Wolfe (1998)
Stroop test	Coloured words (“red”, “green”, “and blue”) or “xxxxx” were presented to the participants and they were instructed to name the ink colour of the letters displayed. The word and ink colour shown may not be coherent. For example, “green” may be presented in red ink colour.	Visual attention	Uttl and Graf (1997)
Birdwatching game	Participants were required to determine the location of the bird while focusing on the letter that appears simultaneously. They get points when they get the letter and location of the bird correct.	Visual attention	Scanlon, Drescher, and Sarkar (2007)
Corsi Block-Tapping Task	Participants were presented with 9 blocks. Facilitators would tap on the blocks and participants were to repeat the same sequence. This sequence gets longer each time the participant is successful.	Visual memory	Kessels, Zandvoort , Postma, Kappelle, and Haan (2000)
Spatial Working Memory Task	Participants were instructed to search through a number of boxes to find a token in one of the boxes. Once a token has been found, it would be hidden again in another box (same box will never be used again) and the participant has to find the token again.	Spatial working memory	Owen, Downes, Sahak, Polkey, and Robbins (1990)
Iowa Card	Four decks of cards were	Learning	Overman

Task	placed in front of the participants, of which two decks were red cards and the other two were blue cards. Participants were then instructed to collect as much “money” as possible by drawing a card from any of the four decks. Each card may cause the participant to win or lose money of various amounts. The red coloured cards would cause the participant to lose in the long term.		et al. (2004)
Hopkins Verbal Learning Test	12 words were read out verbally to the participant who had to recall and repeat the words back to the facilitator. Next, the participant was presented with a yes/no recognition task where he was to identify the target words by responding “yes” and to reject non-target words by responding “no”.	Verbal learning and memory	Benedict, Schretlen, Groninger, and Brandt (2010)

Although previous research have demonstrated the significance of various cognitive components on decision making performance, it is not known which of these components have a greater or smaller effect on decision making. Tenenbaum’s model (see Figure 2.5) showed that these cognitive components interact and contribute to the decision making process of expert athletes, but he also did not conduct experiments to investigate all of these components together. Therefore, in this study, we investigated cognitive components listed in Tenenbaum’s model. By combining methods and theories developed by previous researchers to evaluate each of these cognitive components into a single test, we were able to evaluate all the components together.

3.1.2 Gap 2: No formalized tools or methods to evaluate cognitive abilities in sports

In recent years, there has been increasing interest in the use of talent identification and development programmes in various sports. These sports include soccer, volleyball, handball, rugby, and even badminton (Duncan, Woodfield, & al-Nakeeb, 2006; Gabbett, 2002; Mohamed et al., 2009; Reilly, Williams, Nevill, & Franks, 2000; Vaeyens, Lenoir, Williams, & Philippaerts, 2008; Werkiani, Zakizadeh, feizabadi, Golsefidi, & Rahimi, 2012). Most of these programmes make use of physical measures such as anthropometry or somatotypes and physiological measures such as maximal oxygen consumption (VO_2 max) or heart rate to assess the athletes' physical fitness and their suitability for the sport. These programmes aim to identify athletes at a young age and nurture them into successful players of the sport they are selected for. Several advantages of such programmes adapted from Abbott, Collins, Martindale, and Sowerby (2002) are listed below.

1. Reduces time required to reach high performance substantially
2. Enhance training effectiveness due to superior abilities of athletes
3. Increases competitiveness and results in a stronger and more homogeneous team
4. Increases athletes' self confidence

5. Facilitates sports research as sports scientists can continue monitoring the athletes

While traditional talent identification and development programmes focus mainly on physical and physiological characteristics, current programmes are beginning to incorporate the psychological aspects of an athlete such as his attitude, goal setting abilities, and motivation. Yet, there are still no programmes that include the assessment of high level cognitive abilities to date. This might be due to the lack of research in the area of measuring and training decision making abilities in sports. As such, current talent identification and development programmes are unable to incorporate the evaluation of cognitive abilities without a valid and reliable method to measure the various cognitive skills.

Decision making is an important cognitive skill that is essential for excellence in many sports (Abbott & Collins, 2007). Garland and Barry (1990) explained that physiological and biomechanical factors are able to bring sports skill up to a certain level. Thereafter, continued practice will bring minimal improvement and the athlete will have to focus on psychological factors for further improvement in performance. Therefore, cognitive fitness is just as important as physical fitness in sports performance. The development of a reliable measure of decision making abilities can be greatly beneficial to the identification and development of sports talent.

It is difficult to effectively evaluate decision making performance in open skill sports. Lames and McGarry (2007) explained that there is too much variability within and between games. Due to the nature of open skill sports, performance indicators are a result of the interactive process between players rather than their actual skills and abilities. As such, performance indicators are not stable indicators of sports performance. Thus, Lames and McGarry (2007) proposed the use of qualitative data to complement theoretical performance analysis in open skill sports.

In order to diagnose decision making performance in this study, we studied both subjective and objective assessment methods. We first made use of the Kano model to identify the critical decision making attributes and developed the rating sheet for coaches as a guide for the subjective assessment of players' decision making abilities. Next, we developed the computerized decision making test by combining several cognitive tests to objectively assess the players' cognitive abilities.

3.1.3 Gap 3: Limited application of the concept of NDM in sports

G. Klein et al. (2010) first introduced the concept of NDM when he studied the decision making processes of fire fighters in 1989. In a naturalistic setting, decision makers experience many types of stressors and distractions which are usually not replicated in a laboratory setting. In Figure 3.1, Peacock and Chai (2012) clearly illustrates how noise and distraction are a part of the cognitive process, with significant effects on attention. Various studies have shown that these stressors and distractions have an effect on human decision making behaviour and should therefore be considered during research. Tenenbaum (2003) noted that it is beneficial for future decision making studies to be conducted in realistic situations, "under conditions of optimal and less-than-optimal functioning". In this way, cognition, emotion, and other factors can be measured simultaneously.

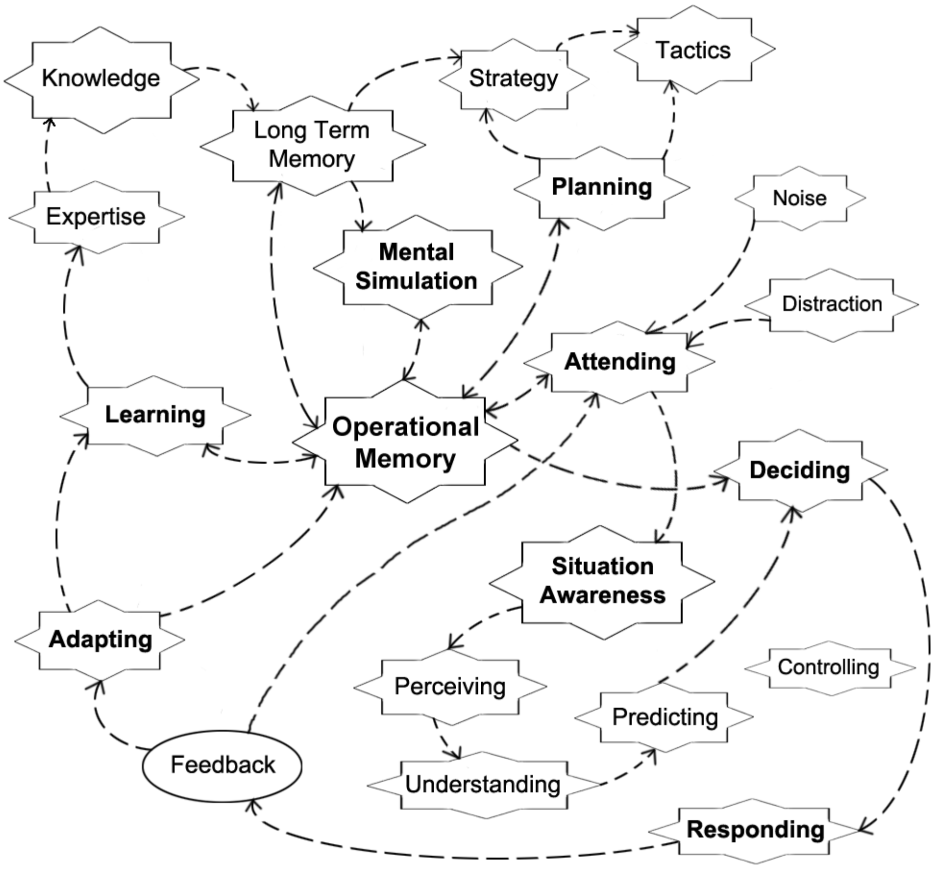

Figure 3.1 A fuzzy model of the cognitive process (Peacock & Chai, 2012)

Besides fire-fighting, NDM has been applied in other areas such as nursing where nurses often have to make critical decisions before the physicians arrive. The application of NDM in nursing has helped researchers to better understand the conditions that nurses work under and how they affect the nurses' decision making processes. In addition, the 'expertise effect' in decision making of nurses was also studied and significant differences were identified. As such, better guidelines and training methods were developed for novice nurses. (Currey & Botti, 2003)

Mascarenhas and Smith (2011) noted that the characteristics of NDM are often observed in sports scenarios. One of the main characteristics of NDM is time stress and this is especially evident in sports. Due to the dynamic environment of sports games, there is constant time pressure throughout the game as the situation continuously evolves. A case study of fencers by Chang, Li, Jou, Pan, and Hsu (2009) noted that fencing players use as little as 0.05 seconds to judge and decide if they want to change direction.

NDM is not the only way to study decision making in dynamic situations. Brehmer and Allard (1991) managed to make use of simulation techniques to do so. First, they explained their theory that decision makers in dynamic tasks basically have three alternatives:

1. Develop a mental model of the task
2. Develop heuristic rules
3. Rely on feedback

Depending on which alternative the decision maker uses, he will then modify his behaviour gradually. Based on their theory, Brehmer and Allard developed DESSY (Dynamic Environment Simulation System) to study decision making in real time. By varying important characteristics of the task and assessing the effects of these variations, DESSY simulates a constantly evolving fire-fighting scenario and records the participants’ commands. From this experiment, Brehmer and Allard found that experience improved decision making performance, and feedback affects learning. Also, the ability to learn quickly is important in efficient and effective use of resources.

However, it is difficult to implement a similar system to study sports such as basketball. In a game of basketball, there are ten players and at least two referees on court at the same time. Actions made by these 12 people constantly change the decision making situation and adds to its complexity. As the situation changes, the decision maker's goal may change. For example, the player with the ball may intend to go for a fast-break, but he may change his mind when he sees the opponent overtaking him and may block his path in the next second. Thus, he changed his mind and chose to slow down to wait for his other teammates instead. Several characteristics of NDM such as ill-structured problems, uncertain dynamic environments and shifting goals can be seen here.

Macquet and Fleurance (2007) applied the concept of NDM on a less complicated sport, badminton. Although they only had four participants, they were able to better understand the decision making process of high level badminton players from a different perspective. Instead of usual laboratory tests, the researchers questioned the players on the actual decisions that they made on court. From this experiment, they were able to map out the thought processes of the players, from their intentions to their actions, and eventually how the result affected the subsequent decisions. The authors also suggested that further research on NDM may provide insights on changes in decision making performance as the athlete gains or loses the advantage during a game or as the athlete experiences performance-based fluctuations throughout the season. Therefore, there is still much more to explore in the study of NDM in sports.

In our study, we compared the results of the cognitive test that we developed (objective measure in laboratory setting), the expert judgment (subjective measure), and the performance statistics in an actual competition (NDM measure). As these performance statistics are a direct result of the athletes’ decisions during competition, we consider them as a measure of their actual decision making performance.

3.2 Research objectives and questions

3.2.1 Research objectives

Based on the research gaps and hypotheses described in the previous section, we can investigate the integrated abilities of the various cognitive components and develop a tool or method to measure decision making performance. Allard and Burnett (1985) suggested that players of open skill sports such as basketball, hockey, and soccer, could offer the best prospects for investigating the decision making process and cognitive requirements in sports as there is a need for strategy and structure in their games. The author also chose to focus this research on basketball due to her passion for the sport and her existing personal contacts of coaches, referees, and players who can contribute to the success of the research.

This study aims to investigate decision making in sports by comparing different ways of evaluating decision making ability in young basketball players. It is hoped that this work will be useful for practitioners in identifying youths with good decision making capability and provide insights on diagnosing human decision making performance.

3.2.2 Research questions

Two main research questions were formulated as follows:

1. How can we measure decision making?

    - What attributes influence how decision making behaviour is perceived?
    - Are there age or gender differences in decision making behaviour?
    - Can cognitive fitness be measured like physical fitness?
    - Can the measurements of various cognitive components (visual search, attention allocation, cue selection, anticipation, memory, choice of action, action evaluation) describe decision making performance?
    - How is decision making performance reflected in game-related statistics?

2. How does decision making affect sports performance?

    - Can cognitive fitness and physical fitness measures be used to predict basketball performance?

4 STUDY 1: PAPER-BASED RATING SHEET FOR COACHES

Basketball is an open skill sport where two teams compete against each other. Each team sends five of their players on court during a match. The match lasts for 40 minutes, which is divided into four quarters of ten minutes each, and teams are allowed to substitute the players on the court any time during the game. There are usually two forwards, one center, one guard, and one controller in the game. Players have to break through the defense of the opponent team and score points by shooting the ball through the opponent's basket. The team with more points wins the match.

Decision making ability in basketball is usually judged by coaches. Therefore, we explored the viability of three different ways of approximating the coaches' judgments in this thesis. This chapter described the first study where a subjective assessment tool was developed and investigated.

4.1 Preparation and development

Preparatory work for the rating sheet for coaches began in late August 2012. The Kano model was used to aid the data collection and analysis in order to develop the rating sheet. As such, interviews with coaches were conducted and questionnaires were distributed to basketball coaches, players, referees, and spectators. The rating sheet for coaches was completed by December 2012.

4.1.1 Kano model

We made use of the Kano model to identify important decision making attributes and categorize them. The Kano model was first developed by

Professor Noriaki Kano in 1984 (Sauerwein, Bailom, Matzler, & Hinterhuber, 1996) to categorize product attributes that affected customer satisfaction. It categorized attributes into five different types – attractive, one-dimensional, must-be, indifferent, reverse. Attractive attributes, also known as “delighters”, were attributes that were beyond expectation. A little fulfillment of it brought a great deal of satisfaction. One-dimensional attributes showed a linear relationship between satisfaction and performance of the attribute – the better the performance, the higher the level of satisfaction. Must-be attributes were basic attributes that were usually taken for granted. Its existence was seldom noticed but its absence would cause significant dissatisfaction. Indifferent attributes were attributes that had no effect on satisfaction levels, while reverse attributes would cause more dissatisfaction as the performance of the attribute increased.

The Kano model was initially developed for studying product attributes but it has also been adapted to study service and process attributes (Bayraktaroğlu & Özge Özgen, 2008; Dran, Zhang, & Small, 1999; Zhao & Dholakia, 2009). As shown in the various human decision making models by Rasmussen (1983), Wickens (1992a), Tenenbaum (2003), and Peacock and Chai (2012) presented in Chapters 2 and 3, decision making is also a process. The decision maker had to gather information and evaluate his/her options before making a decision. In this study, we were interested in deriving the critical attributes of decision making ability to develop a guide for assessing decision making performance subjectively. Unlike previous research that focused largely on the decision maker by investigating their decision making processes or characteristics (Araújo, Davids, & Hristovski, 2006; Campo, Villora, & Lopez, 2011; G. Klein, 1999; Payne, Bettman, & Johnson, 1988; Shanteau, 1987), the Kano model allowed us to obtain the attributes from people who observe and judge decision making performance. Thus, it was believed that the Kano model was suitable for this study and might provide new insights to the human decision making process by considering the attributes from the perspectives of the observers instead of focusing just on the decision maker.

In order to obtain the decision making attributes, four expert basketball coaches were interviewed. The coaches had at least 10 years of coaching experience. As the Kano model had not been applied to study the human decision making process before, there was no prior knowledge on the exact contribution of each cognitive component to decision making performance. Therefore, we did not select the attributes to maintain an equal distribution across the cognitive components and all of the attributes listed by the coaches were translated into a Kano questionnaire. There were a total of 37 attributes in the Kano questionnaire and these attributes were grouped into five main cognitive components – domain knowledge, anxiety and confidence, short-term memory, situation awareness, and learning. The respondents were asked to rate each attribute with respect to a specific age group and sex, on the scale of 1 to 5. Table 4.1 below showed the scale that was used in the questionnaire.

Table 4.1 Scale used in Kano questionnaire

Scale	Description
1	I dislike it when players do this and I cannot accept it
2	I dislike it when players do this but I can understand when they do this
3	I am neutral
4	I expect players to do this or behave this way
5	I am impressed by players who are able to do this

This questionnaire was then distributed to current and past basketball players, coaches, spectators and referees over a period of 3 months. After collecting the responses, the Kano model was used to categorize the attributes into the five main Kano categories - attractive quality (A), one-dimensional quality (O), must-be quality (M), indifferent quality (I), and reverse quality (R).

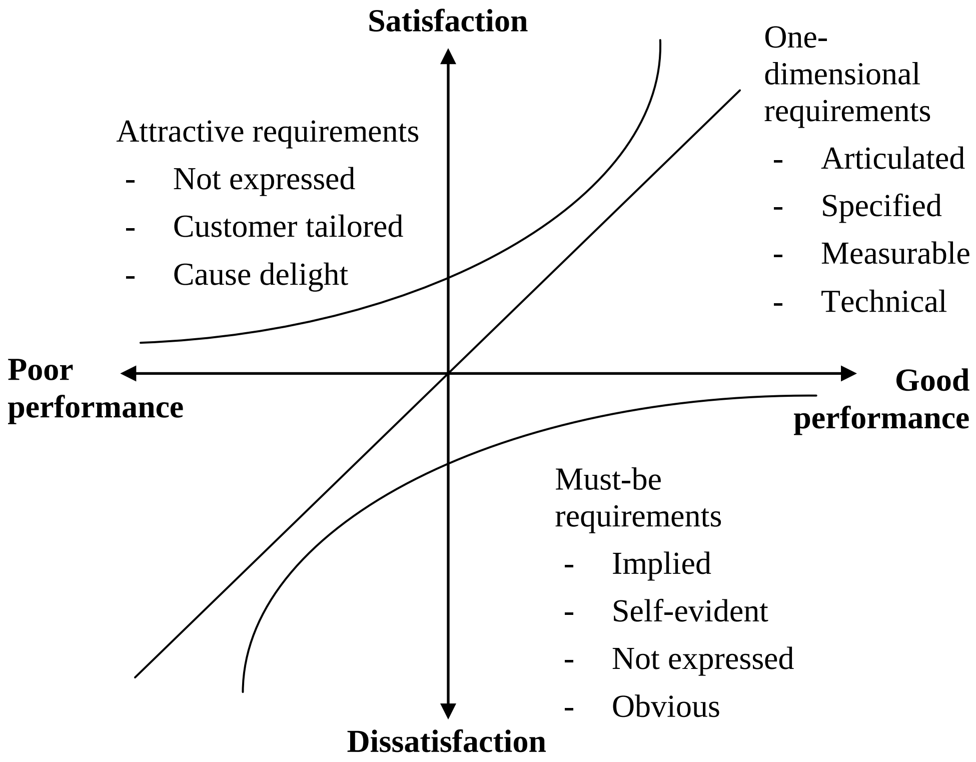

Figure 4.1 Kano model adapted from Berger et al. (1993)

Figure 4.1 showed the Kano model adapted from Berger et al. (1993), with the x-axis representing the athlete's performance on each attribute and the y-axis denoting the level of satisfaction of the coaches with respect to the athlete's performance. An attribute with attractive quality would cause delight in the coaches when they observed the athlete performing well in it, but the coaches were neutral if the athletes did not perform well in that attribute. For example, a basketball player who showed that he was able to identify the opponent team's strengths and weaknesses quickly might cause delight for the coach, but a player who was unable to do so did not cause the coach to be dissatisfied with him. On the other hand, an attribute that was seen as a 'must-be' requirement would cause great dissatisfaction in the coaches if the athletes performed poorly, but the coaches were neutral when the athletes performed well. For example, a basketball player who knew the rules of the game well might not cause much delight to the coach, but the coach might be dissatisfied with the player if he did not know the rules well. Lastly, 'one-dimensional' requirements were attributes that caused the coach to be dissatisfied when the athlete performed poorly and delighted when the athlete performed well.

