Measuring the Cognitive Abilities of Teenage Basketball Players in Singapore

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Abstract—This paper discusses the use of a computerized test to measure the decision-making abilities of teenage basketball players in Singapore. There are five sections in this test – Competitive state anxiety inventory-2 (CSAI-2) questionnaire (measures player's cognitive anxiety, somatic anxiety and self-confidence), Corsi block-tapping task (measures player's short-term spatial memory), situation awareness global assessment technique (SAGAT) (measures players' situation awareness in a basketball game), multiple choice questions on basketball knowledge (measures players' knowledge of basketball rules and concepts), and lastly, a learning test that requires participants to recall and recognize basketball set plays (measures player's ability to learn and recognize set plays). A total of 25 basketball players, aged 14 to 16 years old, from three secondary school teams participated in this experiment. The results that these basketball players obtained from this cognitive test were then used to compare with their physical fitness and basketball performance.

Keywords—Basketball, cognitive abilities, computerized test, decision-making.

I. INTRODUCTION

DECISION-MAKING is most commonly defined as "the selection of one option from a set of two or more options". In all areas of their lives, every individual faces various decision-making situations everyday and the study of decision making has been researched in many distinct yet interrelated disciplines. 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 behavior and human performance, and many more.. Therefore, 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"[1].

II. LITERATURE REVIEW

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. This makes the sports arena a potential laboratory that is appropriate for research in decision making [2].

Despite being a good source of data for decision making research, there has been relatively little literature on the application of decision making research in sports [2]. To date, researchers have studied decision-making in various sports such as basketball, soccer, water polo and handball [3]-[7]. Due to the lack of research in sports cognition, there has not been any standard tools or methods used to measure the decision-making performance of athletes.

In 2003, Tenenbaum [8] studied the decision making processes of expert athletes and developed a model to match the stages of decision making with its corresponding cognitive skill (Fig. 1 illustrates).
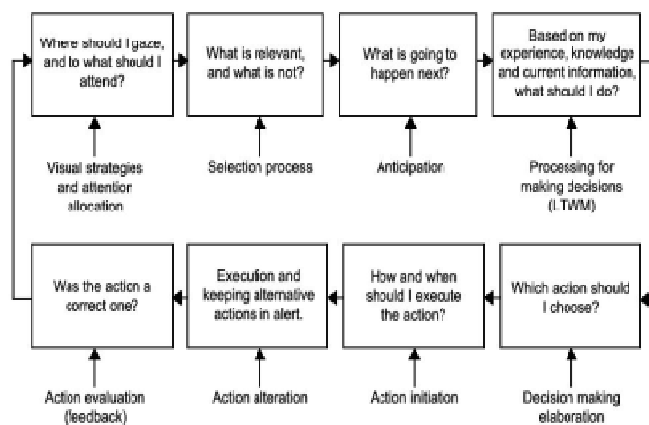

Fig. 1 Model developed by Tenenbaum to match the decision types with their respective cognitive components

Fig. 1 clearly illustrated the different cognitive skills such as visual strategies, attention allocation, anticipation, and even learning and evaluative abilities that contribute to one's decision-making performance in sports. It can also be observed that the decision-making process is a continuous cycle. As one experiences more decision-making scenarios, they will evaluate their decisions and these will affect how similar decisions may be made later.

The cognitive components identified in Fig. 1 are also similar to that of the situation awareness model developed by Endsley [9]. In Endsley's model, situation awareness is divided into three levels – perception, comprehension, and anticipation. By comparing the two models, it can be seen that the perception level in the situation awareness model corresponds to the visual strategies and attention allocation

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cognitive component explained by Tenenbaum, while the comprehension level in the situation awareness model explains the selection process in Tenenbaum's model as it determines the relevance of the information perceived. This then leads the decision-maker to anticipate and predict what might happen next. Using the situation awareness model, Endsley [10] showed that an aircraft pilot's ability in the three levels greatly affects his or her decision-making performance when flying an aircraft.

