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Investigating the cognitive contribution to basketball behavior and performance

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Abstract

This paper summarizes the results of using a sport-specific decision-making test to measure various cognitive components of decision-making in basketball players. The test is computerized and runs on the Apple iOS platform so that users can take the test using an Apple iPad at any convenient location. 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). Research participants took the decision-making test on the iPad (2nd generation) three times. The first test session was scheduled about a month before the start of their competition, the second test session was scheduled 0 – 2 days before their first game of the season, and the last test session was scheduled 0 – 2 days before their last game of the season. The first group of research participants completed all three sessions in February 2013. This paper analyzes the results obtained from this group of participants over the three test sessions.

Keywords: decision-making test; cognitive components; basketball

1. Introduction

Decision making is most commonly defined as "the selection of one option from a set of two or more options" [1]. The study of decision making has been researched in many distinct yet interrelated disciplines [2]. A search of the keywords "decision making" in Google Scholar has revealed about 1.24 million articles in areas such as human factors, psychology, operational research, social science, management science, computer science, neurology, organizational behaviour and human performance, and many more. Klein [3]discussed the two themes in decision research that were 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

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research of decision making. This is especially evident in situations whereby optimal choices are required in human-machine systems [4].

1.1. Decision making and ergonomics

Focusing mainly on human judgment and information processing, the human factors perspective of decision making can be classified under the rationalist paradigm as discussed by Klein [3]. In the field of ergonomics, decision making is seen as "a complex process…(that) involves seeking information relevant to the decision at hand, estimating likelihoods of various outcomes, and attaching values to the anticipated outcomes". 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. Thus, decision making "is at the heart of information processing" [5].

1.2. Decision making in sports

In all areas of their lives, every individual faces various decision making situations every day. 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" [3]. One of the possible applications could be in the area of decision making in sports. 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 [6-10]. In 2003, Tenenbaum [11] 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 this process).

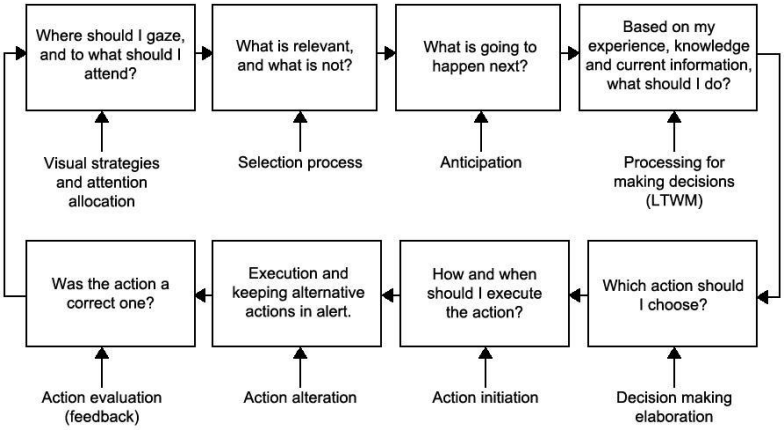

Fig. 1. Model developed by Tenenbaum to match the decision types with their respective cognitive components

From Fig. 1, the various components of situation awareness can also be identified. Endsley [12] explained that situation awareness comprises of three levels – perception, comprehension, and projection. Therefore, visual strategies and attention allocation represents the perception level, the selection process involves comprehension and anticipation skills help in the projection of the future situation. As such, these three levels of situation awareness are important in an athlete's decision making process [13]. Tenenbaum's model also showed that short-term memory is important for the athlete to remember critical information about the current situation, while domain knowledge of

the sport is important for the athlete to process the decision based on past knowledge. An athlete's ability to learn quickly also affects how he evaluates his action and improves his decision making ability. In addition, Tenenbaum also added that an athlete's psychological state such as anxiety and motivation also affects his decision making performance. Therefore, the decision making test that was developed for this experiment covers these five main components - competitive anxiety, short-term memory, situation awareness, domain knowledge, and learning (recognize and recall) ability.