4.1.2 Results and analysis of Kano questionnaire

Data collection using the Kano questionnaire was carried out from September 2012 to December 2012. The questionnaire was distributed at basketball games such as the NBA2K-13 Ultimate Bball Competition, the Singapore Basketball League and the Singapore University Games. It was also circulated to personal contacts of physical education teachers, past basketball players, coaches, and referees. A total of 209 people completed the questionnaire, of which 110 of them were male and 99 were female. Seventeen of the questionnaire respondents did not have any competitive experience in basketball but were avid players recreationally. Thus, their responses were also included in the analysis.

Respondents had to answer the questionnaire with respect to a specific target group preset by the principal investigator or chosen by the respondent depending on his or her area of expertise. For example, a referee for the Singapore University Games might be allocated with the target group of 17-20 year old, male players. However, he might be a coach for a 13-14 year old, female basketball team. As such, he would be allowed to change the target group to 13-14 year old, female if he was more familiar with that target group. The target groups were divided by age and sex. Age groups were chosen based on the general age range for each sports division in the national inter-school championships. Table 4.2 showed the number of questionnaires completed for each target group. Each respondent was only allowed to complete the questionnaire for one target group. See Appendix A for a sample of the Kano questionnaire.

Table 4.2 Number of respondents for each target group

Age group (division)	Male	Female
13-14 years old (C)	27	24
15-16 years old (B)	32	28
17-20 years old (A)	17	30
21 years old and above	30	21

In the Kano questionnaire, respondents were given the functional (positive) and dysfunctional (negative) statements for each attribute and were tasked to rate both statements on the scale of 1 to 5 as shown in Table 4.1. The matrix shown in Table 4.3 was then used to map the attributes into the Kano categories (A: Attractive, O: One-dimensional, M: Must-be, I: Indifferent, R: Reverse, Q: Questionable).

Table 4.3 Matrix used to map attributes and categorize them into the Kano categories

		Functional (Positive)				
		1	**2**	**3**	**4**	**5**
Dysfunctional (Negative)	**1**	Q	M	M	M	O
	2	R	I	I	I	A
	3	R	I	I	I	A
	4	R	I	I	I	A
	5	R	R	R	R	Q

Frequency analysis was then used to determine the final Kano category that the attribute falls into. Twelve attributes were categorized under “Attractive”, “One-dimensional”, or “Must-be”, while the remaining 25 attributes were categorized under “Indifferent”. Table 4.4 showed the twelve attributes and the categories that they fall into.

Table 4.4 Decision making attributes selected for use in rating sheet

Decision making attributes	Category	Cognitive component
Player shows that he/she is able to control the pace of the game to organize his/her team	A	Domain knowledge
Player communicates effectively with teammates on court	A	Domain knowledge
Player does not look distracted during the match	M	Competitive anxiety
Player shows that he/she is not afraid to get the ball	M	Competitive anxiety
Player does not repeat the same mistake(s)	O	Short-term memory
Player shows that he/she is alert	M	Situation awareness
Player shows that he/she is able to identify and pass the ball to teammates with better opportunities	A	Situation awareness
Player shows that he/she is able to read opponents’	A	Situation

moves		awareness
Player shows that he/she is able to pass the ball to teammates successfully without looking directly at them	A	Situation awareness
Player shows that he/she is able to understand and carry out new strategies or plays quickly	A	Learning
Player shows that he/she is able to identify opponents’ strengths and weaknesses quickly	A	Learning
Player shows that he/she is quick to react to situations	A	Learning

In addition, chi-square analysis was used to study the differences between the attributes, the age groups and the sex of the players. The attributes corresponding to the learning cognitive component were found to be more ‘attractive’ than the other attributes. If a player demonstrated ability in understanding and carrying set plays quickly, identifying opponents’ strengths and weaknesses quickly, or reacting to situations quickly, he or she was more likely to be rated positively. Yet, he or she might not be rated negatively for not showing these traits. The attributes corresponding to competitive anxiety were found to be more of ‘must-be’ than the other attributes. Thus, players were expected to not look distracted or be afraid of the ball when they are playing on court. If a player was found to be distracted or seemed to be afraid of the ball, he or she was more likely to be rated negatively. There were no significant differences between age groups or sexes. Therefore, we developed a generic rating sheet for coaches to be used for all our participants regardless of age and sex. This rating sheet made use of a 7-point Likert scale where raters had to rate the player’s ability on each attribute using a scale of 1 to 7. Oslin, Mitchell, and Griffin (1998) developed the Game Performance Assessment Instrument (GPAI) with a similar style as they identified the critical components of game performance and got the respondents to rate each component on a 5-point Likert scale. Likert scales makes the rating sheet more user-friendly and easier to use, especially for fast invasion type games (Mitchell, Oslin, & Griffin, 2013). As such, first-time raters in our experiment could quickly choose a rating for each decision making attribute without much difficulty. See Appendix B for a sample of the rating sheet for coaches.

4.2 Data collection

4.2.1 Research participants

As this study required the participation of human subjects, we sought the approval of the National University of Singapore's Institutional Review Board (IRB) before starting the project. The application for IRB approval was first submitted on 29 June 2012 and the approval to begin research was granted on 22 August 2012. Written approval to conduct this study was also obtained from the Ministry of Education and the study was supported by the teachers-in-charge of basketball and their respective Heads of Department. Informed written consent was obtained from the participants who were at least 21 years old or their parents or guardians if they were below 21 years old.

The basketball coaches were contacted via email, phone calls and phone messages to explain about the research and provide a brief framework of it. Out of the 14 coaches that we managed to reach, five of them agreed to participate in this study.

4.2.2 Research procedure

The coaches were asked to rank and rate the players of each of their teams based on their overall decision making performance at the beginning of the competitive league. Paper forms of the rating sheet for coaches for each participant were passed to the coaches at the beginning of the session and collected back at the end of the session when all the participants had completed the cognitive test. The coaches had to rate each participant on each decision-making attribute using a scale of 1 to 7, as well as rank them in terms of their decision-making performance in a basketball game. After collecting the paper forms back from the coaches, we also had a short interview with them to ask for their opinions on the decision-making attributes and their relation to decision-making performance.

In addition, the paper forms of the rating sheet for coaches were also distributed during the participants' first match. These forms were only given to spectators who were at least 21 years old, had more than two years of experience in competitive basketball, and did not know any of the players on the participating team beforehand. They were tasked to watch at least two quarters of the game and complete the rating sheet for five of the participating players as allocated by the principal investigator. The spectators were instructed to rate the allocated players only if they had watched the respective players play during the match. The paper forms were distributed to at least five spectators during the first match of each participating team and at least two responses were obtained for each participating player.

4.3 Results and analysis

Coaches were first asked to rank their players in terms of their decision making ability. As we were mainly interested in the difference between the superior and the inferior decision makers, each team was divided into two groups – the top half with superior decision making ability and the bottom half with lower decision making ability – to minimize the noise in the data. The 43 participants in the top half group had an average of 4.44 (SD = 2.42) years of experience in competitive basketball and 38 participants in the bottom half group had an average of 3.76 (SD = 2.25) years of experience in competitive basketball. No significant differences were found between the numbers of years of experience for both groups (F = 1.694, $p = 0.197$). The coaches were also asked to complete the decision making rating sheet for each participating player in their team. The decision making rating sheet consisted of two attributes on competitive anxiety, one attribute on short-term memory, four attributes on situation awareness, two attributes on basketball knowledge, and three attributes on learning ability. For ease of analysis, all of the ratings were converted such that a higher score represented better performance on that attribute. The attribute ratings for each cognitive component were summed together to obtain an overall score for the component. The Cronbach's alpha for competitive anxiety, situation awareness, basketball knowledge, and learning ability are 0.713, 0.877, 0.910, and 0.905 respectively. As the Cronbach's alphas were all above 0.7, there was good internal consistency between the attributes used for each cognitive component in the decision making rating sheet (Kline, 2000). Table 4.5 compared the coaches' mean ratings of the participants in the top half and bottom half groups using the analysis of variance (ANOVA). Significant differences were observed between both groups on all five of the cognitive components.

Table 4.5 Comparison of coaches' judgments on the top half and bottom half groups

	Top half	Bottom half			
Coaches' ratings	Mean (SD)	Mean (SD)	F	df	Sig.
Competitive anxiety	11.35 (2.13)	7.44 (2.19)	66.07	79	< .001
Short-term memory	4.35 (1.00)	3.50 (1.33)	10.71	79	.002
Situation awareness	20.37 (4.19)	14.60 (4.32)	37.09	79	< .001
Basketball knowledge	10.84 (2.35)	7.29 (2.20)	48.72	79	< .001
Learning ability	15.63 (3.20)	10.81 (2.95)	49.09	79	< .001

Discriminant analysis was used to further analyze the cognitive ratings of both groups. The discriminant function was found to be statistically significant (p < 0.001). The group centroid for the top half group was 0.685 and the group centroid for the bottom half group was -0.775. Based on the structure matrix of the discriminant function (see Table 4.6), the discriminant loadings of all the five independent variables are greater than 0.3. Therefore, all five cognitive components were important factors in determining if the player falls into the top half or the bottom half group of decision makers. Competitive anxiety was found to be the most important factor followed by learning ability, basketball knowledge, situation awareness, and short-term memory in decreasing order of importance. These results differed slightly from the rank given by the coaches during the interviews, although all coaches did mention that all five components are important. Overall, they ranked situation awareness first, followed by learning ability, competitive anxiety, basketball knowledge, and short-term memory.

Table 4.6 Discriminant function and structure matrix of coaches' ratings for top half and bottom half groups

Discriminant function	Coefficient	Structure matrix
Competitive anxiety (*CA*)	.321	.901
Short-term memory (*STM*)	.035	.363
Situation awareness (*SA*)	-.067	.675
Basketball knowledge (*BK*)	.122	.774
Learning ability (*L*)	.141	.777
Constant	-5.017	

The cross validated classification for the discriminant function showed that overall 82.7% were correctly classified (see Table 4.7). Thus, the discriminant function generated using the coaches' ratings of players' competitive anxiety, short-term memory, situation awareness, basketball knowledge, and learning ability could be used to predict group membership. This implied that the attributes used in the decision making rating sheet were consistent with the coaches' rankings.

Table 4.7 Classification results of coaches' ratings for top half and bottom half groups

		Predicted group membership		
		Top half	Bottom half	Total
Count	Top half	33	10	43
	Bottom half	4	34	38
Percentage	Top half	76.7	23.3	100.0
(%)	Bottom half	10.5	89.5	100.0

Discriminant analysis was also used to study the coaches' ratings after blocking out the effects of age and gender. The participants were separated into age groups according to their respective divisional games. Thus, there were 32 participants in the 'C' Division group (12 – 14 years old), 25 participants in the 'B' Division group (14 – 16 years old), and 24 participants in the 'A' Division group (16 – 19 years old). Forty-five of the participants were male and 36 were female. Although the sample size after blocking was considered too small for the discriminant analysis to be representative, it was interesting to note how the order of importance of the cognitive components differed among these groups. Table 4.8 summarized the order of importance of the cognitive components for each group of participants and presented them together with their overall Kano categories. All the attributes for competitive anxiety were categorized as ‘Must-be’ (M), the short-term memory attribute was categorized as ‘One-dimensional’ (O), one of the attributes for situation awareness was categorized as ‘Must-be’, while the other three attributes were categorized as ‘Attractive’ (A), and all the basketball knowledge and learning ability attributes were also categorized as ‘Attractive’. No significant differences were found between age groups or gender in the Kano analysis, but differences were observed in the order of importance using discriminant analysis. Competitive anxiety was ranked as the most important for the older age groups, but learning ability was the most important for the 12- to 14-year-olds in the ‘C’ division. Situation awareness and basketball knowledge had varying levels of importance, while short-term memory was consistently placed last across all groups.

Table 4.8 Order of importance of cognitive components for different target groups

	Kano category	Male	Female	'A' Division	'B' Division	'C' Division
Competitive anxiety	M	1	1	1	1	4
Short-term memory	O	5	5	5	5	5
Situation awareness	M, A	4	2	3	4	3
Basketball knowledge	A	2	4	4	2	2
Learning ability	A	3	3	2	3	1

Next, we compared the ratings obtained from the spectators with the coaches' rankings of the top and bottom half groups. A total of 129 responses and 156 responses were collected for participants in the bottom half and top half groups respectively. Mean ratings of each cognitive component and the results of their ANOVA analysis were shown in Table 4.9.

Table 4.9 Comparison of spectators' judgments on the top half and bottom half groups

	Top half	**Bottom half**			
Spectators' ratings	Mean (SD)	Mean (SD)	F	df	Sig.
Competitive anxiety	12.00 (1.97)	10.36 (2.64)	36.18	283	<.001
Short-term memory	5.09 (1.30)	4.51 (1.29)	14.06	283	<.001
Situation awareness	21.60 (3.19)	18.05 (4.43)	61.63	283	<.001
Basketball knowledge	10.56 (1.94)	8.44 (2.40)	67.97	283	<.001
Learning ability	16.53 (2.46)	13.71 (3.26)	69.24	283	<.001

Significant differences were observed between both groups on all the cognitive components. Thus, discriminant analysis was used to further analyze the differences between cognitive ratings of both groups. The discriminant function was found to be statistically significant with $p < 0.001$. The discriminant function and its structure matrix were shown in Table 4.10. The group centroid was 0.485 for the top half group and -0.596 for the bottom half group.

Table 4.10 Discriminant function and structure matrix of spectators' ratings for top half and bottom half groups

Discriminant function	Coefficient	Structure matrix
Competitive anxiety (*CA*)	.066	.669
Short-term memory (*STM*)	-.105	.417
Situation awareness (*SA*)	.039	.873
Basketball knowledge (*BK*)	.203	.916
Learning ability (*L*)	.161	.925
Constant	-5.422	

Similar to the coaches' ratings, all five cognitive components were found to be important factors in determining whether a player was in the top half or the bottom half group in decision making ability. The most important factor was learning ability, followed by basketball knowledge, situation awareness, competitive anxiety, and short-term memory in decreasing order of importance. Although the discriminant function was significant ($p < 0.001$), the power of the function was not strong. The cross validation classification (as shown in Table 4.11) resulted in a hit ratio of 68.1% using the discriminant function obtained from the spectators' ratings. If the discriminant function obtained from the coaches' ratings was used, a hit ratio of 64.1% was obtained. The discriminant function had to achieve at least 75.0% hit ratio in order for it to be considered acceptable for predicting group membership.

Table 4.11 Classification results of spectators' ratings for top and bottom half groups

Predicted group membership using spectators' discriminant function				
		Top half	Bottom half	Total
Count	Top half	118	38	156
	Bottom half	53	76	129
Percentage (%)	Top half	75.6	24.4	100.0
	Bottom half	41.1	58.9	100.0
Predicted group membership using coaches' discriminant function				
		Top half	Bottom half	Total
Count	Top half	137	19	156
	Bottom half	77	52	129
Percentage (%)	Top half	87.8	12.2	100.0
	Bottom half	59.7	40.3	100.0

4.4 Discussion

The rating sheet for coaches was developed in a similar style to the GPAI, which was one of the most accepted game performance instrument in literature (Memmert & Harvey, 2008). This rating sheet consisted of 12 attributes that corresponds to competitive anxiety, short-term memory, situation awareness, basketball knowledge, and learning ability. Two groups of raters were tasked to rate each participating player using a 7-point Likert scale for each attribute on the rating sheet. The first group comprised of coaches who had known the players for at least a year, while the second group comprised of spectators who had observed the participating players during their first competitive match of their respective championship leagues. The coaches' ratings were found to be consistent with their rankings of the players' decision making abilities and the discriminant function had a power of 82.7%.

Kano analysis of the decision making attributes revealed no significant differences between age groups and gender when they were used to judge on the decision making abilities of basketball players. Therefore, a generic decision making rating sheet was used for all participants in this study. However, we were interested to check if the coaches emphasized on different cognitive components for different age groups and gender. From Table 4.8, it could be seen that the order of importance of the cognitive components were similar for both genders, but very different between the ‘C’ division group and the other two divisional groups. The ‘C’ division consisted of players aged 12 – 14 years old, while the ‘A’ and ‘B’ divisions consisted of players aged 14 – 19 years old. Therefore, the coaches had similar expectations of the cognitive requirements for both genders, but they placed more emphasis on learning for the younger group and more emphasis on emotional management for the older groups when differentiating the players by their decision making abilities.

It was noted that the order of importance obtained through discriminant analysis of the coaches’ ratings seemed to differ from the order of importance that they explicitly stated through the interview sessions. In addition, it was also observed that only situation awareness had a negative coefficient (-0.067) in the discriminant function. This implied that situation awareness was the only component that defined the poorer decision makers. Based on the Kano categorization of each component, it was initially expected that competitive anxiety might have a negative coefficient instead of situation awareness. All of the competitive anxiety attributes were categorized as ‘must-be’, which meant that raters were not delighted (will not give a high score) if players demonstrated good performance in that attribute, but were displeased (would give a low score) if players demonstrated poor performance in that attribute. However, this expectation was not observed in the coaches' ratings.

There were some possible explanations for these two observations. Firstly, discriminant analysis identified the factors that best discriminates the group of better decision makers from the group of poorer decision makers. The results of the discriminant analyses in Table 4.8 did not reflect the importance placed by the coaches on each component. It only showed that the largest difference between the better and poorer decision makers in the 'A' and 'B' divisions lay in their abilities to manage their competitive anxiety levels, while the largest difference between the two groups in the 'C' division lay in their abilities to learn quickly and accurately. The coaches might still place more importance on situation awareness, but the players at the youth level did not demonstrate a significant difference in their situation awareness levels. As they had similar levels of situation awareness, it was more difficult to distinguish the players based on that cognitive component. Therefore, the results of the discriminant analyses merely indicated the main differences and did not contradict the coaches' explicit ranking of the emotional and cognitive components. In fact, an earlier study by Kioumourtzoglou, Derri, Tzetzis, and Theodorakis (1998) also agreed with the coaches in our experiment that situation awareness is the most important cognitive ability as highly qualified basketball coaches in their study chose the speed of perception, selective attention, response selection, and anticipation to be the most important cognitive abilities in basketball. These abilities were termed as situation awareness in this thesis (see Figure 5.1).

Also, as situation awareness, basketball knowledge, and learning ability were categorized as ‘attractive’ decision making attributes, they were likely to be difficult to achieve at a teenage level. The reason for the players in the ‘C’ division group to be able to be differentiated by their learning abilities was likely due to the difference in expectations. The coaches mentioned that players in the ‘C’ division were mostly trained on basketball skills and physical fitness, while the players in the ‘A’ and ‘B’ divisions were mostly trained on strategy and game play. As such, the coaches’ expectations of the ‘attractive’ attributes would be very much lower for the ‘C’ division players than for the ‘A’ and ‘B’ division players since they were not trained in those areas. Thus, the coaches would be more easily delighted by the ‘C’ division players than the ‘A’ and ‘B’ division players.

To test the effectiveness of the decision making rating sheet in reflecting the coaches’ judgments, the rating sheets were distributed to the spectators who watched the first match of each participating team. A total of 285 responses were collected for 81 participants. There were at least two responses for each participant. Using the cross validation classification, a hit rate of 68.1% was obtained from spectators’ discriminant function and 64.1% was obtained from the coaches’ discriminant function. In practice, the eventual grouping of the players being assessed would not be known beforehand as the purpose of the decision making rating sheet was to produce the grouping. Instead, the coaches’ discriminant functions could be obtained beforehand by getting the coaches to first rate and rank their existing players. This discriminant function could then be used to predict the groupings of prospective players.