Besides these cognitive components, Tenenbaum [8] also explained that one's decision-making performance may be affected by their emotional state during the competition. Amasiatu and Uko [11] also discussed several theories which describe how pre-competition anxiety can affect an athlete's ability to concentrate, leading to variation in sport performance. In 1996, Swain and Jones[12]studied the competitive anxiety of ten basketball players using the Competitive State Anxiety Inventory-2 (CSAI-2) questionnaire and found that cognitive anxiety direction explained 23.4% of performance variance, while somatic anxiety direction explained 17.0% of the variance, and self-confidence had an inverted U-shape relationship and accounted for 21.2% of the performance variance.

Unlike the cognitive components, there is a standard set of tests to measure physical fitness that is used in Singapore. The Singapore National Physical Fitness Award (NAPFA) scheme comprises of six testing tools that measures one's muscular strength, muscular endurance, flexibility, speed, and stamina [13]. All students in Singapore have to take the NAPFA test once a year from the age of 10 to 18 years old, with slight differences for males and females.

III. PURPOSE OF THE STUDY

In this paper, we attempt to compare the participants' cognitive test and NAPFA test results with their basketball performance. It is hypothesized that both cognitive ability and physical fitness are important factors that affect an athlete's performance.

IV. METHODOLOGY

A. Subjects

A total of 25 basketball players (14 male, 11 female) aged 14 to 16 years old, from three different secondary school teams, took part in this experiment. The players had 0 to 7 years of competitive basketball experience. Table I below shows the spread of the player age and experience at the start of the competition.

TABLE I
PARTICIPANT AGE AND EXPERIENCE

Age\Experience (years)	0-1	2-3	4-5	6-7
14.0-14.9	1	3	4	0
15.0-15.9	0	3	9	3
16.0-16.9	0	0	0	2

All the participants competed in the National Schools 'B' Division Basketball Championship 2013 which lasted from January 2013 to March 2013. Parents of all the participants were informed of this research study and parental consent was obtained before the start of the experiment.

B. Computerized Test to Measure Cognitive Abilities

Based on the model by Tenenbaum [8], a computerized test was developed to measure a basketball player's level of competitive anxiety, short-term memory, situation awareness, knowledge of basketball rules and concepts, and ability to learn basketball set plays quickly and accurately. Therefore, this test is used in this experiment to measure the participants' abilities in the various cognitive components. The whole test consists of five sections.

In the first section of the test, participants are tasked to complete the CSAI-2 questionnaire so as to obtain a measure of their cognitive anxiety, somatic anxiety, and self-confidence. There are 27 statements in this questionnaire and participants are required to state if each of the statements reflect how they are actually feeling by choosing from one of these options - "not at all", "somewhat", "moderately so", or "very much so" [14].

After completing this questionnaire, they will proceed to the next section where their short-term spatial memory is tested using the Corsi block-tapping task. In this task, participants are presented with nine squares spread out across a 2-dimensional space. The layout of the nine squares and sequences used in this test is based on the recommendations by Kessels et al. and Busch et al. [15], [16]. The number of squares that participants are able to recall accurately represents their short-term spatial memory ability.

For the third section, participants are tested on their situation awareness using an adaptation of the Situation Awareness Global Assessment Technique (SAGAT) developed by Endsley [10]. Based on this technique, participants are shown a 5 to 7 minute video of an actual basketball game. The video will be paused three times. During these pauses, participants are asked four to five multiple-choice questions regarding the video. These questions measure their perception, comprehension, and anticipatory abilities.

In the fourth section, participants are presented with ten multiple-choice questions that test their domain knowledge. There are five questions on basketball rules and five questions on basketball concepts. These questions were selected with the help of four expert basketball coaches.

The last section is split into two parts – recall and recognize. Participants are first presented with a 25-second video clip of a basketball set play. Then, they are asked to recall and reproduce the set play. After successfully recalling the set play, they are then required to watch eight 20- to 30-second video clips of people playing basketball and observe if they did or did not run the set play that they had just learnt.