It should also be noted that the sub processes involved in human decision making are all susceptible to influence by noise, lost information and level of expertise [14]. Thus the decision making process is inherently fuzzy and the outcomes are probabilistic at best. Success or failure in a basketball or indeed any decision making process is a product of the collective vulnerable contributions of various information processing and situation awareness stages including attention, perception, operational memory, comprehension, judgement, prediction, action selection and execution.

2. Purpose of the study

This paper describes a series of tests developed to measure a basketball player's anxiety and self-confidence before a game, short-term memory, situation awareness, knowledge of basketball rules and concept, as well as his ability to learn basketball set plays quickly and accurately. The results obtained from the first group of research participants are also discussed in this paper.

3. Methodology

3.1. Decision-making test

The information processing tests were programmed as an app that runs on the Apple iOS platform. This app was then installed in six sets of 2nd generation Apple iPad. The test comprises of 5 sections to measure each of the 5 contributions to decision making as listed below:

- Competitive anxiety – Participants are required to complete the Competitive Sports Anxiety Inventory-2 (CSAI-2) questionnaire [15]. The CSAI-2 questionnaire that consists of 27 items. These 27 items measure an athlete's cognitive anxiety (CA), somatic anxiety (SA), and self-confidence (SC), with 9 statements for each component. Participants are required to rate on a 4-point Likert scale ("Not at all", "Somewhat", "Moderately so", "Very much so") for each of these items. The minimum score for each component is 9 (very low cognitive anxiety, very low somatic anxiety, very low self-confidence) and the maximum score for each component is 36 (very high cognitive anxiety, very high somatic anxiety, very high self-confidence).
- Short-term spatial memory – In this section, participants are presented with the Corsi block-tapping task. The Corsi block-tapping task makes use of nine squares. These squares will be highlighted one at a time (1 second per square) and participants are required to repeat the sequence. The task starts with a sequence of two squares and keeps increasing by one more square when the participant gets the sequence correct. The task will end after the sequence of nine squares or when the participant has made two mistakes. The task setup (dimensions of blocks, location of blocks, sequence, sequence time) used in this experiment was programmed as recommended by Kessels, Zandvoort, Postma, Kappelle and Haan [16], and Busch, Farrell, Lisdahl-Medina and Krikorian [17].
- Situation awareness – This section makes use of the test format of the Situation Awareness Global Assessment Technique developed by Endsley [18]. Participants will first watch a 5 – 8 minute video clip of a tertiary level basketball match. The video will be paused three times and participants will be asked to answer 4 – 5 multiple choice questions about the video at each pause. These questions aim to test the participant's level of perception, comprehension, and anticipation for the game that they have just watched.
- Knowledge of basketball – This section comprises of ten multiple-choice questions, with five questions on the rules of basketball and the other five on the concepts of basketball. Three expert coaches were asked to select the questions to be used in this section.

- Ability to recall and recognize set plays – Participants are first presented with a video of a set play in basketball and asked to reproduce (recall) the set play after viewing it. Thereafter, they will watch a series of 20 – 30 seconds video clips of people playing basketball. For each of these videos, they are asked to observe and indicate if the players did or did not use (recognize) the set play that they had just learnt.

3.2. Participants

For the convenience of data collection, participants were recruited based on the basketball leagues in which they are competing. The first group that participated in this experiment consists of players who are representing their school in the Institute-Varsity-Polytechnic (IVP) 2013 games. Eight out of ten players who agreed to participate in this research completed all three test sessions. The participants are all female, aged 18-27 years old. They had 5-13 years of experience in playing basketball.

3.3. Research procedure

The participants are required to take the decision-making test on three separate test sessions. The first test session is usually conducted about a month before the game season begins, while the next two test sessions are held about 1-2 days before their first and last match respectively. These test sessions are conducted in an enclosed room in their school, with proper desks and chairs for the participants to take the test.

Six participants are allowed to take the decision-making test at the same time. During the test, they are not allowed to communicate or make any distracting sounds or actions. 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 usually take about 30 – 45 minutes to complete each test session.