From the classification results using the coaches' function in Table 4.11, it was observed that the sensitivity of the classification was high (87.8%), but the specificity was low (40.3%). More players were grouped as good decision makers by the spectators (214 out of 283) than by the coaches (43 out of 81). This was not surprising as the spectators might have been more lenient than the coaches in rating the participating players. Hastorf and Cantril (1954) explained that judgments of human behaviour were often affected by the observer's prior knowledge and the outcome of the activity. All the participating teams won their first match; hence, the spectators might be influenced by the outcome and compared the participating player on the winning team with their weaker opponents. Plessner and Haar (2006) explained the differences between local and global judgments by studying and reviewing the empirical researches in earlier papers. They defined local judgments as judgments made for performances in a limited time or space, while global judgments were made after observing performances over an extended period of time. Thus, the judgments made by the spectators would be considered local judgments and those of the coaches were global judgments. Plessner and Haar found much more biases in local judgments than in global judgments such as order effect and reputation bias that were not evident in global judgments. These biases might also have caused the differences between the coaches' and the spectators' ratings. For example, the spectator might give better ratings to the player who appeared last as he or she best remembered the last player’s performance.

Despite the inherent biases of local judgment, the decision making rating sheet offered a quick and convenient way of assessing a large group of players as it could be distributed to many observers for all the players to be rated at the same time. During selection trials, coaches often had to assess a large pool of prospective players within a limited time. With this decision making rating sheet, the coaches could get the prospective players to play matches and have the assistant coaches, alumni players, or even the current players to rate them on the critical decision making attributes. This helps to reduce the load and stress of the coaches as it is difficult for them to focus on all ten players at the same time. Although the ratings of the other observers cannot accurately replace the coaches’ judgments, it could provide the coaches with an additional reference, which might be more useful in marginal cases such as having to choose between two or three prospective players for the last spot in the team.

5 STUDY 2: COMPUTERIZED TEST FOR PLAYERS

Standardized physical fitness tests were commonly used in countries such as the United States of America, Canada, and Hong Kong to assess the physical fitness of school-going children and youths (California, 2012; HKCF, 2001; Tremblay et al., 2010). In Singapore, the National Physical Fitness Awards (NAPFA) programme was introduced in 1982 to measure the physical fitness levels of school-going children and youths. Children and youths of the same age and sex took the same physical fitness tests across the nation. All primary, secondary, and junior college students were required to take the NAPFA test once every year. The NAPFA test comprised of six testing tools that measured one’s muscular strength, muscular endurance, flexibility, speed, and stamina (Schmidt, 1995).

Cognitive and physical functions are closely interrelated and interdependent (Brooker, Kirk, Braiuka, & Bransgrove, 2000). However, unlike physical fitness, there were no standardized tools to measure the cognitive fitness of school-going children and youths. Thus, this chapter described the development and investigation of an objective assessment tool that was designed in a similar format to the NAPFA test. As Wickens (1992a) explained that decision making is at the heart of the human information processing system, we focused on decision making as the core of our research and measured the different components that contribute to the decision making process.

5.1 Preparation and development

The cognitive test used in this study was developed as a mobile application (app). It was programmed using XCode version 4.0.2 and installed in six sets of 2nd generation iPads using the iOS 6.0.1. The programming of the app began in May 2012 and the final version of the app was completed in December 2012.

5.1.1 Cognitive and emotional components of decision making in sports

The decision making model (see Figure 2.5) by Tenenbaum (2003) was adapted to develop the model used for the cognitive test (Figure 5.1 illustrates). Thus, the cognitive test was designed to measure competitive anxiety, short-term spatial memory, situation awareness, basketball knowledge, and learning ability.

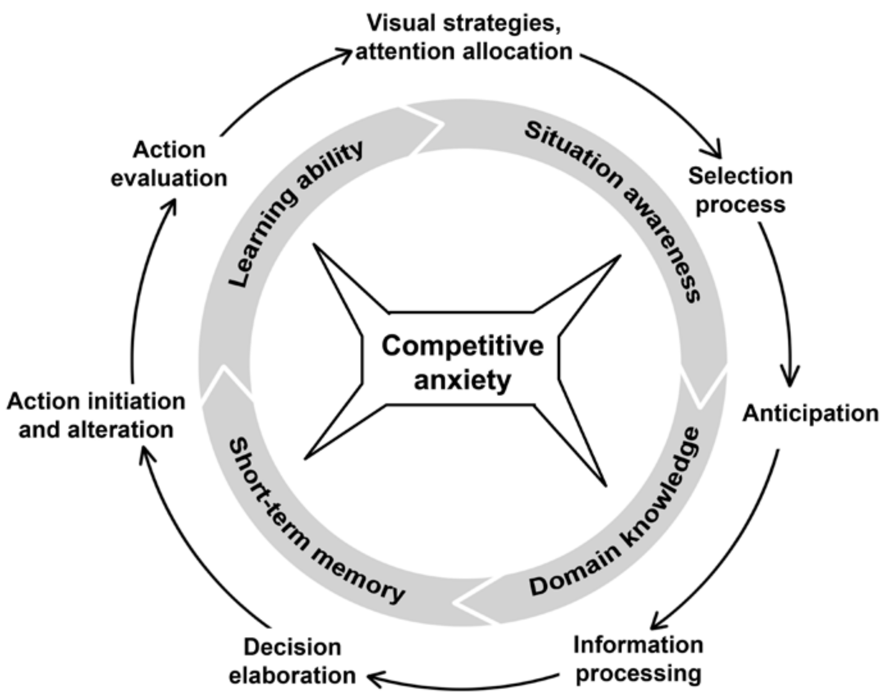

Figure 5.1 Adapted model used for the development of cognitive test

There were many different types of cognitive tools available to test and train various cognitive abilities. The Competitive Sports Anxiety Inventory-2 (CSAI-2) was chosen to measure competitive anxiety in this study as it was widely used for measuring the competitive state anxiety levels of athletes and it was easy to computerize and implement. Compared with more comprehensive tests, the CSAI-2 questionnaire only had 27 multiple-choice questions, which participants were usually able to complete in less than ten minutes. To measure short-term memory, the Corsi block-tapping task was used as it tests spatial memory. Thus, it was more relevant in the basketball context as athletes were required to remember open spaces and locations rather than words or numbers. In addition, it was also widely used in sports psychological assessment tools such as the Vienna Test System (Furley & Memmert, 2010). As there were no existing validated tests available to measure situation awareness in sports, basketball knowledge, and learning ability in basketball, we adapted tests from other domains for this app. To do so, we engaged the help of seven coaches to provide their knowledge and opinions on these three aspects.

In 1988, Endsley developed the Situation Awareness Global Assessment Technique (SAGAT) to measure the situation awareness of military pilots. To date, SAGAT is the most widely used objective tool for measuring situation awareness (Hogan, Pace, Hapgood, & Boone, 2006). Therefore, we decided to adapt the use of SAGAT in our app. Using the goal-directed task analysis method recommended by Endsley (2000a), a flowchart was drawn to identify the goals and sub-goals in a game of basketball, and the decisions to be made in order to achieve these goals. With this flowchart as a framework for the interviews, we were able to extract the situation awareness requirements in various basketball scenarios and categorize them into the three levels of situation awareness – perception, comprehension, and anticipation. Figure 5.2 depicts the flowchart of goals and sub-goals we have identified.

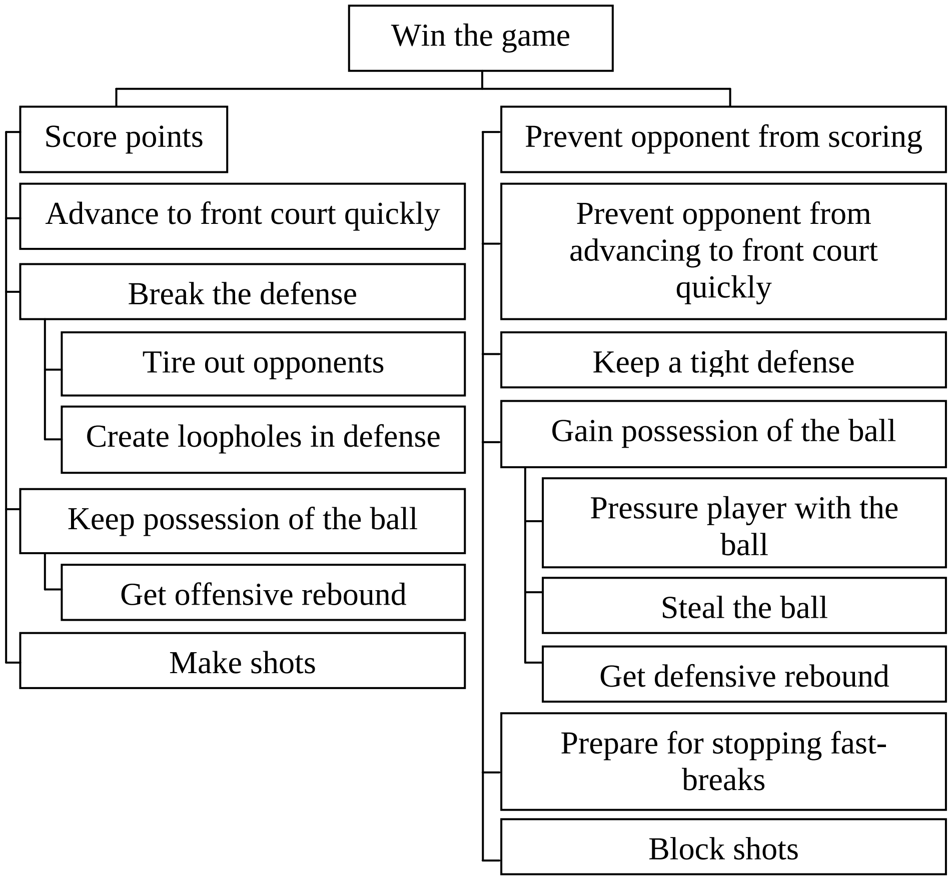

Figure 5.2 Flowchart of main goals and sub-goals in basketball

Videos of actual tertiary-level basketball games were used. Two of the Singapore University Games 2012 basketball matches were filmed and used for this research. As some of the coaches mentioned that there were differences in playing style and speed of male and female players, we used the video of the men's game for male participants and the video of the women's game for female participants. The videos were paused three times for the participants to answer the queries. Based on Endsley's guide, the first pause occurred at least three minutes after the start of the video and subsequent pauses were at least one minute after each other. As it was not possible to test all decision making scenarios in basketball, we asked the coaches to suggest common decision making scenarios that usually occur in all basketball matches. Nine common basketball scenarios were chosen for this test – start of offensive play by a point guard, sideline or baseline throw-in, a generic player's choice to pass, shoot, or drive-in, a fast-break, a defensive player's choice to steal the ball, getting a rebound, choosing whether or not to double-team the player with the ball, deciding whether or not to assist when there is a gap in the defense, and lastly, when to jump and block a shot. Table 5.1 listed all the questions that might be asked for each of these nine scenarios.

Table 5.1 List of situation awareness queries for each basketball scenario

Scenario	Perception questions	Comprehension questions	Anticipation questions
Point guard	Where is the player with the ball located just before the video ended?	Why do you think the player will take that action?	What is the player with the ball likely to do next?
Throw-in	Where are the empty spaces on court?	How will the remaining time on the shot clock affect the thrown-in?	Where do you think the player doing the throw-in will pass the ball to?
Pass/ Shoot/ Drive-in	How many of the attacking team players are open (including player with the ball)?	Why do you think the player with the ball will choose that action?	What do you think the player with the ball will do next?
Fast-break	The video showed a fast break scenario just before it was	Why does the attacking or defending team have an advantage?	What do you think will happen next?

	paused. Which team has the advantage?		
Steal the ball	A defender is shown when the video is paused. Where is the defender located with respect to the player with the ball?	Why should the defender try to or not try to steal the ball?	
Rebound	How many players of each team are in the key (3-second zone)?	Which team is likely to get the rebound?	If the shot does not go in, where do you think the rebound will land?
Double-team	What is the player with the ball doing just before the video is paused?	Why should the defender leave or not leave her player to help double team the player with the ball?	
Assist defense	What type of defense is the defending team using?		What do you think will happen next?
Block a shot		Why should the defender attempt to or not attempt to block the shot?	What is the player with the ball likely to do next?

The domain knowledge section of the cognitive test aimed to measure a participant's knowledge of basketball. Anderson's theory of knowledge acquisition explained that there were two main stages of knowledge – declarative and procedural (Anderson, 1982). Declarative knowledge covered the facts of the domain where a high level of declarative knowledge was represented by a deep understanding of the domain. Procedural knowledge was then represented by the ability to implement this understanding into actions. Therefore, declarative knowledge answered the "what" and "why" components of the domain, while procedural knowledge answered the "how" component of the domain. Starkes and Ericsson (2003) and Abrahama and Collins (1998) also agreed that Anderson's theory was suitable for studying knowledge representations in sports. Hence, the domain knowledge questions section tested the participants on their knowledge of basketball rules (declarative) and concepts (procedural). From the Official Basketball Rules 2012 by the International Federation of Basketball (FIBA, 2012), 15 common and "ought-to-know" rules were shortlisted by the coaches. The coaches were also asked to suggest several basketball concepts that players of different ages and experience should know. After formulating these concepts into questions, the coaches selected 15 of them to be included in the test.

Brehmer and Allard (1991) explained that the ability to learn quickly is especially important in the efficient and effective use of limited resources when making decisions in fast-changing situations. Learning abilities were often tested by measuring accuracies in recall and recognition tasks (Eagle & Leiter, 1964). In this test, we adapted the method used by Mulligan (2001) to study how quickly and accurately sports players learn set plays and divided the section into two parts to measure recall and recognition speed and accuracy. In team sports, set plays were planned sequences of coordinated actions of two or more players on the offensive team to create opportunities to score. As different opponents had different playing styles and defense strategies, set plays were sometimes taught only during the match and players had little time to learn and execute the sequences. For this test, ten set plays were first shortlisted from Breakthrough Basketball (2012), Bobby Cremin's Ultimate Offense (Cremins, 2008) and The Basketball Coaches' Complete Guide to

Zone Offenses (Kimble, 2007). These set plays were then presented to the coaches for them to provide their comments and choose the three best set plays for the participants to learn. We engaged the help of a volunteer basketball team for the recognition part of the learning test. This team was taught the three set plays and asked to play two matches of ten minutes each. During this game, they can choose to run any of three set plays or just play freestyle. The game was recorded on video and edited for use in the app.

5.1.2 Testing and improving the cognitive test app

The testing phase of the cognitive test app began in late October 2012. Two groups of volunteers helped to test out the app. The first group consisted mainly of non-basketball players who were tasked to play around with the app and find problems with the running of the app. After debugging all the problems that were discovered by the first group, the second group of volunteers helped to provide feedback on the app as a cognitive test. This group consisted of basketball players and coaches. Based on their comments and feedback, several changes were made to the cognitive test. For example, most of the volunteers complained that the videos in the situation awareness section were too lengthy and the pauses were too abrupt. They suggested reducing the time to the first pause and to inform the participants on the type of scenario tested so that they can look out for information that is critical to the scenario. As such, the time to the first pause was reduced by about two minutes and the time between subsequent pauses was reduced by about 30 seconds. The participants were also informed on the type of scenario tested for each pause. The number of video clips in the second part of the learning section was reduced from ten to eight. The instructions for each section were also improved to help participants better understand how to take the test.

5.1.3 Final version of cognitive test app

The first section of the test aimed to measure the competitive anxiety of the participants using the CSAI-2 questionnaire. This questionnaire made use of 27 statements to measure one's cognitive anxiety, somatic anxiety, and self-confidence. Examples of these statements include "I am concerned about this competition", "I feel tense in my stomach", "I am confident of coming through under pressure". With respect to each of these statements, participants were required to select one of the given options – "Not at all", "Somewhat", "Moderately so", and "Very much so" (Martens, Vealey, & Burton, 1990). A score of 1 to 4 was given for each response and the measure of cognitive anxiety, somatic anxiety, and self-confidence was obtained by the summation of the response scores for each respective statement. Therefore, the minimum score for each component was 9 and the maximum score was 36.

The second section of the test aimed to measure the short-term spatial memory of the participants using the Corsi block-tapping task. In this task, there were nine blue squares spread out on a 2-dimensional space. The layout of the squares and the sequences used in this task were based on the recommendation by Kessels and colleagues (2000). The squares would be highlighted in orange, one at a time, at a speed of one per second. Participants were then tasked to repeat the highlighted sequence by tapping on the squares when the presented sequence has ended. The sequence began with a length of two squares and increased by one square at a time if the participants got the sequence correct. The maximum sequence length was nine. Participants could make up to two incorrect sequences. This task would end when two incorrect sequences were made or after the completion of the maximum sequence length. For this task, the total number of correctly repeated squares and the average time taken to recall each correct square were recorded.

The third section of the test adapted the use of SAGAT, developed by Endsley (2000a), to measure the situation awareness of the basketball players. Participants were tasked to watch a tertiary-level basketball competition on video and look out for the stated scenario (e.g. fast-break, point guard, rebound, throw-in). They were not allowed to pause, fast-forward, or rewind the video. The video clip would pause automatically during one of the stated scenarios in the game and the last frame of the video would remain on screen for 1.0 second. Thereafter, the participants would be presented with multiple-choice questions asking them about the match that they had just watched. The participants were not allowed to re-watch the video. As situation awareness could be divided into three levels – perception, comprehension and anticipation (Endsley, 1997), the questions used in this test were also categorized into perception-, comprehension- and anticipation-type questions. The number of correct responses for each type of questions was recorded in this section of the test.

The fourth section of the test aimed to measure the knowledge of basketball rules and concepts using ten multiple-choice questions. Participants had to answer five rule-based and five concept-based questions during each test session. The number of correct responses was recorded for this section of the test.

The last section of the test aimed to measure how quickly and accurately a player learns basketball set plays using a recall and recognition task. This section was split into two parts. In the first part, participants were to watch an animated video that showed the sequences of a set play as if it were played out on a strategy board. They were then instructed to list out the steps of the set play. Participants were allowed to return to view the video as many times as needed to correctly list out the entire set play. The number of views, errors made and the time taken to learn and recall the set play were recorded. After successfully recalling the set play, participants were required to recognize the set play. They were presented with eight video clips of basketball games and were instructed to determine if the players did or did not run the set play that they had just learnt. The number of correct responses was recorded in this part. See Appendix C for screenshots of the app.

5.2 Data collection

5.2.1 Research participants

Ninety-three basketball players were recruited at the start of the study. However, some dropped out in the middle of the research. A total of 81 players from nine teams completed the research. There were three teams in each division. The composition of the players in each division was listed in Table 5.2.

Table 5.2 Composition of players in each division

	'A' division	'B' division	'C' division
Sex			
Male	9	14	22
Female	15	11	10
Age at start of competition			
12 years old	0	0	4
13 years old	0	0	11
14 years old	0	12	17
15 years old	0	12	0
16 years old	5	1	0
17 years old	9	0	0
18 years old	8	0	0
19 years old	2	0	0
Competitive playing experience	0	0	2
0 years	0	1	11
1 year	0	4	3
2 years	0	2	8
3 years	6	4	7
4 years	1	9	1
5 years	6	4	0
6 years	3	1	0
7 years	5	0	0
8 years	3	0	0
9 years			
Playing position			
Center	7	10	8
Forward	5	7	9
Guard	7	2	7
Point guard	5	6	8
Total	24	25	32

5.2.2 Research procedure

The research participants had to take the computerized cognitive test three times on three separate occasions. The principal investigator first met with the participants about a month before the start of their respective divisional championships. During that session, the participants were first briefed on the research procedure. They then took the computerized cognitive test to familiarize themselves with the format of the test. The second test session occurred about one to two days before their first match of the championship league and the last test session was held about one to two days before their last match of the championship league. During each of the computerized cognitive test session, the participating team was split into two groups. The second group would take the test after all members of the first group had completed it. The participants took the test after their classes, in a quiet location with proper tables and chairs. The principal investigator was present at all test sessions to answer any questions with regards to the use of the app. Most of the participants were able to navigate through the app without difficulty. The participants took about 30 – 45 minutes to complete each test session.