All the participants took this cognitive test three times – the first session was held about one month before the start of the competition for them to familiarize themselves with the format of the test, then one to two days before their first match of the competition, and lastly, one to two days before their last match of the competition.

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C. Physical Fitness Test

The standard NAPFA test used in the schools consists of six stations – sit-ups (number of sit-ups in one minute), standing broad jump (stationary horizontal jump distance), pull-ups for males and inclined pull-ups for females (number of pull-ups or inclined pull-ups in 30 seconds), 4 x 10m shuttle run (time taken to complete), sit-and-reach (distance reached), and 2.4km run/walk (time taken to complete). The requirements for males and females are different. Tables II A and B show the score table and the corresponding physical fitness score for 15 to 16 year old students [17].

TABLE II A
NAPFA SCORE REQUIREMENTS FOR 15-16 YEAR OLD MALES

Score	Sit-ups	Standing broad jump (cm)	Sit-and-reach (cm)	Pull-ups	Shuttle run (s)	2.4km run/walk (min : s)
5	> 42	> 237	> 45	> 7	< 10.2	< 10:41
4	40-42	228-237	42-45	6-7	10.2-10.3	10:41-11:40
3	37-39	218-227	38-41	5	10.4-10.5	11:41-12:40
2	34-36	208-217	34-37	3-4	10.6-10.9	12:41-13:40
1	30-33	198-207	29-33	1-2	11.0-11.3	13:41-14:40

TABLE II B
NAPFA SCORE REQUIREMENTS FOR 15-16 YEAR OLD FEMALES

Score	Sit-ups	Standing broad jump (cm)	Sit-and-reach (cm)	Inclined Pull-ups	Shuttle run (s)	2.4km run/walk (min : s)
5	> 30	> 182	> 45	> 16	< 11.3	< 14:11
4	29-30	174-182	43-45	14-16	11.3-11.6	14:11-15:10
3	25-28	165-173	39-42	10-13	11.7-12.0	15:11-16:10
2	21-24	156-164	35-38	7-9	12.1-12.4	16:11-17:10
1	17-20	147-155	30-34	3-6	12.5-12.8	17:11-18:10

Students get a gold award if they obtain at least a score of 3 in every station, a silver award if they obtain at least a score of 2 in every station, and a bronze award if they obtain at least a score of 1 in every station. The NAPFA test period begins in April each year. As all students are required to take the NAPFA test, the participants' test results for the year of 2013 were obtained from the teachers-in-charge and used for analysis in this paper.

D. Basketball Performance

The first and last matches of each participating team were recorded on video. Using these recordings, we were able to obtain the game statistics for each participant and convert these statistics into a basketball performance score. The formula developed by Sonstroem and Bernard [18] was used to derive the basketball performance score:

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

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.

E. Procedure

The principal investigator first meets with the research participants about a month before the start of National Schools 'B' Division Basketball Championship 2013. During that session, the participants are briefed on the research procedure. They also took the computerized cognitive test to familiarize themselves with the format of the test. About one to two days before their first match, the principal investigator met with the research participants again for them to take the computerized cognitive test. Their game statistics for the first match were then collected. Similarly, about one to two days before their last match, the research participants took the computerized cognitive test for the last time and their game statistics for that last match were collected.

During each computerized cognitive test session, six of the participants took the test at the same time. The test was done on an Apple 2nd generation iPad that was provided by the principal investigator. The research participants took the test after their classes, in a quiet location with proper tables and seats. They were told not to talk, or perform any actions that may distract the others. The principal investigator was present throughout all the test sessions.

Their physical fitness tests were conducted at the end of the game season by their respective schools. The results were then obtained from the teachers-in-charge of the basketball team in each school.

V. RESULTS AND ANALYSIS

Although 25 students participated in this research study, 7 of them were not fielded in to play in the first and last matches of the championship. Therefore, we were only able to obtain the basketball performance scores for 18 of the research participants. The average basketball performance scores of these 18 participants were then used to compare with their physical fitness scores and average performance on the computerized cognitive test.