5.3 Results and analysis

The participants took the computerized decision making test three times. The first session was held about a month before the start of their respective divisional championships for the participants to familiarize themselves with the format of the test. The next two test sessions were held about one to two days before their first and last matches of the championship league to study the differences in the participants' cognitive functions at the start and end of their season. Table 5.3 showed the mean and standard deviation values for the 13 variables recorded by the decision making test at each test session.

Table 5.3 Summary of decision making test results

Results	Pre-season Mean (SD)	First match Mean (SD)	Last match Mean (SD)
Cognitive anxiety score (x_1)	25.3 (5.0)	25.3 (4.9)	24.8 (5.2)
Somatic anxiety score (x_2)	18.2 (4.8)	18.0 (5.0)	17.7 (4.8)
Self-confidence score (x_3)	24.3 (5.2)	24.6 (5.2)	24.7 (5.6)
Short-term memory score (x_4)	42.2 (16.4)	46.7 (16.9)	44.7 (16.8)
Short-term memory time taken per square (seconds) (x_5)	.48 (.09)	.46 (.08)	.45 (.10)
Perception correct answers proportion (x_6)	.49 (.19)	.56 (.19)	.58 (.16)
Comprehension correct answers proportion (x_7)	.46 (.25)	.45 (.20)	.46 (.22)
Anticipation correct answers proportion (x_8)	.40 (.23)	.35 (.24)	.48 (.20)
Domain knowledge score (x_9)	7.3 (1.5)	8.2 (1.0)	8.8 (1.2)
Learning of set plays view count (x_{10})	3.0 (1.6)	2.5 (1.3)	3.4 (1.6)
Learning of set plays error count (x_{11})	1.9 (6.3)	1.2 (4.4)	2.4 (5.3)
Learning of set plays time taken (seconds) (x_{12})	404.0 (215.3)	231.2 (124.5)	431.7 (205.8)
Learning of set plays recognition score (x_{13})	5.1 (1.4)	5.3 (1.7)	4.7 (1.5)

In general, it was recommended for the sample size of the smallest group to be at least five times the number of predictors (Teh, Othman, & Khoo, 2010). Due to the large number of variables collected using the decision making test, the sample size of the smallest group was less than five times the number of predictors. Thus, we could (1) combine the results from all three test sessions and increase the size of each group, or (2) reduce the number of predictors by combining the variables that measure the same cognitive component together. Both methods were used to obtain the discriminant functions for distinguishing the top and bottom half groups of decision makers. The discriminant function obtained from method (1) was statistically significant ($p < 0.001$), with three variables that were found to be more important – cognitive anxiety score (-0.314), somatic anxiety score (-0.504), and self-confidence score (0.857). The group centroids for the top half and bottom half groups were 0.419 and -0.474 respectively. Overall 67.9% of the cases were correctly classified, with 62.3% of the cases correctly classified in the bottom half group and 72.9% of the cases correctly classified in the top half group. Although the discriminant function was significant, the power was not strong. For method (2), the number of variables was reduced by combining some of the variables as shown in the formulas below:

- Short-term memory: $x_{\text{STM}} = (88 - x_4)^* x_5$
- Situation awareness: x_{SA} = [x_6*(*number of perception questions*) + x_7*(*number of comprehension questions*) + x_8*(*number of anticipation questions*)]/(*total number of questions*)
- Learning ability: $x_{\text{L}} = 8 - x_{13} + x_{10} + x_{11} + x_{12}/60$

For short-term memory, the two measures x_4 and x_5 were combined into one variable x_{STM}. The number '88' in the formula was the maximum value of x_4 that a participant could get if he or she recalled all the sequences in the task correctly. Thus, using the formula, we obtained a variable (x_{STM}) that varied inversely with performance in short-term memory. For situation awareness, the proportion of correct answers over the entire test was obtained. This variable (x_{SA}) varied proportionately with performance in the SAGAT test. The formula for the learning ability composite variable (x_{L}) was similar to that of short-term memory. The number '8' in the formula was the maximum value of x_{13} that a participant could get if he got all the recognition questions correct in part two of the learning test. Likewise, x_L varied inversely with performance in the learning ability test. The rest of the variables remained the same and a total of seven predictor variables were used for the discriminant analysis. A separate discriminant function was generated for each of the test sessions. The discriminant function for the pre-season test was insignificant (p = 0.228), while the discriminant functions for the first (p = 0.002) and last (p = 0.014) matches were statistically significant. Self-confidence (0.931) was the only important predictor identified for the first match and the group centroids were 0.541 and -0.613 for the top and bottom half groups. For the last match, self-confidence (-0.694) and somatic anxiety (0.683) were important predictors of decision making ability and the group centroids were -0.477 (top half) and 0.540 (bottom half). The hit ratio was 72.8% for the first match and 71.6% for the last match. Table 5.4 summarized the results of the discriminant analyses using methods (1) and (2).

Table 5.4 Comparison of discriminant analyses for computerized decision making test

			Correct classification (%)		
Method	**Sig.**	**Important predictors**	Top	Bottom	All
(1) Overall	< .001	Self-confidence (.857), somatic anxiety (-.504), cognitive anxiety (-.314)	72.9	62.3	67.9
(2) Pre-season	.228	-	-	-	-
(2) First match	.002	Self-confidence (.931)	72.1	73.7	72.8
(2) Last match	.014	Self-confidence (-.694), somatic anxiety (.683)	72.1	68.4	70.4

In addition, it was also of interest to compare the differences in the participants' cognitive performance at the beginning and end of their competitive season. As the content of the situation awareness, basketball knowledge, and learning ability sections of the test were different for the two test sessions, the change in results across the two test session were compared instead of their absolute values. Table 5.5 displayed the ANOVA results for the comparison between the top half and bottom half groups of participants. Only the differences in the somatic anxiety score was found to be significant (p = 0.021).

Table 5.5 ANOVA comparison of change in decision making test results over one competitive season

	Top half	**Bottom half**			
Test items	Mean (SD)	Mean (SD)	**F**	**df**	**Sig.**
Cognitive anxiety score	.14 (3.03)	.68 (3.67)	.535	79	.467
Somatic anxiety score	1.23 (4.32)	-.79 (3.27)	5.522	79	.021
Self-confidence score	.40 (3.23)	-.82 (4.00)	2.270	79	.136
Short-term memory score	-.58 (18.90)	-3.34 (17.41)	.463	79	.498
Short-term memory time taken per square (seconds)	-.01 (.07)	-.02 (.06)	.770	79	.383
Perception correct answers proportion	.01 (.24)	.04 (.22)	.416	79	.521
Comprehension correct answers proportion	.01 (.24)	.04 (.22)	.181	79	.672
Anticipation correct answers proportion	.10 (.25)	.18 (.29)	1.888	79	.173
Domain knowledge score	.53 (1.33)	.71 (1.37)	.340	79	.561
Learning of set plays view count	.88 (1.73)	.87 (1.80)	.002	79	.969
Learning of set plays error count	2.28 (5.98)	-.11 (5.43)	3.495	79	.065
Learning of set plays time taken (seconds)	206.84 (251.77)	179.55 (204.98)	.281	79	.597
Learning of set plays recognition score	-.16 (2.41)	-.97 (2.37)	2.324	79	.131

5.4 Discussion

The computerized decision making test was a combination of emotional and cognitive tests that measured competitive anxiety, short-term spatial memory, situation awareness, basketball knowledge, and learning ability. The CSAI-2 questionnaire was used to measure the cognitive anxiety, somatic anxiety, and self-confidence levels of the participants at three separate sessions about one month apart. It was noted that cognitive anxiety scores were consistently higher than somatic anxiety scores (see Table 5.3). Cognitive anxiety was defined as "the mental component of anxiety and is caused by negative expectations about success or by negative self-evaluation" and somatic anxiety was defined as "the physiological and affective elements of the anxiety experience that develop directly from autonomic arousal" (Martens et al., 1990). Therefore, the participants tended to think negatively or worry more about their competitions, but they experience less bodily reactions such as racing heart rate or sweaty palms throughout their competitive season. This observation was similar to the results obtained by Swain and Jones (1996) where ten tertiary level basketball players took the CSAI-2 questionnaires before their league matches and their mean cognitive and somatic anxiety scores were 20.25 and 14.97 respectively.

In addition, minimal changes in the participants' cognitive anxiety, somatic anxiety, and self-confidence scores were also observed across the three test sessions. This observation differed from that of Thuot, Kavouras, and Kenefick (1998) who studied 23 high school basketball players throughout their competitive season. They found that the players experienced higher cognitive and somatic anxiety and lower self-confidence when they were playing against stronger opponents. In our experiment, the players experienced similar levels of cognitive anxiety, somatic anxiety, and self-confidence levels just before their first match where they played against a much weaker opponent, and just before their last match where they played against a much stronger opponent. Unlike the study conducted by Thuot et al. (1998), the participants in this experiment did not take the CSAI-2 questionnaire for all their matches. Despite playing against weaker opponents, it was possible that the players did not report lower anxiety levels or higher self-confidence because it was the first match of their competitive season. Y. L. Hanin (2010) explained that it was common for athletes to report high anxiety and low confidence just before the start of their competition due to their negative anticipatory emotions while waiting for the competitive season to begin. Thus, the measurements of the participants' competitive anxiety levels could have been confounded with their negative anticipatory emotions from the impending competition.

Besides the competitive anxiety scores, there was also little changes in the short-term memory scores across the three test sessions. However, the mean short-term memory score (number of correct squares) was much lower than that observed by Kessels et al. (2000). In a study of 70 healthy participants with mean age of 31.2 years old, Kessels and colleagues obtained the mean number of correct squares to be 55.7 (SD = 20.3), while the median for a group of 21 participants below 20 years old was 60.0. The mean number of correct squares obtained from the 81 participants in this experiment was

44.5, while the median was 40.0. This could be due to the introduction of time pressure in the Corsi block-tapping task used in this experiment. A timer was placed at the lower-right corner of the screen during the block-tapping task and participants were instructed to complete the task as quickly and accurately as possible. The presence of a timer induced time pressure on the participants (Bertuccelli & Cummings, 2012) that could affect the capability of their short-term memory adversely. The effect of time pressure on memory has been widely studied and time pressure was known to reduce accuracy in memory tasks (Benjamin & Craik, 2001; Ratcliff, 1978). Thus, it was not surprising for the participants in this experiment to perform worse than those in Kessels's experiment. The results of the remaining sections were not compared across test sessions as the content of each section was different.

Next, discriminant analysis was used to compare the results of the computerized decision making test with the coaches' judgments. Two different methods were used and four discriminant functions were obtained. Three of the discriminant functions were found to be statistically significant but the hit rate of all three functions were below acceptable level. Also, only the competitive anxiety measures were identified as important predictors for all three of the discriminant functions. Self-confidence (0.857), somatic anxiety (-0.504), and cognitive anxiety (-0.314) were important predictors for the discriminant function that combined the data from all three test sessions. Self-confidence (0.931) was the only important predictor for the discriminant function that used the data from the first match (second test session), while self-confidence (-0.694) and somatic anxiety (0.683) were important predictors for the last match (third test session). From the coaches' judgments in the previous section, competitive anxiety was also found to be the most discriminating factor between the two groups of decision makers. Yet, the computerized decision making test seemed to be unable to discriminate the decision makers in the cognitive components.

Many previous researchers have found and demonstrated that experts in a sport exhibit superior cognitive abilities. Campo, Villora et al. (2011) described the cognitive superiority of experts in that they "are faster and more accurate in organizing patterns, have superior knowledge of both factual and procedural matters, possess knowledge organized in a deeper, more structural form, have superior knowledge of situational probabilities, plan their own actions in advance, anticipate the actions of an opponent, and possess superior self-monitoring of tactical decision making process". A Mark Williams and Ericsson (2005) mentioned that it would be fruitful to study working memory in sports and several studies on attention and decision making in sports showed that these two functions rely heavily on working memory (Knudsen, 2007). Karalejic and Jakovljevic (2008) also found that the elite basketball players were significantly better than the intermediate and novice groups in their general intelligence and perceptual abilities, although there was no significant difference in their visual-spatial abilities. The subjective assessment from the coaches' and spectators' ratings in the previous chapter also showed that the better decision makers differed from the poorer decision makers in all of the five emotional and cognitive components. Yet, no significant differences were observed in the objective measurements of the computerized cognitive tests.

K Anders Ericsson, Charness, Feltovich, and Hoffman (2006) explained that experts and novices should only differ in areas that are directly related to their domain of expertise and differences should not be observed in generic cognitive tests. They further listed multiple research studies that pointed in the same direction. Based on their theory, it was expected that the results from the Corsi-block tapping task should not be able to distinguish between the better and the poorer decision makers, as observed in this experiment. However, there had also been exceptions. Bellenkes, Wickens, and Kramer (1997), Green and Bavelier (2003), and Allen, Mcgeorge, Pearson, and Milne (2006) found expert-novice differences on basic attention tasks and generic visual tracking tests among pilots, video-gamers, and radar operators. From these experiments, it seemed that experts had adapted so much to their difficult performance environment that they applied these superior cognitive abilities even to their daily environment. Thus, it might still be possible to differentiate expertise in sports players' spatial memory abilities, but the participants in our experiment have yet to achieve that threshold due to their young age.

Besides the high threshold that possibly demarcates the experts from the novices, the insignificant results may also be due the lack of sensitivity of the Corsi block-tapping task. Furley and Memmert (2010) did a similar experiment by testing 112 male college students using the Corsi block-tapping task, but did not find significant differences between the students with at least ten years of basketball experience and those who did not have any team-ball sports experience at all. They attributed their finding to the lack of sensitivity of the test as there were only nine levels of sequences for participants to recall and repeat. In our experiment, we used the actual number of squares correctly repeated instead of the levels of sequences, as well as the average time taken to tap each correct square (total time taken divide by number of correct squares) in an attempt to increase the sensitivity of the Corsi block-tapping task. Yet, it might be possible that these measures were still inadequate in sufficiently raising the sensitivity of detecting the differences in the better and poorer decision makers. The Corsi block-tapping task could be further modified to increase the difficulty of the higher levels to further distinguish the participants with much better spatial memory. This could be done by changing the speed that the sequences were presented, or changing the locations of the squares for each sequence, or even getting the participants to repeat the sequences in reverse.

The last three sections of the computerized decision making test were domain-specific and thus, should not conform to K Anders Ericsson et al. (2006)'s theory. Yet, significant differences were still not found between the better and poorer decision makers for these sections. In order to measure the situation awareness of basketball players, SAGAT was adapted for use in this experiment. It was widely used in the aviation sector and had been proven to be effective in measuring the situation awareness of pilots, especially when comparing the different types of interfaces used for the multiple instruments and monitors in the cockpit (Endsley, 2000a). Similar to that of the aviation experiments, video simulations were also used to test the situation awareness of basketball players in this experiment. The videos were paused three times and participants were tasked to answer several questions during these pauses. The questions were formulated with the help of the coaches and were deemed appropriate in measuring a player's perception, comprehension, and anticipation abilities.

However, the videos used might have been inadequate in simulating the basketball scenarios realistically. The videos were taken from the spectators' stands, which provided the participants with a third-party perspective. This enabled the participants to be better able to see the 'big picture' than when they were actually playing in the basketball court. For example, a participant watching the video was able to see the movements of all ten players clearly and might quickly identify a double-teaming event when he or she sees a defender moving away from an attacker and running towards the ball. However, if this participant was actually playing on court, he or she might be less aware of the movements of the other players as he or she is also on the move. Even if the participant was the player holding the ball, he or she might be blocked by the defender and might not see another defender running to double-team him or her. In this case, a participant might score high on the SAGAT section, but might not be considered as a good decision maker by his or her coach.

Furthermore, previous researchers had claimed that video presentations do not effectively simulate sports scenarios as they were presented on a 2-Dimensional (2D) surface and this lack of fidelity could influence an athlete's perceptual abilities (Bruce, Farrow, Raynor, & Mann, 2012). In an experiment with expert tennis players, Shim, C., W., and W. (2005) found that the experts exhibited better anticipatory performance when they were faced with a “live” opponent, as compared to a 2D projection of the same opponent. Therefore, the players who were identified by the coaches as better decision makers might also have performed worse in the situation awareness section due to a lack of fidelity in the video presentations.

In the fourth section of the computerized decision making test, the participants were tested on their basketball knowledge through ten multiple-choice questions. The questions for each test session were different. All 30 questions were chosen by the coaches and identified as important knowledge for good decision making in basketball. The coaches were also asked to rate the questions on their level of difficulty so that the 30 questions could be better distributed to maintain the overall difficulty of the basketball knowledge section across the test sessions. Despite including difficult questions, the differences between the top half and bottom half groups of participants were still statistically insignificant. This comes as a surprise as many researchers have found and acknowledged that knowledge plays an important role in decision making in sports (Devine & Kozlowski, 1995; French & Thomas, 1987; Gutiérrez & García-López, 2012; McPherson, 1993). French and Thomas (1987) examined the role of sport-specific knowledge on different sport performance measures for 47 basketball players aged eight to 12 years old. The players were tested at the start and end of their competitive season. A significant correlation was found between an increase in basketball knowledge and improvement in decision making performance for all the players. In addition, expert players were found to have higher basketball knowledge and decision making performance than novice players of the same age. This showed that the expert-novice differences in knowledge and decision making could be observed even at such a young age and should also be observable in 12 to 19 years old basketball players.

However, it was possible that there were too few questions in our experiment to sufficiently detect the differences between the participants' basketball knowledge. In order to measure the various emotional and cognitive components of decision making ability together in a single test session, we had to moderate the participants' time spent on each section so as to minimize their fatigue. This reduced the sensitivity and could be seen in the results as more than 50% of the participants were able to get at least seven out of ten questions correct for each session. Hence, it was difficult to achieve a statistically significant difference between the top half and bottom half groups of decision makers. Although the results were not statistically significant, it was still interesting to note that the findings in this study were similar to the findings of French and Thomas (1987). For the top half group in this experiment, the mean number of correct answers for the pre-season, first match, and last match test sessions were 7.6, 8.2, and 8.8 respectively, while those of the bottom half were 6.9, 8.1, and 8.8 respectively. Like the participants in French's and Thomas's experiment, the basketball knowledge increased over time and the better decision makers scored higher on two out of three of the test sessions. Thus, it might be possible to observe significant differences between the better and poorer decision makers by increasing the number of participants or by increasing the sensitivity of the test.

Lastly, the participants' learning abilities were tested using a customized test. Mulligan (2001) explained that it was important for players of invasion games to be able to learn set plays quickly. This was especially true for basketball games. Coaches were often seen calling for a time-out to explain a new set play to their teams in order to break their opponent's defense. The players had to learn the new set play within 30 seconds and carry it out soon after the time-out is over. Therefore, in this section, the participants were tested on their ability to recall and recognize set plays. Different set plays were used for each test session. The set plays were chosen by the coaches who confirmed that their teams had not learnt them before.

Unlike the experiment conducted by Mulligan (2001) on ice hockey players, the results of this learning section did not seem to be indicative of the basketball players' actual learning speed and accuracy. The participants in our experiment took on average 404.0 seconds to learn the first set play, 231.2 seconds for the second set play, and 431.7 seconds for the last set play. This was much longer than the 30 seconds they have during a time-out event to learn and run a new set play. One possible reason could be due to the need to recall the entire set play in the learning test. In an actual game, most players do not memorize the entire set play during the short time-out period. Instead, they just focused on their own parts and the cues for them to begin acting out their parts. As such, the participants were able to learn and act the set plays out very quickly in a match, while they found it difficult to complete the learning section of the computerized decision making test. During our interview session with the coaches, most of them acknowledged that their players only remembered their own steps during a set play and expected even the best players to be unable to do well in this section. Yet, they also mentioned that it was beneficial for them to remember the whole set play as it makes them more versatile and even allows them to effectively alter the set play according to the situation. Hence, some adult players in their club teams (not included in this experiment) do memorize the full set play as they recognized the benefit of it, but this was not observed in the teenage players in our experiment.

In the second part of the learning ability test, the participants were tasked to recognize the set play that they had just learnt from a series of video clips. On average, the participants were able to recognize about five out of eight video clips correctly, with no significant differences between the better and the poorer decision makers. The coaches mentioned that the ability to recognize set plays in actual basketball games requires a high-level observation skill that is not easy even for senior, more experienced players. Some even mentioned that it is more of a skill that is required of coaches rather than players.

Besides comparing the results of the better and poorer decision makers at each test session, the change in the participants' results from the beginning to the end of their competitive season were also analyzed. Only the change in somatic anxiety was found to be statistically significant (see Table 5.5). As it was out of the scope of this thesis to study the reasons for changes in a player's emotional state, the change in somatic anxiety could only be attributed to fluctuations over the course of the competitive season (Jones, Mace, & Williams, 2000). Nonetheless, it was of interest to consider the less significant changes in the other cognitive components as it might provide insights for future research. In particular, it was noted that the participants in the bottom half group seemed to have improved more than those in the top half group in the situation awareness, basketball knowledge, and learning sections. These three sections were domain-specific, which the participants in the top half group were supposed to be better at. This seemed to imply that players who were lower on the decision making ability scale improved at a faster rate than players who were higher on the decision making ability scale over a competitive season. Although the cognitive tests used in this experiment were incapable of proving this observation significantly, further research work could be done in this area to test this phenomenon in greater detail.

The computerized decision making test seemed to pale in comparison to the decision making rating sheet in terms of its ability to differentiate the cognitive abilities of the better and poorer decision makers. However, its strength lay in its objective assessment as all players took the exact same test and it could also provide more details than the decision making rating sheet. Instead of just looking at the scores of the cognitive tests that were insensitive to the differences between the better and poorer decision makers, the coaches could consider the actual answers of each player for the domain-specific sections. In this way, the coaches would be able to gain an understanding of the players' existing knowledge that observers might not be able to assess just from one round of game play. This might prove to be more useful to the coaches when comparing player-to-player. Furthermore, the coaches need not be involved in the administration of this test at all. The task of getting the prospective players to take the test and invigilating them could be passed to the assistant coaches or teachers-in-charge.

6 STUDY 3: BASKETBALL PERFORMANCE STATISTICS

Performance statistics are commonly used as indicators of player performance in professional sports (ESPNFC, 2014; NBA.com, 2014; NHL.com, 2014). This chapter investigated the use of basketball performance statistics in approximating the coaches' judgments of superior and inferior decision makers. In addition, the contribution of decision making ability to basketball performance was also analyzed and discussed.

6.1 Data collection

The game statistics of the participants were collected to use as an objective measure of their actual basketball performance. Based on the formula (1) developed by Sonstroem and Bernard (1982), the performance statistics that were collected were SHOT%, TP, REB, AS, ST, TO, and PF.

$$Performance = SHOT\% \, (TP+REB+AS+ST) - TO - PF + 10, \qquad (1)$$

where *SHOT%* = field goal and free throw percentage combined; *TP* = total points scored by the individual during the game; *REB* = sum of defensive and offensive rebounds; *AS* = number of assists; *ST* = number of steals; *TO* = number of turnovers; *PF* = number of personal fouls; "10" is a constant used to ensure positive scores. Compared to other basketball performance formulas available today, this formula by Sonstroem and Bernard provided a simple and convenient way of obtaining an indication of overall basketball performance. Other analyses of game statistics at various competitive levels had also found assists, steals, rebounds, shooting percentages, and turnovers to be discriminating factors of basketball performance (Akers & Buttross, 1991;

Ibañez Godoy et al., 2008; Karipidis, Fotinakis, Taxildaris, & Fatouros, 2001; Melnick, 2001; Sampaio, Godoy, & Feu, 2004; Sampaio, Janeira, Ibanez, & Lorenzo, 2006).

These performance statistics were also reflective of the cognitive abilities of the athletes (Allard, Graham, & Paarsalu, 1980; Sampaio et al., 2004) as the performance of winning teams were found to be affected by player decision making quality (Trninić, Dizdar, & Luksić, 2002). The shot percentage (SHOT%) measured an athlete's overall shooting accuracy over the entire game by taking the total points scored by the athlete as a percentage of the total points attempted. Shooting accuracy was expected to be affected by one's competitive anxiety and situation awareness. Wilson, Vine, and Wood (2009) demonstrated that increased anxiety affects one's ability to concentrate on a goal and led to reduced success rate in basketball free throw shooting. Similarly, competitive anxiety was also believed to affect points scored (PS), steals (S), and turnovers (TO), where the visual concentration of a longer duration was essential for successful execution. Besides competitive anxiety, situation awareness also played an important role in making successful shots during the game. To achieve high SHOT% and PS, an athlete needed to be able to perceive an open location and correctly anticipate that the opponents were unable to block the shot. In fact, situation awareness affected all performance statistics as it was required for the entire game of basketball. In order to perform well in basketball, an athlete needs to be able to perceive opportunities, understand the situation and game dynamics, as well as make accurate predictions. To score more points in a game of basketball, an athlete also needs to have good short-term memory, declarative and procedural knowledge of basketball, and learning ability. Good short-term memory allowed the athlete to accurately remember the positions of teammates and opponents on court and quickly identify open spaces to attack and score, and thus, enabled him to score more points and make more assists (A). Adequate declarative and procedural knowledge of the game was essential for athletes to be able to apply game concepts and strategies to score points, and commit less violations and personal fouls (PF), which leads to higher TO. Lastly, the ability to learn quickly and accurately could help the athlete to identify the opponents' strengths and weaknesses in a short time and use this knowledge to create opportunities to win. Therefore, an athlete's learning ability could affect his PS, A, and S scores. Table 6.1 summarized the list of performance statistics that were collected and the respective cognitive constructs that they measure.

Table 6.1 List of performance statistics and cognitive constructs

Performance statistics	Cognitive constructs
Shot percentage (SHOT%)	Competitive anxiety, situation awareness
Points scored (PS)	Competitive anxiety, situation awareness, short-term memory, domain knowledge, learning ability
Rebounds (REB)	Situation awareness
Assists (A)	Situation awareness, short-term memory, learning ability
Steals (S)	Competitive anxiety, situation awareness, learning ability
Turnovers (TO)	Competitive anxiety, situation awareness, domain knowledge
Personal fouls (PF)	Situation awareness, domain knowledge

In this study, we were interested in the players' cognitive performance and how it affected their performance statistics. Therefore, the players were asked to take computerized test (as described in Section 5.1.3) one to two days before the day their performance statistics were collected. As the players may have matches every other day, it would be too disruptive for them to take the computerized test before every match. Moreover, the players would be fatigued and results collected from the computerized test would be less reliable. As such, only the performance statistics from the first and last matches of the participating teams were collected and used for this study.

The first and last matches of all the participating teams were recorded on video. The videos were recorded on full high-definition, with a wide-screen aspect ratio of 16:9 and a resolution of 1920x1080, using an iPhone 4S. Performance statistics of the participating teams and their opponents were obtained from these videos manually. Table 6.2 showed the dates of the matches and the level of competition for each match.

Table 6.2 Dates and competition levels of first and last matches

Team	Date of first match	Level of competition	Date of last match	Level of competition
A-1	23-Apr-2013	Round 1	22-May-2013	Finals
A-2	12-Apr-2013	Round 1	22-May-2013	Finals
A-3	16-Apr-2013	Round 1	22-May-2013	Finals
B-1	18-Jan-2013	East zone round 1	08-Mar-2013	East zone finals
B-2	14-Jan-2013	West zone round 1	04-Mar-2013	West zone round 2
B-3	15-Jan-2013	South zone round 1	17-Apr-2013	Nationals $3^{rd}/4^{th}$
C-1	15-Jul-2013	East zone round 1	19-Aug-2013	Nationals round 1
C-2	10-Jul-2013	West zone round 1	01-Aug-2013	West zone round 2
C-3	22-Jul-2013	South zone round 1	27-Aug-2013	Nationals round 1

6.2 Results and analysis

All of the participating teams won their first match, while six of the teams lost their last match. The mean score difference for the first and last matches were 49.9 (SD = 22.0) and 0.6 (SD = 18.7) respectively. Thus, the first matches were mostly unbalanced games that were favourable for the participating teams, while the last matches were mostly close games that were more stressful for the participating teams (Csataljay, James, Hughes, & Dancs, 2012). A total of nine performance statistics were collected: amount of time a player got to play for that match (min), shooting accuracy, attempted points, points scored, as well as the number of rebounds, assists, steals, turnovers, and personal fouls committed by each player. As the amount of points attempted, points scored, rebounds, assists, steals, turnovers, and personal fouls were affected by the amount of time each player got to play during the game, these statistics were usually normalized by dividing with the player's playing time (Sampaio et al., 2006). This also made the resultant derived rate variables more robust for discriminant analysis (Norusis, 1993). ANOVA test of the two matches revealed significant differences between shooting accuracy (p = 0.024), attempted points per playing time (p = 0.041), points scored per playing time (p = 0.001), assists per playing time (p = 0.001), steals per playing time ($p < 0.001$), and turnovers per playing time (p = 0.015). Hence, the statistics for the two matches were analyzed separately using discriminant analysis.

Table 6.3 showed the ANOVA comparison of the participating players in the top half and bottom half groups for both matches. In general, better decision makers performed better over all aspects of the first match, but significant differences were observed only for three of the performance statistics: playing time, attempted points per playing time, and points scored per playing time. On the other hand, the group of better decision makers committed more turnovers and personal fouls than the group of poorer decision makers during the last match, and the differences between the two groups in terms of their playing time, shooting accuracy, attempted points per playing time, points scored per playing time, assists per playing time, steals per playing time, and turnovers per playing time were statistically significant.

Table 6.3 ANOVA comparison of basketball performance statistics

First match	**Top half**	**Bottom half**			
Game statistics	Mean (SD)	Mean (SD)	**F**	**df**	**Sig.**
Playing time (min)	19.00 (6.56)	12.61 (8.59)	14.33	79	<.001
Shooting accuracy	.34 (.20)	.29 (.30)	.56	79	.458
Attempted points per playing time	1.13 (.72)	.65 (.71)	8.85	79	.004
Points scored per playing time	.44 (.39)	.25 (.24)	6.95	79	.010
Rebounds per playing time	.24 (.18)	.22 (.22)	.21	79	.647
Assists per playing time	.05 (.06)	.04 (.07)	.04	79	.842
Steals per playing time	.17 (.13)	.14 (.16)	.97	79	.328
Turnovers per playing time	.04 (.06)	.05 (.07)	.04	79	.842
Personal fouls per playing time	.05 (.07)	.06 (.11)	.13	79	.720
Last match	Mean (SD)	Mean (SD)	F	df	Sig.
Playing time (min)	22.74 (11.72)	12.43 (10.91)	16.64	79	<.001
Shooting accuracy	.25 (.18)	.12 (.19)	9.09	79	.003
Attempted points per playing time	.81 (.57)	.25 (.39)	25.91	79	<.001
Points scored per playing time	.26 (.21)	.08 (.14)	19.00	79	<.001
Rebounds per playing	.21 (.21)	.15 (.17)	2.01	79	.160

time					
Assists per playing time	.02 (.04)	.01 (.02)	5.73	79	.019
Steals per playing time	.10 (.11)	.03 (.05)	12.96	79	.001
Turnovers per playing time	.09 (.09)	.04 (.06)	6.22	79	.015
Personal fouls per playing time	.07 (.07)	.06 (.09)	.77	79	.384

The performance statistics were then analyzed further using discriminant analysis. The discriminant functions from both matches were significant with $p = 0.011$ for the first match and $p < 0.001$ for the last match. Playing time (0.738) was found to be the most important predictor of the first match while attempted points per playing time (0.805) was the most important predictor of the last match. Other important predictors included attempted points per playing time (0.580) and points scored per playing time (0.514) for the first match, and points scored per playing time (0.690), playing time (0.646), steals per playing time (0.570), shooting accuracy (0.477), turnovers per playing time (0.395), and assists per playing time (0.379) for the last match. The group centroids for the first match were 0.536 (top half) and -0.606 (bottom half) and the group centroids for the last match were 0.660 (top half) and -0.747 (bottom half). Table 6.4 listed the coefficients and structure matrices of the discriminant functions generated from both matches.

Table 6.4 Discriminant function and structure matrix of basketball performance statistics for top half and bottom half groups

Discriminant function	First match		Last match	
	Coefficient	Structure matrix	Coefficient	Structure matrix
Playing time (min)	.104	.738	.053	.646
Shooting accuracy	-1.842	.145	-2.243	.477
Attempted points per playing time	.570	.580	.682	.805
Points scored per playing time	1.535	.514	2.569	.690
Rebounds per playing time	-.914	.090	-2.152	.224
Assists per playing time	-.008	.039	6.312	.379
Steals per playing time	.393	.192	3.941	.570
Turnovers per playing time	-3.072	-.039	1.224	.395
Personal fouls per playing time	2.622	-.070	-.117	.138
Constant	-1.995		-1.385	

The leave-one-out cross-validated classification showed that overall 75.3% of the cases were correctly classified using the discriminant function from the first match and overall 76.5% of the cases were correctly classified using the discriminant function from the last match. As the overall hit rates of both discriminant functions were more than 25% above that due to chance, both could be used to distinguish between the better and poorer decision makers from their performance statistics. Table 6.5 described the classification results for the two functions. Although the overall hit rates of both discriminant functions are similar, the function from the last match was more balanced in its predictive power for grouping participants into the top half and bottom half groups. On the other hand, the function from the first match was less sensitive in grouping the better decision makers.

Table 6.5 Classification results of performance statistics of first and last matches

Predicted group membership using discriminant function of first match				
		Top half	Bottom half	Total
Count	Top half	36	7	43
	Bottom half	13	25	38
Percentage (%)	Top half	83.7	16.3	100.0
	Bottom half	34.2	65.8	100.0
Predicted group membership using discriminant function of last match				
		Top half	Bottom half	Total
Count	Top half	33	10	43
	Bottom half	9	29	38
Percentage (%)	Top half	76.7	23.3	100.0
	Bottom half	23.7	76.3	100.0

In the previous section, it was suggested that some of the cognitive components might be more closely related to specific performance statistics than others (see Table 6.1). As such, we also attempted to study which of the decision making ability ratings, the results of the computerized decision making test, or the results of the physical fitness test were more closely related to basketball performance. The standardized physical fitness test, known as the National Physical Fitness Award (NAPFA), for school-going children in Singapore consists of six stations. Girls (all ages) and boys below 15 years of age were tested on the number of sit-ups they could complete in a minute (abdominal strength), the distance they were able to jump from a standing position (lower limb strength), the distance they were able to reach while sitting with their legs straight (flexibility), the number of inclined pull-ups they could do (upper limb strength), the time they took for shuttle run (short distance speed), and the time they took to complete a distance of 2.4km (long distance speed). Boys who were 15 years old and above were tested on the number of pull-ups instead of inclined pull-ups as a measure of their upper limb strength. This NAPFA test was conducted by the Physical Education teachers of each school in August every year. The participants' NAPFA test results were obtained from their respective teachers for analysis in this experiment.

Using the basketball performance statistics as the response variables, Multiple Linear Regression (MLR) was used to fit an equation for each of the basketball performance statistics using the ratings and results of the tests. Considering only those equations with a significant model fit, a *t*-test was then used to check the significance of the individual regression coefficients. Table 6.6 displayed the regression coefficients that were found to be statistically significant ($p \leq 0.05$). The basketball performance statistics – playing time in minutes (PT), shooting accuracy (S%), points attempted (PA), points scored (PS), rebounds (RB), assists (AS), steals (ST), turnovers (TO), and personal fouls (PF) – were used as the response variables. Performance statistics from the first and last matches were analyzed separately. Five sets of independent variables were tested with each performance indicator. The first set consisted of the coaches' ratings of competitive anxiety (CA-coach), short-term memory (STM-coach), situation awareness (SA-coach), basketball knowledge (BK-coach), and learning ability (L-coach). The second set consisted of the spectators' ratings of the same five cognitive components (CA-spec, STM-spec, SA-spec, BK-spec, L-spec). The third set consisted of the participants' cognitive anxiety (cga-DMTest), somatic anxiety (sma-DMTest), self-confidence (sc-DMTest), short-term memory (STM-DMTest), situation awareness (SA-DMTest), basketball knowledge (BK-DMTest), and learning ability (L-DMTest) results from the computerized decision making test. The fourth set consisted of the participants' results of their physical fitness test from for sit-ups (SU), standing board jump (SBJ), sit-and-reach (SAR), pull-ups (PU), inclined pull-ups (IPU), shuttle run (SR), and 2.4km run/walk (R/W), while the last set compared the participants' years of experience in competitive basketball with their performance statistics. Empty rows (insignificant regression coefficients across all performance statistics) and columns (insignificant regression model across all sets of independent variables) were excluded from the table.

Table 6.6 Statistically significant regression coefficients of basketball performance statistics

Independent variables	Response variables (first match)							
	PT	S%	PA	PS	RB	AS	ST	TO
SA-coach	-	-	-	-	-	-	-.034	-
BK-coach	-	-	-	-	-	-	.015	-
SA-spec	-	-	-	-	-	.024	-	-
L-spec	-	-	-	-	-	-.025	-	-
cga-DMTest	-	-	-	-	.017	-	-	-
sma-DMTest	-	-	-	-	-	-	.009	-
sc-DMTest	-	-	.067	.026	.012	-	.009	-
L-DMTest	-	-	-	-	-	-	-.005	-
IPU	-	-	-	-	-	-	-.005	-
SR	-	-	-	-	-	-	.021	-
Experience	-	-	.082	0.039	-	.011	-	-
Independent variables	**Response variables (last match)**							
	PT	S%	PA	PS	RB	AS	ST	TO
STM-coach	-	-	-	-	-	-	-	.012
L-coach	-	-	-	-	-	-	.020	-
CA-audience	-	-	.139	-	-	-	-	-
STM-audience	-	-	-	-	-	-	.042	-
sc-DMTest	.758	-	-	-	-	-	-	-
SA-DMTest	-	-	-	-	-	-	-	-.159
SBJ	-	.003	-	.003	-	-	-	-
Experience	1.571	-	-	-	-	-	-	-

Table 6.6 identified the cognitive ratings or results and physical fitness results that were found to be related to each performance indicator. In general, self-confidence and the number of years of experience were found to be significantly related to playing time during the last match, while lower limb strength was related to shooting accuracy. The amount of points attempted per minute of playing time was related to the number of years of experience and competitive anxiety, in particular, self-confidence during the first match. The amount of points scored was also related to experience and self-confidence during the first match, but it was more closely related to lower limb strength

during the last match. The number of rebounds obtained by a player was found to be related to his or her cognitive anxiety and self-confidence levels, while the number of assists was related to one's situation awareness, learning ability, and experience. The number of successful steals was related to somatic anxiety, self-confidence, short-term memory, situation awareness, basketball knowledge, learning ability, upper limb strength, and short-distance running speed. Lastly, the number of turnovers committed during the last match was related to short-term memory and situation awareness.

6.3 Discussion

NDM is concerned with studying the differences between expert and novice decision makers in their natural environment (Mascarenhas & Smith, 2011). In this experiment, the line separating the expert from the novice decision makers was determined by the coaches instead of the number of years of experience in basketball like most other studies (K Anders Ericsson et al., 2006). Years of experience might not accurately represent expertise in decision making for teenage basketball players as a younger player (e.g. 10-12 years old) with two years of experience might have experienced less decision making scenarios than an older player (e.g. 16-18 years old) with two years of experience at a higher level. In this experiment, there were no significant differences between the number of years of experience of the top half and bottom half groups of decision makers. K. Anders Ericsson, Krampe, and Romer (1993) explained that people who demonstrate expert performance tended to possess superior cognitive abilities that were required in their respective fields. For example, people who perform exceptionally well in chess were found to have superior memory (Simon & Chase, 1973). Thus, the players' performance statistics were used as a measure of their decision making abilities in their natural environment and tested on how well they reflected the coaches' judgments.