A. Computerized Test to Measure Cognitive Abilities

In the first section of the computerized test, the CSAI-2 questionnaire was used to measure the participants' cognitive and somatic anxiety, as well as their self-confidence. Using this questionnaire, a score ranging from 9 to 36 will be obtained for each component. Table III A below shows the ANOVA analysis for the CSAI-2 results and the basketball performance score.

TABLE III A
ANOVA ANALYSIS FOR COGNITIVE ANXIETY, SOMATIC ANXIETY, AND SELF-CONFIDENCE SCORES AGAINST AVERAGE BASKETBALL PERFORMANCE SCORE

Model	Sum of squares	Df.	Mean square	F	Sig.
Regression	132.114	3	44.038	1.780	0.182
Residual	519.622	21	24.744		
Total	651.737	24			

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TABLE III B
ANOVA ANALYSIS FOR NUMBER OF CORRECT SQUARES AND TIME TAKEN
AGAINST AVERAGE BASKETBALL PERFORMANCE SCORE

Model	Sum of squares	Df.	Mean square	F	Sig.
Regression	115.481	2	57.741	2.369	0.117
Residual	536.255	22	24.375		
Total	651.737	24			

TABLE III C
ANOVA ANALYSIS FOR PERCEPTION, COMPREHENSION, AND ANTICIPATION
SCORES AGAINST AVERAGE BASKETBALL PERFORMANCE SCORE

Model	Sum of squares	Df.	Mean square	F	Sig.
Regression	56.002	3	18.667	0.658	0.587
Residual	595.735	21	28.368		
Total	651.737	24			

TABLE III D
ANOVA ANALYSIS FOR DOMAIN KNOWLEDGE SCORE AGAINST AVERAGE
BASKETBALL PERFORMANCE SCORE

Model	Sum of squares	Df.	Mean square	F	Sig.
Regression	68.503	1	68.503	2.701	0.114
Residual	583.234	23	25.358		
Total	651.737	24			

TABLE III E
ANOVA ANALYSIS FOR LEARNING TIME AND ACCURACY AGAINST AVERAGE
BASKETBALL PERFORMANCE SCORE

Model	Sum of squares	Df.	Mean square	F	Sig.
Regression	274.246	4	68.561	3.632	0.022
Residual	377.491	20	18.875		
Total	651.737	24			

In the second section of the computerized test, the participants' short-term spatial memory was measured using the Corsi block tapping task. In this task, we recorded the number of squares that participants were able to correctly remember and the time they took to recall. Table III B shows the ANOVA analysis with the basketball performance score.

The third section of the computerized test measures the participants' situation awareness using SAGAT. In this section, we recorded the participants' number of correct responses for three components of situation awareness – perception, comprehension, and anticipation. Table III C shows the ANOVA analysis for these three components compared with the basketball performance score.

The fourth section of the computerized test measures the participants' knowledge of rules and concepts in basketball. The participants' number of correct responses was recorded for this section. Table III D shows the ANOVA analysis comparing the number of correct responses with the basketball performance score.

Lastly, in the fifth section of the computerized test, the participants' ability to learn basketball set plays quickly is measured. We recorded the time taken by the participants to correctly recall the set play in the first part, the number of views and errors they made while trying to recall the set play, as well as the number of correct responses when they are tasked to recognize the set play in the second part. Table III E shows the ANOVA analysis comparing these two variables with the basketball performance score.

B. Physical Fitness Test

Most of the participants obtained a gold award for the standard NAPFA test conducted by the school. They scored an average of 27.4, with standard deviation of 3.2. Table IV below shows the average performance at each station for the male and female participants.

TABLE IV
AVERAGE NAPFA PERFORMANCE FOR EACH STATION

	Male (N=14)		Female (N=11)	
	Average	Std dev.	Average	Std dev.
Sit-ups	46.5	4.9	34.9	4.4
Standing broad jump (cm)	240.1	12.8	183.6	12.4
Sit-and-reach (cm)	50.1	7.1	47.1	3.1
Pull-ups/Inclined Pull-ups	7.1	3.0	22.9	10.3
Shuttle run (s)	9.41	0.5	10.7	0.5
2.4km run/walk (min : s)	10:20	1:11	12:44	0:51

An ANOVA analysis was done using the NAPFA test scores and the basketball performance score that we calculated. Table V below shows the results of the ANOVA analysis.