In this experiment, the better decision makers played an average of 19.00 minutes in the first match and 22.74 minutes in the last match, while the poorer decision makers played an average of 12.61 minutes in the first match and 12.43 minutes in the last match (see Table 6.3). The amount of time a player gets to play in a match was usually controlled by the coaches as they were the ones who decide who plays when and for how long. This showed that decision making ability is important in team ball sports such as basketball and is greatly valued by coaches as they chose to play the better decision makers more often than the poorer decision makers both for unbalanced games as well as close games. The better decision makers also attempted to score more points than the poorer decision makers in both matches, and their shooting accuracy and points scored were also significantly higher in the last match. This seemed to imply that the better decision makers perform better at offensive game play. According to Tenenbaum's model (see Figure 2.5), it is possible that the better decision makers were better able to perceive the opportunities to score and take advantage of them, which helped them to do better on these performance statistics.

In addition, the better decision makers made more assists and steals in the last match. Good teamwork and situation awareness were needed for players to make successful assists (Sampaio et al., 2004). In order to make a successful assist, a player needed to be able to work with his or her teammates and accurately anticipate that they would be open to put in the shot. Good situation awareness was also required for players to make successful steals. Players might steal the ball directly from the opponent when he or she was dribbling or holding on to the ball, or intercept a pass between the opponent team players. Thus, they needed to accurately perceive the distance, speed, and even the ball-handling skills of the opponents before deciding whether or not to steal the ball. A failed attempt at stealing the ball might result in a gap in the defense and provide a chance for the opponent to score.

On the other hand, no significant differences were observed between the better and poorer decision makers on the number of rebounds, turnovers, and personal fouls in both matches. The top half group of decision makers obtained more rebounds than the bottom half group for both matches, but the differences were not statistically significant. Although decision making abilities might play a part in rebounding performance, the ability to obtain rebounds might be more affected by the players' physical height and playing positions. Sampaio et al. (2006) found that centers obtain about three times more rebounds than the forwards and guards. He explained that the centers were usually positioned near the key and were closer to the basket than the other players most of the time. Moreover, they were usually physically taller than the other players, bringing them even closer to the basket. When a rebound falls from the basketball, the taller center players were more likely to reach the ball and get the rebound faster than the other players.

The effect of decision making abilities on turnovers and personal fouls were inconsistent as the better decision makers made less turnovers and personal fouls in the first match but more turnovers and personal fouls in the last match. Therefore, turnovers and personal fouls might be less affected by decision making abilities and more affected by other factors such as ball-handling skills (Sampaio et al., 2006) or aggressiveness of playing style (Trninic, Perica, & Dizdar, 1999).

Discriminant analysis was further used to identify the important performance statistics that could be used to discriminate between the better and the poorer decision makers. One discriminant function was generated for each match and both functions were found to be statistically significant and acceptable as a predictive model (hit rate > 75%). Playing time, attempted points per minute of playing time, and points scored per minute of playing time were identified as important predictor variables for both matches, while shooting accuracy, assists per minute of playing time, steals per minute of playing time, and turnovers per minute of playing time were identified as important predictor variables only for the last match (see Table 6.4). Based on the point difference at the end of the matches, the first matches were considered unbalanced games that were in favour of the participating teams and the last matches were considered close games. The results of our experiment seemed to imply that close games were better at bringing out the differences between the better and poorer decision makers.

Rink (2001) explained that it was difficult to separate cognitive abilities from behavioural responses, especially in domains such as sports where cognitive abilities were closely linked with motor execution abilities (Bruce et al., 2012; Gallego, Gonzalez, Calvo, Barco, & Alvarez, 2010). When playing against weaker opponents, the basketball players were able to overcome the opposing team with just their physical strength and superior basketball skills. For example, a stronger basketball player in a fast-break situation could control the ball and run faster than his or her defender to finish the lay-up easily. If the opponent were stronger, it may be difficult for the attacking player to finish the lay-up in one direct move and he or she might have to consider passing the ball to other teammates or making a fake move to create gaps in the defense. Gallego et al. (2010) explained that players had more shooting opportunities and were able to score more points in unbalanced games as the defensive pressure was less than those of close games. Interviews with coaches also revealed that they found it easier to identify good decision making skills when the players were playing against stronger teams. As the players meet with more difficult and challenging situations when playing against stronger opponents, they were exposed to more opportunities for critical decision making. These opportunities bring out the decision making ability and potential of the players as the coaches were able to observe what different players do in similar scenarios. Some coaches might even be able to observe how quickly a player learns about his or her opponents from changes in his or her play throughout the game. A player who was quick to identify the strengths and weaknesses of the opponents was able to make use of this knowledge and adopt strategies that help to create an advantage for winning the game. Therefore, close games provide more decision making opportunities, which were better for discriminating between players' decision making abilities.

Performance statistics were commonly used in basketball to discriminate between groups of players or to study the effects of various factors on team and individual performance. One of the most common uses was to identify the important performance statistics that differentiate the winning teams from the losing teams. Pojskic, Separovic, and Uzicanin (2009) studied the performance statistics of the successful and unsuccessful teams in the 2008 Beijing Olympics, while Ibañez Godoy et al. (2008) conducted a longitudinal study of the performance statistics of successful and unsuccessful teams in the Spanish Basketball League over five years. Pojskic and colleagues found that assists, shooting accuracy, points scored, and rebounds were important predictors of victorious teams in the Olympics. On the other hand, Ibañez Godoy and colleagues found that assists, steals, and blocks were more important predictors of long-term success. Furthermore, Gallego et al. (2010) investigated close games in the Hungarian Basketball League and found that successful free throws and rebounds were the main factors that differentiate the winning from the losing teams in close situations. Besides discriminating between winning and losing teams, performance statistics were also used to compare changes in performance due to game location (Sampaio, Ibafiez, Gomez, Lorenzo, & Ortega, 2008; Silva & Andrew, 1987; Varca, 1980), between sexes and competitive levels (Sampaio et al., 2004), and between different player positions (Sampaio et al., 2006; Trninic & Dizdar, 2000). Although performance statistics were widely used and commonly seen as reliable measures of objective player performance, there were still limitations in using the method.

In invasion games such as basketball, handball or soccer, winning a match is not just about penetrating the defense and making shots. It is also important for teams to maintain possession of the ball and play a more cooperative game as it keeps the ball away from the opponent so they are unable to score. (Campo et al., 2011) However, a more cooperative play affects the players' performance statistics adversely as they make less shots, assists, steals, or rebounds than players who play more aggressively. As such, the performance statistics might not accurately reflect the players' decision making abilities. Nonetheless, differences were observed in the performance statistics and the power of the discriminant function showed that the performance statistics could be used to predict group membership of the decision makers. Therefore, coaches could still use the performance statistics as a reference of player decision making ability.

7 GENERAL DISCUSSION

In this study, we aimed to investigate the decision making behaviour of basketball players in Singapore. Two main research questions were formulated for this thesis. The answers to these questions were explained in this chapter.

7.1 How can we measure decision making?

The first research question was to find out how the decision making ability of basketball players can be effectively measured. Currently, a player's decision making ability is mainly judged by the coaches who observed the player's actions during various decision making scenarios in a basketball match. As such, we investigated the viability of three ways of assessing the decision making abilities of basketball players by comparing how well they reflect the coaches' judgments. The three methods of assessment are: (a) a rating sheet consisting of 12 critical decision making attributes to help guide observers on the areas to focus on when judging the players, (b) a computerized test for players to measure their emotional and cognitive abilities that are critical to their decision making process, and (c) game statistics of the players' actual performance at the beginning and end of their competitive season. The coaches' judgments were used as the main measure of decision making performance and discriminant analysis was used to examine the viability of the three research instruments in approximating the coaches' judgments.

Firstly, we would like to know what attributes influence how decision making behaviour is perceived and whether there are age or gender differences in the decision making behaviour of basketball players in Singapore. This was investigated using the Kano questionnaire where the expectations of the basketball players' decision making performance were obtained from 209 basketball coaches, referees and players. These respondents answered the Kano questionnaire with respect to a specific target group. There were a total of eight target groups: (a) 13- to 14-year-old, male; (b) 13- to 14-year-old, female; (c) 15- to 16-year-old, male; (d) 15- to 16-year-old, female; (e) 17- to 20-year-old, male; (f) 17- to 20-year-old, female; (g) 21 years old and above, male; (h) 21 years old and above, female.

Frequency analysis was used to determine the Kano categories of the decision making attributes in the questionnaire. Twelve decision making attributes were found to be important in how observers perceive the decision making performance of basketball players. Chi-square analysis was then used to compare the results across the target groups and no significant differences were found between the age groups or genders. Thus, the results implied that a generic rating sheet consisting of the 12 important attributes can be used to measure the decision making ability of basketball players across the age groups and for both genders.

Next, we would like to find out if cognitive fitness can be measured like physical fitness, where the overall fitness level is obtained by measuring individual components separately. Tenenbaum's (2003) sports decision making model was used to identify the important emotional and cognitive components that contribute to the decision making process of athletes. A computerized test for players was developed to measure their competitive state anxiety, short-term spatial memory, situation awareness, basketball knowledge, and learning ability.

However, the computerized test was not able to significantly approximate the coaches' judgments. This was attributed to a lack of sensitivity of the individual cognitive tests as they were adapted from other domains and not specifically designed for sports players. Therefore, we cannot conclude on the infeasibility of this format of assessment from this experiment. It is beneficial to continue researching and improving on the computerized test for players as this method of assessment allows us to separate the players' cognitive performance from their physical abilities. Unlike the rating sheet for coaches, the results from this computerized test for players were not confounded with the players' abilities in performing the actions. For example, a player may have chosen to dribble or hold the ball instead of passing it to an open teammate as he lacked the strength to make a successful long pass. Yet, observers using the rating sheet may rate the player poorly, thinking that he was not aware of his teammate who was open for an easy score.

Lastly, we also wanted to know if it was possible to identify the better decision makers by looking at their basketball performance statistics. Performance statistics have been widely used to analyze sports in the professional leagues. Nine performance statistics that measure a basketball players' shooting and rebounding performance, steals, turnovers, and personal fouls were collected from the participants' first and last matches. These statistics were normalized by the amount of playing time each player had in the game. ANOVA analysis showed that the better decision makers attempted more shots and scored more points in both the first and last matches, and had better shooting accuracy, more rebounds, steals, and turnovers in the last match. The participating teams played against weaker teams in their first matches than in their last matches. Thus, the results suggest that better decision makers perform better in more aspects of the game when they are faced with stronger opponents. The players may experience more difficult decision making scenarios when playing against stronger opponents, which provide more opportunities for them to use their decision making abilities to gain an advantage and overcome the difficult situations.

In summary, the viability of the three assessment methods in approximating the coaches' judgments was explored in this thesis. These methods provided a way to measure and compare the decision making ability across players numerically. Table 7.1 summarized the pros and cons of each tool in terms of the resources needed, efficiency, and accuracy of diagnosis. Although the accuracy of the computerized test seemed to pale in comparison to the other two methods, it does not imply that the better decision makers do not have superior ability in the four cognitive components. Results from the rating sheet for coaches show that there are observable differences between the two groups of decision makers. The poor accuracy of the computerized test points to the lack of sensitivity of the four tests in discriminating the expert from the novice decision makers. There are many other existing cognitive tools that have yet to be researched in sports and it is possible to continue to search for more appropriate tools. Therefore, after comparing the three methods, the subjective assessment of the rating sheet for coaches seems to be the most convenient and effective way to diagnose the decision making abilities of teenage basketball players.

Table 7.1 Comparison of the three methods of diagnosing decision making ability in basketball players

	Rating sheet	**Computerized test**	**Performance statistics**
Resources needed	• Observers to rate the players • Inexpensive to print multiple rating sheets if there are many players • May be difficult to find qualified observers	• iPads, proper table and chair setting, invigilators • Expensive to get many iPads to test multiple players together	• Camera, cameraman, and people to transcribe the performance statistics • Inexpensive but time-consuming to transcribe performance statistics for each player
Efficiency of tool	• Many players can be rated by a single observer • Helps to reduce load on coaches by getting more observers	• One player to take the test on one iPad at each time • Coaches need not be present to invigilate the test	• One camera to record one match at each time • Coaches need not be present to watch the matches
Accuracy of diagnosis	• Ratings of coaches can be used to discriminate between the better and poorer decision makers • Results are based on the observers' expectations	• Results of test do not sufficiently discriminate between the better and poorer decision makers • Results can be compared across age groups and teams	• Performance statistics of last match can be used to discriminate between better and poorer decision makers • Performance statistics are dependent on opponents

7.2 How does decision making affect sports performance?

The importance of good decision making abilities in open skill sports has been articulated by researchers over the years (Allard & Burnett, 1985; Araújo et al., 2006; Michael Bar-eli, Tenenbaum, & Elbaz, 1990; Michael Bar-Eli & Tractinsky, 2000; Payne et al., 1988; Tenenbaum, 2003). Therefore, the second research question was to find out how decision making ability affects basketball performance.

The coaches' and spectators' judgments obtained using the rating sheet and the participants' results from the computerized decision making test were used to compare with the participants' basketball performance statistics for their first and last matches. Besides the measures of decision making ability, the players' physical fitness and years of competitive experience in basketball were also used as independent variables to investigate the variance in basketball performance. With this analysis, we may be able to single out possible emotional, cognitive, or physical fitness components that may be more important to certain aspects of basketball performance. It is useful for coaches to know the critical elements of successful performance that can lead the team to victory, especially in close games, as it helps them to better plan training sessions to develop these critical elements in their players and possibly increase their chances of winning (Csataljay et al., 2012).

Firstly, none of the independent variables correlated significantly with the amount of playing time during the first match, while the participants' self-confidence score on the computerized decision making test and their years of experience correlated positively with the amount of playing time during the last match. Unlike the competitive anxiety attributes in the decision making rating sheet that measures a player's ability to manage his or her emotions, the CSAI-2 questionnaire used in the computerized decision making test measures the actual state of the player's competitive anxiety level before the game. This seems to suggest that the coaches did not consider their players' emotional management, cognitive abilities, physical fitness, or experience levels in deciding who to play for the first match against much weaker opponents, but were more concerned with their players' self-confidence and experience levels for close matches against stronger opponents.

Next, shooting accuracy was found to correlate only with jump performance during the last match. This finding shows that a player's shooting efficiency improves with his or her lower limb strength. Basketball is usually seen as a sport where the physical height of players or the jumping abilities are advantageous as players who are taller or able to jump higher are less likely to get their shots blocked by their opponents (Carter, Ackland, Kerr, & Stapff, 2005; Matavulj, Kukolj, Ugarkovic, Tihanyi, & Jaric, 2001). This possibly explains why the better jumpers in our experiment are able to put in more of their attempted shots. However, this jump advantage was only observed in the close last matches but not in the unbalanced first matches.

In the first matches, the participating teams already had the upper hand as they were more skillful than their opponents. It is possible that the opposing team players were unable to keep up with the participating teams and did not pose a threat in blocking their shots. As such, the participating team players were able to make their shots easily, even for the participants with lower jump power. Therefore, better jump ability was not found to be significant in enhancing shooting performance when the participants were playing against weaker opponents.

The number of points attempted by the participants was found to be significantly related to their competitive anxiety measures and years of experience. Players who scored higher on the self-confidence component of the CSAI-2 questionnaire and players with more years of experience were more likely to attempt more shots and score more points in the first match. In the last match, players who were rated higher on their competitive anxiety attributes by spectators were more likely to attempt more shots, while players with more jump power were more likely to score more points. Thus, higher levels of self-confidence and years of experience have helped the participants of this experiment to increase their shooting opportunities and score more points in favourable, unbalanced matches, but not in close matches. As the more experienced players may have seen similar defense styles before, they are more likely to identify the common lapses in defense. These lapses are more evident when playing against weaker opponents as they are likely to be slower in covering up the gaps in their defense. As such, the more experienced players are able to take advantage of these opportunities to shoot and score more points. This may also help them with assisting their teammates to the basket as they are more likely to spot their teammates in the defense gaps and pass the ball to them.

Many previous researchers have also found self-confidence to be positively correlated with sports performance (Craft et al., 2003; Parfitt & Pates, 1999; J. Taylor, 1987; Thomas, 1994; Woodman & Hardy, 2003). This possibly explains the positive correlation between self-confidence and shooting, rebounding, and steals performances of the participants. Attempting shots, rebounds, or steals in basketball involves risks. A missed shot may lead to a rebound opportunity where the opponent can gain possession of the ball; an unsuccessful rebound may lead to a fast-break opportunity for the opponents, while an unsuccessful steal may lead to a gap in defense that the opponents can take advantage for an easy score. Hence, results of our experiment seems to support the findings of Krueger and Dickson (1994) that people who are more confident of themselves are more likely to take risks.

However, with stronger opponents, the risk of attempting shots increases greatly as the opponents have a higher chance of scoring points from the unsuccessful attempts at shooting, rebounding, or stealing. With just higher self-confidence or experience alone, the participants in our experiment did not make significantly more attempted shots, score more points, obtain more rebounds, or make more steals in their last matches. It is possible that the more experienced players with higher self-confidence did attempt more shots or score more points in close games, but the interaction effects of the independent variables were not studied in this experiment due to the small sample size and the scope of the paper.

Significant correlations were also observed for rebounds, assists, and steals in the first match, as well as steals and turnovers in the last match.

However, some of these correlations seem to contradict previous research findings. Cognitive anxiety scores were found to correlate positively with the number of rebounds, learning ability ratings were found to correlate negatively with the number of assists, learning ability scores, situation awareness ratings, and arm strength were found to correlate negatively with the number of steals, somatic anxiety scores were found to correlate positively with the number of steals, and short-term memory ratings were found to correlate positively with the number of turnovers. These results contradict previous findings that anxiety adversely affects performance (Behan & Wilson, 2008; Janelle, 2002), while learning ability, situation awareness, and short-term memory enhances performance (Endsley, 2000b; Furley & Memmert, 2010; Starkes & Ericsson, 2003; Tenenbaum, 2003). The contradictory results could be due to the lack of variance in these performance statistics. For example, the number of points scored in the first match ranged from zero to 36, while the number of assists only ranged from zero to four and more than half of the participants made zero assists.

The five sets of independent variables analyzed in this experiment seemed weak in explaining the variance of basketball performance consistently and even contradictory in some cases. There are two main difficulties in using these performance statistics to study the contribution of decision making abilities to basketball performance. Firstly, it is difficult to separate influence of cognitive abilities from motor execution in sports performance (Bruce et al., 2012; Gallego et al., 2010; Rink, 2001). Turner and Martinek (1999) explained that correct decisions do not necessarily lead to correct actions. For instance, a player may have correctly identified an open teammate and makes a quick pass to him or her for an easy shot. However, he or she may have lacked the strength or accuracy in making the pass, which allowed the opponent to steal the ball and resulted in a turnover for his or her own team. In this case, the player may have scored well on the cognitive assessments, but poorly in terms of his or her performance statistics. Gutiérrez and García-López (2012) found that basketball players who were better in decision-making performed better in getting open, tackling, marking players without the ball, and double-teaming. However, the performance statistics were unable to reflect the performance of the players in these aspects as they require subjective assessment of how well the acts were performed.

In addition, the measures of competitive anxiety were also poor in explaining the variance in basketball performance. Emotional factors such as competitive anxiety fluctuate from game to game and were found to explain variance in sports performance (Behan & Wilson, 2008; Janelle, 2002; Parfitt & Pates, 1999; J. Taylor, 1987; Tenenbaum, 2003; Thomas, 1994). Terry and Youngs (1996) explained that psychological state measures tend to be better predictors of performance in sports that are of shorter duration (less than ten minutes) such as bobsleigh, swimming, rowing, and wrestling, and found that they were insignificant predictors of performance in rugby and cricket. Like most previous experiments, the CSAI-2 questionnaire used in this experiment was only administered once before the competition (Filaire, Sagnol, Ferrand, Maso, & Lac, 2001; Lundqvist, Genttä, & Raglin, 2011; Ryska, 1998; Stoeber, Otto, Pescheck, Becker, & Stoll, 2007; Swain & Jones, 1996; Terry &

Youngs, 1996; Woodman & Hardy, 2003). As such, the fluctuations in the participants' competitive state anxiety throughout the game were not captured.

Jones et al. (2000) measured the emotional fluctuations of athletes during their games and found that they predict variation in performance significantly better than pre-competitive assessments. The competitive anxiety levels of the participants in our experiment could have fluctuated throughout their game, resulting in the poor predictive ability of the pre-competition CSAI-2 assessment measures. There may have been wider fluctuations in the last match as Cerin et al. (2000) found that athletes experience more stress when their teams are winning or losing by a small margin and this heightened stress level leads to fluctuations in their competitive anxiety levels. As the participating teams are more equally matched with their opponents in the last matches, they experienced more periods of high stress where they were winning or losing by a few points. This possibly explains why the CSAI-2 measures were unable to explain the variance in any of the performance statistics for the last match, except for playing time. In our experiment, it is difficult to administer the CSAI-2 questionnaire throughout the basketball matches as it is too intrusive and may affect the players' performances.

Secondly, measures of individual game performance in team sports have been extensively researched and are known to be difficult to accurately represent a player's actual performance (Chen & Rovegno, 2000; Grehaigne, Godbout, & Bouthier, 1997; Griffin & Richard, 2003). Although the performance statistics used in this experiment are commonly used as performance indicators in the sports domain, it may not accuracy represent the actual quality of play. In invasion team sports such as basketball, netball and soccer, team performance depends on players with complementary skills. Having good individual performance statistics is usually not due to individual effort, but the work of the entire team. For example, a player may be able to obtain a rebound because his teammates helped to box-out the opponent players so that they are unable to run into the key to fight for the rebound. In our experiment, there were less significant relationships between the independent variables and the performance statistics in the last match than in the first match. As the participating teams played against stronger opponents in their last matches, they may have displayed more teamwork and played cooperatively in order to break through the tougher defense. Therefore, their performance statistics were less indicative of their individual performance in the last match.

There are also different roles for different players to play in basketball. These roles may allow some players to have more shooting opportunities such as the forwards or centers due to their positions on court, while other roles such as the point guards may have more turnovers as they are usually the ones dribbling the ball (Sampaio et al., 2006). It is difficult to separate our participants by their playing positions as most players within this age group play several positions even within a match. Most players in Singapore only start learning to play basketball competitively at about 10 to 12 years old. Thus, the coaches still continue to expose their players to the requirements of different playing positions by allowing them to take on the different roles. As the participants in this experiment do not have fixed playing positions, it is difficult to separate their performance statistics based on the positions that they play. Moreover, the players' performance statistics are dependent on their opponents' abilities. Even if the opponent teams are the same, the opponents' performance may also vary from match to match (Hughes & Bartlett, 2002). The poor results of this analysis showed that it is not feasible to combine the performance statistics of all the participating teams and analyze them together.

8 CONCLUSION AND FUTURE WORK

8.1 Introduction

Sporting success depends on a combination of abilities in different areas (Ackerman, 1988). An athlete cannot rely on physical fitness or physiology alone to win sports games, be it archery, bowling, or swimming. This is even more evident in team sports such as basketball. In studies of basketball performance, it is important to consider the athletes' cognitive, perceptual, motor, and psychological abilities that underlies their performance (Derm, Kioumourtzoglou, & Tzetzis, 1998). Although most early researchers focused on the physical and physiological aspects of sports performance, there has been increasing interest in the cognitive and psychological aspects in the recent years (K Anders Ericsson et al., 2006). Therefore, this thesis focused on decision making as a central cognitive requirement of sports performance and compared three ways of estimating the coaches' judgments of their players' decision making abilities.

This chapter concludes this research study by presenting the contributions and limitations of the study, as well as the recommendations for future research.

8.2 Contributions

The Direct School Admission (DSA) programme was introduced in 2004 for secondary schools and junior colleges in Singapore. Through this programme, the participating schools are allowed to select students based on their non-academic achievements and talents. As such, it is now common for coaches of various sports to conduct DSA trials to select their prospective players. These coaches usually have just a few hours to observe and assess up to 30 players at a time. Due to limited time and resources, the basketball coaches usually assess the prospective players' physical fitness and basketball skills using training drills, and get them to play matches against each other to assess their decision making behaviour and playing styles. The coaches explain that it is most difficult to assess the players' decision making abilities as they have to observe many players in a single match and the players may not have sufficient opportunities during the match to display their decision making abilities. Moreover, it is most beneficial to be able to accurately assess decision making abilities as it is easier to train a player's physical fitness and basketball skills than to teach them how to make the correct decisions in limitless scenarios.

In the first study, critical attributes that contribute to decision making performance in basketball were identified using the Kano analysis. A rating sheet was then developed using these decision making attributes. This rating sheet for coaches can serve as a guide for the subjective assessment of decision making abilities. Coaches explained that it is easy for them to identify the best and worst decision makers from a group of players, but it is difficult for them to judge the players who are in the middle. In such cases, they usually engage the help of assistant coaches and senior players. Therefore, the coaches can make use of this rating sheet to guide the assistant coaches and senior players in focusing on the same attributes and obtain their opinions on them. This rating sheet can also be further developed into a mobile application that uses the coaches' discriminant function to automatically calculate the discriminant score for each player and use this score to rank the players. In this way, the coaches' judgments can be approximated using the judgments of the assistant coaches and senior players. Thus, the mental fatigue of the coaches can be reduced and the prospective players can also have a fairer assessment of their decision making abilities.

Besides the rating sheet for coaches, a computerized decision making test was also developed. This decision making test was developed as a mobile application that runs on the Apple iOS platform. As the DSA trials are usually conducted at the basketball courts, a mobile application makes it easier and more convenient for the coaches as it reduces the logistical need of having to prepare a computer lab for the prospective players to take the test. Although the computerized test is not as effective as the rating sheet as a diagnostic tool, it can be used as a training tool. Coaches have found the situation awareness and basketball knowledge sections particularly useful in highlighting inadequacies in the players' knowledge and understanding of the sport. In the situation awareness section, nine scenarios were tested. All the nine scenarios are commonly encountered in every basketball match, yet not every player know what to look out for in each scenario. For example, when a generic player is holding the ball within the three-point line and deciding whether to shoot, he or she may only consider the distance from the defender. If the defender is far away, he or she may choose to shoot. However, coaches mentioned that players should also be aware of the time left on the shot-clock and the number of rebounders in the key when deciding to shoot. Therefore, by looking at the players’ responses to the questions on the SAGAT section, the coaches are able to find out if their players were aware of the remaining time and the number of rebounders in that scenario. Through this computerized decision making test, the coaches can identify the areas that their players are lacking in and better cater the training needed for each team of players.

The rating sheet for coaches and basketball performance statistics were found to be acceptable for predicting decision making ability. Both methods help to quantify decision making performance, which makes it easier for coaches to make comparisons across their players. It is usually easy for coaches to identify the top few and last few, but not those in the middle. With the rating sheet, the coaches can better compare the players in the middle group using the ratings of each attribute. Moreover, this rating sheet can provide better feedback to the players as they can easily identify the attributes that they lacked and how much they pale in comparison to the best player on the team. The coaches’ verbal feedbacks are usually descriptive and may be difficult for the players to understand exactly what areas to work on. The performance statistics can also help coaches identify players who perform better in areas other than shooting. When watching basketball games, it is easy to be distracted by players who score more points. Therefore, the coaches can use the performance statistics to help them identify players who do not score well but are able to make assists and steals.

This study also contributed to the research of decision making by comparing three types of assessment methods. Although K Anders Ericsson et al. (2006) recommended a benchmark of ten years of experience to differentiate between experts and novices, results of this study showed that there are significant expert-novice differences between the decision making abilities of youth basketball players who had less than ten years of experience. These expert-novice differences were observable by the human eye and reflected in the players' basketball performance but not detected by the computerized decision making test. Cognitive tests with higher sensitivity are needed to significantly differentiate between decision making abilities. Results of this study also showed that subjective assessment is still the best way to identify the differences between the decision making abilities of young basketball players.

In summary, this research contributed to the study of decision making in sports by developing and comparing different methods of diagnosing decision making abilities of teenage basketball players in Singapore. While previous research focused on the expert-novice differences in high level athletes, this study helped to better understand decision making expertise in the early stages by focusing on younger players.

8.3 Limitations and challenges of this study

The human cognitive process is highly complex and it is still largely a 'black box' despite years of research in psychology and neurology. Many researchers have developed their own theories and models of how the human brain works (Endsley, 2000b; K. Anders Ericsson & Kintsch, 1995; Humphreys & Revelle, 1984; Kahneman, 2003; Rasmussen, 1983; Ross, Klein, Thunholm, Schmitt, & Baxter, 2004; Salthouse, 1991; J. C. Taylor &

Evans, 1985; Tenenbaum, 2003; Wickens, 1992a), and none have been proven to be superior to the rest. The decision making model developed by Tenenbaum (2003) that was used in this study, is just one of the many existing models of the human information processing system. Although Tenenbaum developed this model to illustrate the decision making process in most open sports, it has its limitations. This model considers only visual input as the main source of information. As such, the role of auditory information was left out of this experiment. In sports such as basketball, auditory input also plays an important role in providing information to the decision maker. For example, a player may not focus his or her visual attention on the shot clock when attacking. Yet, he or she may obtain the information when the supporters count down the last ten seconds on the shot clock. This additional auditory information may cause a player to decide to hasten his or her game play and take a quick shot at the basket.

In addition, this experiment is further limited by the small sample size. Due to the poor research culture in Singapore, especially in the area of sports, it was difficult to get the coaches and players to participate in the research. The initial research plan for this study included participants from the age of ten years as that is the age that students in Singapore are allowed to play basketball competitively. However, all the primary schools were not interested in letting their students take part in the research. Thus, only players from 12 to 19 years old took part in this research. It was also difficult to recruit participants from these ages. Ten secondary schools and five junior colleges were approached, but only three secondary schools and two junior colleges agreed to participate in this study.

Emotions are known to affect sports performance. In this study, only one type of emotion – anxiety – was measured. Although anxiety is the most commonly experienced emotion in competitive sports (Laborde, Dosseville, & Raab, 2013), athletes also experience other emotions such as happiness and satisfaction. These emotions may cause variation in their sports performance that cannot be explained in this thesis. Moreover, only one test was used to measure competitive anxiety and each of the cognitive components in the computerized decision making test. Due to limited time and resources, as well as to minimize the fatigue of the participants, only the most commonly used tests that were suitable for this experiment were used to provide measurements for each component.

8.4 Recommendation for future research

A cross sectional study design was used for this research to compare the various assessment methods and to investigate the roles of the cognitive abilities in the athletes' decision making abilities. This study design allows the investigation of multiple variables at one time, but it does not provide information on cause-and-effect interactions and developmental changes over time. Thus, future studies may consider using a longitudinal design to better understand how decision making performance changes as the athlete matures. It can also provide insights on whether the identification of superior cognitive abilities during youth can be used to predict better decision making performance in the later years. Besides expanding the research to include high level athletes, changes in the athletes' sports performance, cognitive abilities, and emotional fluctuations throughout their competitive seasons can also be observed in a longitudinal study. With a larger sample size, the differences in the athletes' performance statistics between playing positions, gender, age, experience, and other factors can also be analyzed.

The computerized decision making test should also be improved for future research as the current version is incapable of identifying significant differences between the better and poorer decision makers. For example, the Corsi block-tapping task lacked the sensitivity, while the SAGAT tool lacked the fidelity needed to successfully simulate the decision making scenario. The Corsi block-tapping task can be modified to increase the difficulty and sensitivity or it can be replaced by another short-term spatial memory test entirely. With the advent of technology, future versions of the SAGAT tool may use videos from the first person perspective by attaching cameras on the players such as Google Glass (https://www.google.com/glass/start/) or by using 3-Dimensional (3D) computer graphics. The computerized decision making test can also be further modified to cater to a variety of sports. This can be done by first identifying the cognitive functions that are important for each sport and finding or developing cognitive tests that are most suitable for testing these functions. The common tests can then be programmed together to form a generic decision making test.

Future research may also consider studying the effect of training cognitive skills on the athletes' decision making abilities and use the Critical Decision Method (CDM) to better understand the decision making process of athletes in their natural environment. G. A. Klein, Calderwood, and Macgregor (1989) explained that CDM helps to identify decision points and investigates the factors that each decision maker evaluates at each decision point, which makes it useful for identifying training requirements. Using this method, researchers may be able to better observe the expert-novice differences and develop training devices that work on these differences.

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Appendix A – Kano questionnaire used to categorize decision making attributes

Questionnaire for Decision Making Attributes: KANO SURVEY. This survey is to examine how we judge a basketball player's decision making ability by looking at the factors that affect his or her performance. The questionnaire would take less than **10 minutes** to accomplish. **All the information provided is kept strictly confidential**. Please try to give your best estimate rather than leaving the answers blank. Your time is greatly appreciated.

SECTION A	**GENERAL INFORMATION** This section asks questions about your demographic attributes. It will be helpful in making comparisons between categories, such as age, experience, etc.

1. Gender **:** ☐ Male ☐ Female
2. Age (years) **:** ☐ ≤ 15 ☐ 16 – 20 ☐ 21 – 30 ☐ 31 – 40 ☐ 41 – 50 ☐ > 50
3. Experience in watching basketball matches (matches per year) **:**

   ☐ 0 – 5 ☐ 6 – 10 ☐ 11 – 15 ☐ 16 – 20 ☐ > 20
4. Experience in playing basketball recreationally **:**

   ☐ No ☐ Seldom ☐ Once a year ☐ Once a month ☐ Frequently
5. Experience in playing basketball competitively (years) **:**

   ☐ 0 ☐ 1 – 5 ☐ 6 – 10 ☐ 11 – 15 ☐ > 15

   Highest level you competed in **:**

   ☐ Intra-school/college ☐ Zone ☐ National ☐ International

   When was the last competition you played (years ago) **:**

   ☐ 0 ☐ 1 – 5 ☐ 6 – 10 ☐ 11 – 15 ☐ > 15
6. Experience in coaching basketball (years) **:** ☐ 0 ☐ 1 – 5 ☐ 6 – 10 ☐ 11 – 15 ☐ > 15

SECTION B	**KANO SURVEY** This section aims to explore how we judge a ________________ basketball player's performance of the various decision making attributes. There are 5 parts in this section: A – *Knowledge and concept of basketball*, B – *Anxiety, self-confidence*, C – *Short term memory*, D – *Situation awareness*, E – *Learning ability*.

Instructions:

Based on your experiences in the basketball, please encircle one of the following **five choices**:

5 = I am impressed by players who are able to do this
4 = I expect players to do this or behave this way
3 = I am neutral
2 = I dislike it when players do this but I can understand when they do this
1 = I dislike it when players do this and I cannot accept it

No	Player's actions	Choices				
A	**KNOWLEDGE AND CONCEPT OF BASKETBALL**					
1	a. Player shows that he/she **is** able to understand the pace of the game and react accordingly	1	2	3	4	5
	b. Player shows that he/she **is not** able to understand the pace of the game and react accordingly	1	2	3	4	5
2	a. Player shows that he/she **is** able to control the pace of the game to organize his/her team	1	2	3	4	5
	b. Player shows that he/she **is not** able to control the pace of the game to organize his/her team	1	2	3	4	5
3	a. Player **communicates** effectively with teammates on court	1	2	3	4	5
	b. Player **cannot communicate** effectively with teammates on court	1	2	3	4	5
4	a. Player **knows** basketball terms (e.g. layup, outlet, backdoor)	1	2	3	4	5
	b. Player **does not know** basketball terms (e.g. layup, outlet, backdoor)	1	2	3	4	5
5	a. Player shows that he/she **knows** most of the rules in basketball	1	2	3	4	5
	b. Player shows that he/she **does not know** most of the rules in basketball	1	2	3	4	5
6	a. Player shows that he/she **understands** most of the referee's hand signals	1	2	3	4	5
	b. Player shows that he/she **does not understand** most of the referee's hand signals	1	2	3	4	5

No	Player's actions	Choices				
B	**ANXIETY, SELF-CONFIDENCE**					
1	a. Player **looks** calm and composed before the match begins	1	2	3	4	5
	b. Player **does not look** calm and composed before the match begins	1	2	3	4	5
2	a. Player shows that he/she is competitive	1	2	3	4	5
	b. Player shows that he/she is not competitive	1	2	3	4	5
3	a. Player **looks** lost during the match	1	2	3	4	5
	b. Player **does not look** lost during the match	1	2	3	4	5
4	a. Player **looks** distracted during the match	1	2	3	4	5
	b. Player **does not look** distracted during the match	1	2	3	4	5
5	a. Player **fumbles** with the ball under pressure	1	2	3	4	5
	b. Player **does not fumble** with the ball under pressure	1	2	3	4	5
6	a. Player shows that he/she **is** afraid to get the ball	1	2	3	4	5
	b. Player shows that he/she **is not** afraid to get the ball	1	2	3	4	5
7	a. Player shows that he/she **is** eager to get the ball	1	2	3	4	5
	b. Player shows that he/she **is not** eager to get the ball	1	2	3	4	5
8	a. Player **plays** aggressively on court	1	2	3	4	5
	b. Player **does not play** aggressively on court	1	2	3	4	5
9	a. Overall, player shows that he/she **is** confident	1	2	3	4	5
	b. Overall, player shows that he/she **is not** confident	1	2	3	4	5
10	a. Overall, player shows that he/she **is** nervous	1	2	3	4	5
	b. Overall, player shows that he/she **is not** nervous	1	2	3	4	5

Choices:
5 = I am impressed by players who are able to do this
4 = I expect players to do this or behave this way
3 = I am neutral
2 = I dislike it when players do this but I can understand when they do this
1 = I dislike it when players do this and I cannot accept it

No	Player's actions	Choices				
C	**SHORT-TERM MEMORY**					
1	a. Player **shoots** at the wrong basket	1	2	3	4	5
	b. Player **did not shoot** at the wrong basket	1	2	3	4	5
2	a. Player **remembers** where to run	1	2	3	4	5
	b. Player **does not remember** where to run	1	2	3	4	5
3	a. Player **remembers** to carry out strategies or plays	1	2	3	4	5
	b. Player **does not remember** to carry out strategies or plays	1	2	3	4	5
4	a. Player **remembers** where opponents usually take shots	1	2	3	4	5
	b. Player **does not remember** where opponents usually take shots	1	2	3	4	5
5	a. Player **repeats** the same mistake(s)	1	2	3	4	5
	b. Player **does not repeat** the same mistakes(s)	1	2	3	4	5

Choices:

5 = I am impressed by players who are able to do this
4 = I expect players to do this or behave this way
3 = I am neutral
2 = I dislike it when players do this but I can understand when they do this
1 = I dislike it when players do this and I cannot accept it

No	Player's actions	Choices				
D	**SITUATION AWARENESS**					
1	a. Player shows that he/she **is** alert	1	2	3	4	5
	b. Player shows that he/she **is not** alert	1	2	3	4	5
2	a. Player shows that he/she **is** able to identify and pass the ball to teammates with better opportunities	1	2	3	4	5
	b. Player shows that he/she **is not** able to identify and pass the ball to teammates with better opportunities	1	2	3	4	5
3	a. Player shows that he/she **is** able to read opponents' moves	1	2	3	4	5
	b. Player shows that he/she **is not** able to read opponents' moves	1	2	3	4	5
4	a. Player shows that he/she **is** aware of remaining time and game score	1	2	3	4	5
	b. Player shows that he/she **is not** aware of remaining time and game score	1	2	3	4	5
5	a. Player shows that he/she **is** able to pass the ball to teammates successfully without looking directly at them	1	2	3	4	5
	b. Player shows that he/she **is not** able to pass the ball to teammates successfully without looking directly at them	1	2	3	4	5
6	a. Player shows that he/she **knows** when to help out teammates when defending	1	2	3	4	5
	b. Player shows that he/she **does not know** when to help out teammates when defending	1	2	3	4	5
7	a. Player shows that he/she **knows** when to help out teammates when attacking	1	2	3	4	5
	b. Player shows that he/she **does not know** when to help out teammates when attacking	1	2	3	4	5
8	a. Player shows that he/she **is** aware of open spaces and opportunities on court	1	2	3	4	5
	b. Player shows that he/she **is not** aware of open spaces and opportunities on court	1	2	3	4	5
9	a. Player shows that he/she **is** aware of players being substituted on court	1	2	3	4	5
	b. Player shows that he/she **is not** aware of players being substituted on court	1	2	3	4	5
10	a. Player shows that he/she **is** aware of how his/her teammates move around the court	1	2	3	4	5
	b. Player shows that he/she **is not** aware of how his/her teammates move around the court	1	2	3	4	5
11	a. Overall, player shows that he/she **is** aware of what is going on around him/her	1	2	3	4	5
	b. Overall, player shows that he/she **is not** aware of what is going on around him/her	1	2	3	4	5