TABLE V
ANOVA ANALYSIS FOR NAPFA SCORE AGAINST AVERAGE BASKETBALL
PERFORMANCE SCORE

Model	Sum of squares	Df.	Mean square	F	Sig.
Regression	148.812	1	148.812	7.647	0.013
Residual	330.801	17	19.459		
Total	479.613	18			

C. Basketball Performance

The basketball performance scores were calculated using the formula developed by Sonstroem and Bernard [18]. These scores were obtained for the first and last matches of all three teams. Table VI below shows the average score obtained by each team for the first and last matches.

TABLE VI
AVERAGE BASKETBALL PERFORMANCE SCORE FOR THE FIRST AND LAST
MATCHES OF EACH TEAM

Team	N	Basketball performance score	
		First match	Last match
A	4	13.63	10.24
B	11	15.07	8.80
C	10	18.42	11.20

As the NAPFA test was only taken once, we compared the contribution of the NAPFA test results with those of the cognitive test results and basketball performance scores averaged across the two matches. Table VII below shows the multiple linear regression results using the average basketball performance scores and the results of the cognitive and physical fitness tests.

The cognitive test was taken twice, before the first and last matches. Thus, the cognitive test results can also be compared with the performance scores of the first and last matches. Tables VIII A and B show the multiple linear regression analysis for the first and last matches.

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TABLE VII
MULTIPLE LINEAR REGRESSION ANALYSIS FOR COGNITIVE AND PHYSICAL
FITNESS TESTS AGAINST AVERAGE BASKETBALL PERFORMANCE SCORES

Model	B	Std. Error
Constant	32.467	23.420
NAPFA	-0.275	0.334
Cognitive	-0.526	0.375
Somatic	0.782	0.321
Self-confidence	0.265	0.296
Corsi-#squares	0.165	0.081
Corsi- time taken	-20.918	14.993
Perception	-1.660	1.100
Comprehension	-0.514	1.154
Anticipation	1.195	1.614
Domain knowledge	-2.391	2.068
Learning1-#views	-0.567	1.342
Learning1-#errors	0.385	0.334
Learning1- time taken	-0.005	0.011
Learning2 score	0.515	1.394

TABLE VIII A
MULTIPLE LINEAR REGRESSION ANALYSIS FOR COGNITIVE RESULTS AGAINST
THE BASKETBALL PERFORMANCE SCORE FOR THE FIRST MATCH

Model	B	Std. Error
Constant	-7.269	20.093
Cognitive	0.044	0.515
Somatic	0.624	0.391
Self-confidence	1.184	0.471
Corsi-#squares	-0.005	0.116
Corsi- time taken	-40.188	23.602
Perception	-0.800	1.611
Comprehension	1.014	1.160
Anticipation	-3.195	2.525
Domain knowledge	0.634	2.036
Learning1-#views	-0.384	2.986
Learning1-#errors	-1.286	1.790
Learning1- time taken	-0.002	0.020
Learning2 score	0.604	1.192

TABLE VIII B
MULTIPLE LINEAR REGRESSION ANALYSIS FOR COGNITIVE RESULTS AGAINST
THE BASKETBALL PERFORMANCE SCORE FOR THE LAST MATCH

Model	B	Std. Error
Constant	7.396	28.252
Cognitive	0.177	0.500
Somatic	-0.167	0.455
Self-confidence	0.242	0.391
Corsi-#squares	0.078	0.108
Corsi- time taken	-12.056	24.276
Perception	-1.371	1.779
Comprehension	0.355	1.582
Anticipation	0.194	1.067
Domain knowledge	-1.931	2.314
Learning1-#views	-0.057	0.933
Learning1-#errors	0.443	0.309
Learning1- time taken	0.000	0.011
Learning2 score	1.426	1.008

VI. DISCUSSION

Several observations can be made from the results of the data collected in this experiment. From the ANOVA analysis of each of the cognitive skills and the NAPFA score, it is observed that the NAPFA score can best explain the variance in basketball performance. This is followed by learning ability, domain knowledge, short-term spatial memory, competitive anxiety, and lastly, situation awareness.