Choices:
5 = I am impressed by players who are able to do this
4 = I expect players to do this or behave this way
3 = I am neutral
2 = I dislike it when players do this but I can understand when they do this
1 = I dislike it when players do this and I cannot accept it

No	Player's actions	Choices				
E	**LEARNING ABILITY**					
1	a. Player shows that he/she **is** able to understand and carry out new strategies or plays quickly	1	2	3	4	5
	b. Player shows that he/she **is not** able to understand and carry out new strategies or plays quickly	1	2	3	4	5
2	a. Player shows that he/she **is** able to identify opponents' strengths and weaknesses quickly	1	2	3	4	5
	b. Player shows that he/she **is not** able to identify opponents' strengths and weaknesses quickly	1	2	3	4	5
3	a. Player shows that he/she **is** quick to react to situations	1	2	3	4	5
	b. Player shows that he/she **is not** quick to react to situations	1	2	3	4	5
4	a. Player shows that he/she **is** able to follow coaches' instructions and carry them out correctly	1	2	3	4	5
	b. Player shows that he/she **is not** able to follow coaches' instructions and carry them out correctly	1	2	3	4	5
5	a. Player shows that he/she **is** able to understand the rationale behind coaches' instructions or strategies	1	2	3	4	5
	b. Player shows that he/she **is not** able to understand the rationale behind coaches' instructions or strategies	1	2	3	4	5

Choices:
5 = I am impressed by players who are able to do this
4 = I expect players to do this or behave this way
3 = I am neutral
2 = I dislike it when players do this but I can understand when they do this
1 = I dislike it when players do this and I cannot accept it

Appendix B – Rating sheet for coaches provided to coaches

Decision making questionnaire

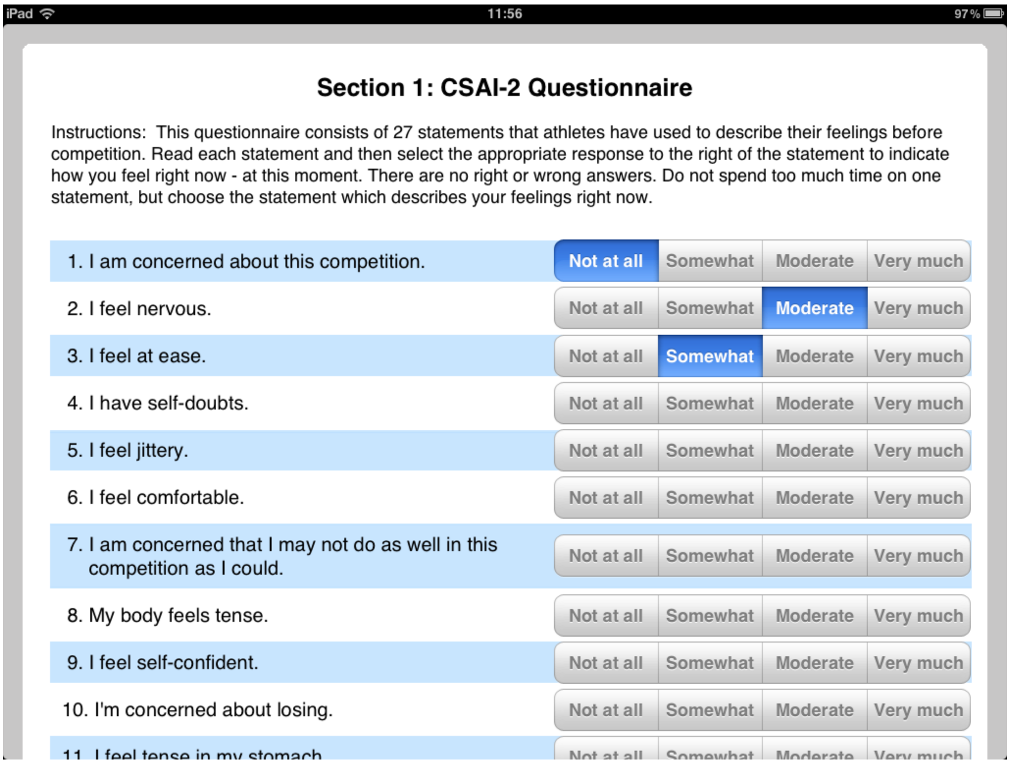
Name of player:

School:

Instructions: The table below shows a list of attributes that affects a player's decision making performance in a game of basketball. With reference to the player mentioned above, please highlight a number from 1 (strongly disagree) to 7 (strongly agree) on the right that best represents your response towards each attribute in the table below.

No.	Attribute	Strongly disagree	<---		Neutral		--->	Strongly agree
1	Player looks distracted during the match	1	2	3	4	5	6	7
2	Player is able to identify and pass the ball to teammates with better opportunities	1	2	3	4	5	6	7
3	Player is able to understand and carry out new strategies or plays quickly	1	2	3	4	5	6	7
4	Player is alert	1	2	3	4	5	6	7
5	Player is able to read opponents' moves	1	2	3	4	5	6	7
6	Player is able to identify opponents' strengths and weaknesses quickly	1	2	3	4	5	6	7
7	Player seems afraid to get the ball	1	2	3	4	5	6	7
8	Player is able to pass to teammates successfully without looking directly at them	1	2	3	4	5	6	7
9	Player repeats the same mistake(s)	1	2	3	4	5	6	7
10	Player communicates effectively with teammates on court	1	2	3	4	5	6	7
11	Player is quick to react to situations	1	2	3	4	5	6	7
12	Player is able to control the pace of the game and organize his/her team	1	2	3	4	5	6	7

Appendix C – Screenshots of decision making app test (instructions for each section)



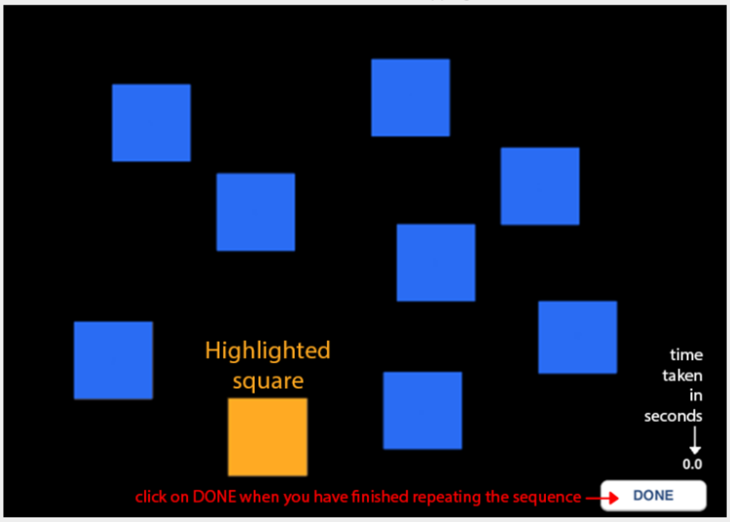
iPad 22:56 100%

Section 2: Corsi block-tapping task

Instructions

You are about to take part in a memory test known as the Corsi block-tapping task. This test measures your ability to remember a sequence of locations on the screen. You will see nine blue squares on the screen. On each trial, the squares will be highlighted one at a time in a sequence. Remember the sequence. When the sequence is finished. You need to tap on each square IN THE SAME ORDER AS THEY WERE GIVEN. When you are done, tap on the button labeled 'DONE' at the bottom right corner of the screen (as shown in the screenshot below). If you cannot remember the order of squares, tap them in as close to the original order as you can.

Screenshot of Corsi block tapping task



Steps for this test:

1. Watch the sequence
2. Remember the sequence from beginning to end
3. Tap on the squares in the same sequence
4. Tap on 'DONE' when you have finished repeating the sequence

You will start with a sequence of two squares, and you will have to attempt each sequence length twice. The sequence length will increase by one when you get both the attempts correct. If either of the attempts is incorrect, you will repeat that sequence length again. The test will end when you have a total of two incorrect sequences. For example:

-- Test start --
sequence of two squares -> correct
sequence of two squares -> correct
sequence of three squares -> correct
sequence of three squares -> incorrect
sequence of three squares -> correct
sequence of four squares -> correct
sequence of four squares -> incorrect
-- Test end --

The maximum sequence length is nine. If you made less than two incorrect attempts, the test will end after the second attempt of the sequence of nine squares.

The score you obtained for this test depends on your accuracy of recalling the sequences and the time you take to complete each trial. Therefore, your ability to recall the sequences quickly and accurately will earn you more points in this test.

There are THREE PRACTICE SEQUENCES for you to try out before you begin the actual test.

If you are unclear about the instructions or have any questions, please clarify all doubts with the principal investigator before you start the test.

When you are ready to begin this test, please tap on the 'START' button below.

START

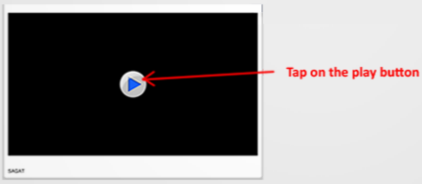
Section 3: Situation awareness global assessment technique (SAGAT)

Instructions

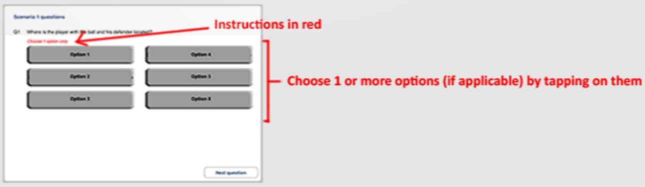
You are about to take part a situation awareness test known as the Situation Awareness Global Assessment Technique (SAGAT). This test measures your abilities of perception, comprehension and anticipation in the game of basketball. You will be watching a video of a basketball game. This video will be paused several times while you are watching. During these pauses, you will be asked about 4 - 5 questions about the basketball game. In order to answer these questions, you will need to imagine that you are playing in the match and think about the decisions that you might make if you were in the game.

Steps for this test:

1. Click on the play button in the middle of the screen to start watching the video



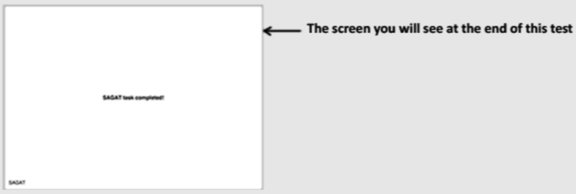
2. When the video is paused, choose 1 or more options (according to the instructions in red)



3. Click on 'Next question' when you are done and continue with the next question

4. When you have completed all the questions, you will be directed back to the video. Click on the play button again to continue watching the match.

5. Repeat steps 1 - 3 until you have completed all the questions for this test



There are NO PRACTICE QUESTIONS for this test. You will begin with the SAGAT test immediately.

If you are unclear about the instructions or have any questions, please clarify all doubts with the principal investigator before you start the test.

When you are ready to begin this test, please tap on the 'START' button below.

START

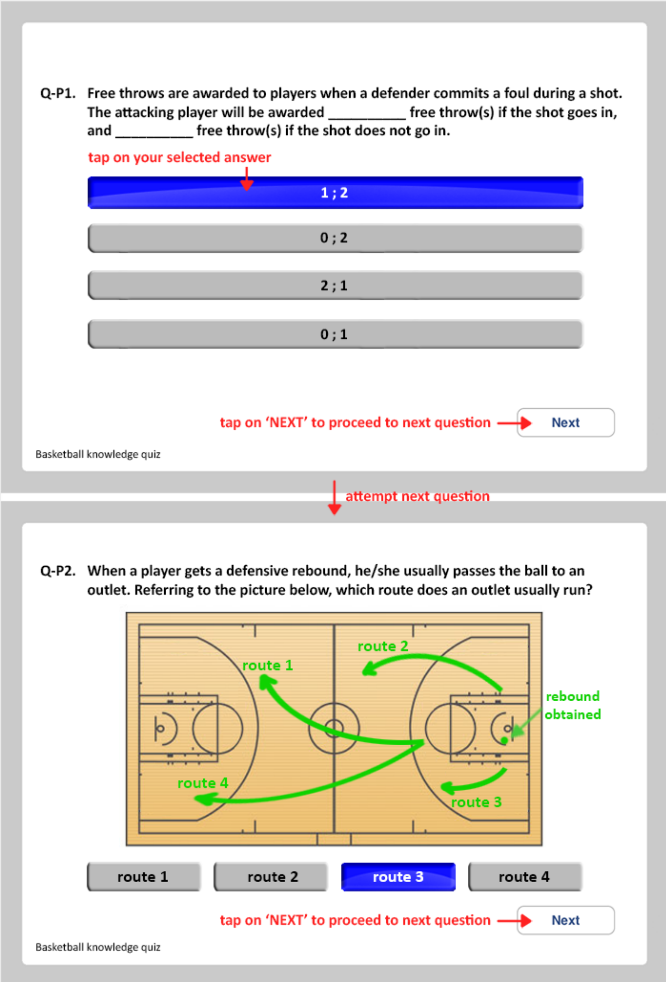
iPad 23:16 100%

Section 4: Basketball knowledge quiz

Instructions

You are about to take part in a quiz that measures your knowledge of basketball. For this test, you will have to complete 10 multiple choice questions. These questions are related to the rules and plays of the basketball game. There are four options for every question. Choose the option that best answers the question by tapping it. Click 'NEXT' on the bottom right hand side of the screen once you are done with each question. See screenshots below for examples of the type of questions and take note of the positions of the buttons.

Screenshot example of Basketball knowledge quiz



Steps for this test:

1. Read the question
2. Select the option that best answers the question
3. Tap on 'NEXT' to proceed to the next question.

You may take your time to think through the questions in this test. The score you obtained for this test depends only on the accuracy of your answers.

There are NO PRACTICE QUESTIONS for this test. You will begin the multiple choice questions immediately.

If you are unclear about the instructions or have any questions, please clarify all doubts with the principal investigator before you start the test.

When you are ready to begin this test, please tap on the 'START' button below.

START

iPad 23:17 100%

Section 5: Learning test - Part 1

Instructions

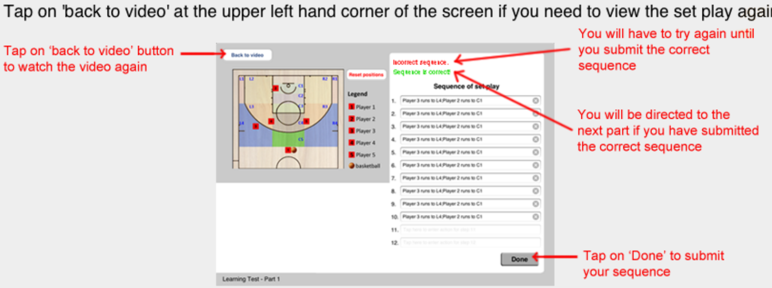
You are about to participate in a learning test customized for basketball. This test measures your ability to learn set plays quickly and accurately by watching and replicating the set plays. You will first be shown a video of the set play on screen. At the end of the video, you will be directed to the next screen to repeat the set play that was shown to you. If you have difficulty recalling the set play, you may go back and watch the video again.

Steps for this test:

1. Watch the video
2. At the end of the video, you will be directed to the screen to try and repeat the set play from your memory. On the top-left side of the screen, red squares representing each player will be shown in their correct starting positions

3. List the sequence of activities for the players chronologically
If two players act at the same time, choose the 2 actions for that step (separated by a semicolon;)
4. Tap on 'Animate' to see the players on the half court moving to the specified areas as stated in the action.
5. Tap on 'Reset positions' to clear your actions and move the players back to their starting positions.

6. Tap on 'back to video' at the upper left hand corner of the screen if you need to view the set play again



7. Tap on 'DONE' at the bottom right hand side of the screen once you are done. You can advance to the next part only after submitting the correct sequence.

There are NO PRACTICE QUESTIONS for this test. You will begin the learning test immediately.

If you are unclear about the instructions or have any questions, please clarify all doubts with the principal investigator before you start the test.

When you are ready to begin this test, please tap on the 'START' button below.

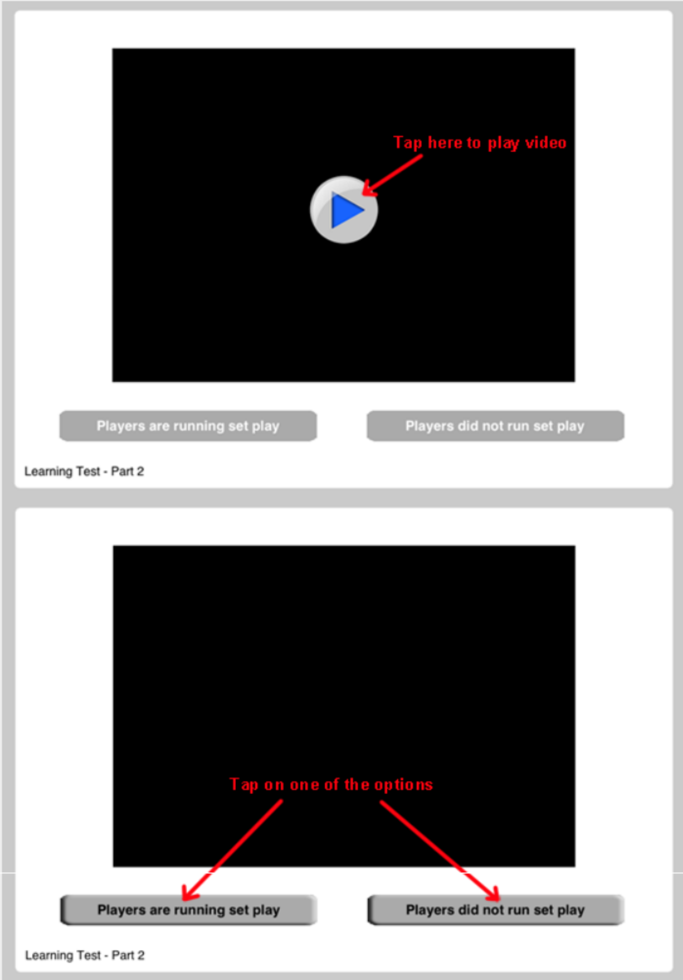
START

Section 5: Learning test - Part 2

Instructions

Now that you have successfully remembered and replicated the play, you will have to identify the set play in an actual game. In this test, you will be shown ten video clips of actual games one at a time. Each video clip lasts for about 20-30 seconds. While the video is running, tap on the button 'PLAYERS ARE RUNNING SET PLAY' the moment you recognize the set play. At the end of the video clip, tap on 'PLAYERS ARE RUNNING SET PLAY' or 'PLAYERS DID NOT RUN SET PLAY' to proceed to the next video.

Screenshot of part 2 of learning test



Steps for this test:

1. Watch the video
2. Tap on the 'PLAYERS ARE RUNNING SET PLAY' button if you identify the set play at any time when the video is running or at the end of the video
3. Else, tap on 'PLAYERS DID NOT RUN SET PLAY' at the end of the video
4. Repeat steps 1-3 for all 10 videos

There are NO PRACTICE QUESTIONS for this test. You will begin the learning test immediately.

If you are unclear about the instructions or have any questions, please clarify all doubts with the principal investigator before you start the test.

When you are ready to begin this test, please tap on the 'START' button below.

START