It was surprising to note that situation awareness was the least significant factor in basketball performance. Endsley [9] described the importance of situation awareness in naturalistic decision making scenarios that are closely similar to that of a basketball game where decision makers are in a dynamic environment and face great time pressure. However, Endsley studied decisions made by pilots, whose performances are largely dependent on their own actions. In a game of basketball, five players of one team play against another five players of the opposing team. As such, the success of one's decision can be affected by the actions of the other nine players on court. For example, a player may have made a good decision to pass to an open teammate for a clear shot, but the teammate did not manage to score, resulting in lower performance scores for the both of them.

Besides ANOVA, multiple linear regression was also used to study the contribution of each variable to basketball performance by attempting to fit a model using these variables. Two models were obtained using the first and last matches and their preceding cognitive test results. Comparing these two models, it was found that the time taken per square in the short term spatial memory test (*Corsi-time taken*) has the largest coefficient while the time taken to recall the set play in the learning test (*Learning1-time taken*) has the smallest coefficient for both models. This result seems logical as a player who is able to recall open spaces quickly will be able to take advantage of that opportunity for an easy score. Also, when players are presented with a new set play during a game and have limited time to remember the set play, they tend to memorize only their own roles rather than the whole set play. Thus, it is also not surprising that the time taken to learn a set play has an insignificant contribution to basketball performance in both models.

However, contradicting results were also observed from the two models. Somatic anxiety score (*somatic*) and *domain knowledge* score have positive coefficients in the first model but negative coefficients in the second model. On the other hand, the number of squares correctly recalled in the short term spatial memory test (*Corsi-#squares*), *anticipation* score in the situation awareness test, and the number of errors made when recalling the set play in the learning test (*Learning1-#errors*) have negative coefficients in the first model but positive coefficients in the second model.

From the average basketball performance scores for the first and last matches of each team, it can be seen that the average scores for all three teams were higher in the first match. For the first matches of all three teams, their opponents were much weaker than those of the last matches. In the first matches, all three teams won their opponents by at least 25 points. For the last matches, Teams A and C lost to their opponents while Team B won their opponent team by just 2 points. Therefore, the basketball performance score is more of a measure of the

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player's performance with reference to that of the opponent team, rather than an objective measure of their actual performance. Baker and Cote [3] also found difficulty in studying team ball sports and used interviews in their research study instead.

There are several limitations in this research study. Due to the nature of the sport, it is difficult to have an objective measure of game performance. Performance statistics such as total points scored, number of rebounds, steals, and turnovers are commonly used to measure the performance of professional basketball players. As shown in this experiment, such performance statistics are largely dependent on the opponent. The teams did not necessarily perform worse in the last match, but their performance scores were lower as the opponents in the later rounds of the championship were stronger than those in the first round. It is also difficult to measure decision-making performance in basketball. Bar-Eli and Tractinsky [4] made use of expert judgment to rate the decision-making performance of basketball players. In their experiment, expert coaches were invited to watch a basketball game on video and tasked to rate the players' decisions on a linear scale. Although this is one of the possible ways to get a score on decision-making performance, it is still subjected to the coaches' preferences and they may also be influenced by the consequences of the players' decisions resulting in hindsight bias.

VII. CONCLUSION

In this paper, we attempted to compare the contribution of cognitive and physical fitness levels with basketball performance. It was found that the physical fitness score can best explain the variance in the basketball performance score as computed by the formula developed by Sonstroem and Bernard [18]. However, we also noted that basketball performance is also greatly dependent on the strength of the opposing team. Therefore, if similar performance statistics were to be used for future research, comparisons should not be made across matches.

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