4. Results

The test results of the eight participants who completed all three test sessions were collated and analyzed. The first test session was conducted on 19 November 2012, the second test session was conducted on 10 January 2013, and the last test session was conducted on 1 February 2013. Their first game was held on 12 January 2013 and their last game was held on 1 February 2013.

4.1. Section 1: Competitive anxiety

In this section, the participants were asked to complete the CSAI-2 questionnaire to measure their competitive anxiety levels. Table 1 below shows the scores obtained by each of the participants for all three test sessions.

Table 1. CSAI-2 scores for all participants

Participant No.	Test session 1			Test session 2			Test session 3		
	CA	SA	SC	CA	SA	SC	CA	SA	SC
A	27	22	17	22	24	18	24	25	21
B	29	26	23	23	16	23	23	17	25
C	26	23	24	26	25	25	27	24	26
D	31	14	26	18	13	26	24	12	28
E	25	22	17	27	26	22	27	24	16
F	28	24	21	31	15	18	22	22	14
G	16	9	31	16	10	29	14	10	28
H	28	17	18	25	16	16	18	19	18

Overall average: CA = 24.0, SA = 19.0, SC = 22.1; Overall standard deviation: CA = 3.1, SA = 2.2, SC = 1.9;
Overall range: CA = 14 to 31, SA = 9 to 26, SC = 14 to 31

4.2. Section 2: Short-term spatial memory

In this section, the participants are tested on their short-term spatial memory using the Corsi block-tapping task. Table 2 below shows the total number of correct squares that each participant is able to recall accurately and the average time taken per square for the correct sequences.

Table 2. Corsi block-tapping task scores for all participants

Participant no.	Test session 1		Test session 2		Test session 3		Personal best	
	Number of correct squares	Time taken per square (s)	Number of correct squares	Time taken per square (s)	Number of correct squares	Time taken per square (s)	Number of correct squares	Time taken per square (s)
A	28	0.53	54	0.45	34	0.47	54	0.45
B	28	0.34	47	0.39	47	0.32	47	0.32
C	40	0.70	34	0.56	47	0.49	47	0.49
D	18	0.61	40	0.60	23	0.47	40	0.60
E	70	0.43	40	0.47	47	0.39	70	0.43
F	47	0.44	28	0.45	28	0.44	47	0.44
G	40	0.54	40	0.52	23	0.51	40	0.52
H	62	0.51	54	0.63	18	0.54	62	0.51

Overall average: Number of correct squares = 39.0, time taken per square = 0.49 seconds
Overall standard deviation: Number of correct squares = 12.8, time taken per square = 0.05 seconds

4.3. Section 3: Situation awareness

In this section, the participants are tested on their situation awareness using SAGAT. The test measures three components – perception (P), comprehension (C), and anticipation (A). Percentages are used in this section as the number of questions for each component is different for all three test sessions. Table 3 below shows the percentage of correct answers for each participant.

Table 3. Percentage of correct answers in SAGAT

Participant no.	Test session 1			Test session 2			Test session 3		
	P	C	A	P	C	A	P	C	A
A	50.0%	33.3%	100.0%	75.0%	44.4%	75.0%	50.0%	22.2%	16.7%
B	50.0%	11.1%	100.0%	75.0%	44.4%	25.0%	62.5%	22.2%	33.3%
C	50.0%	11.1%	100.0%	50.0%	33.3%	50.0%	25.0%	22.2%	33.3%
D	50.0%	33.3%	33.3%	50.0%	55.6%	0.0%	50.0%	33.3%	50.0%
E	62.5%	44.4%	66.7%	75.0%	55.6%	25.0%	62.5%	55.6%	33.3%
F	62.5%	33.3%	100.0%	50.0%	55.6%	0.0%	37.5%	55.6%	16.7%
G	87.5%	33.3%	66.7%	100.0%	11.1%	50.0%	37.5%	22.2%	50.0%
H	37.5%	33.3%	33.3%	25.0%	11.1%	50.0%	25.0%	22.2%	16.7%

Overall average: P = 54.2%, C = 33.3%, 46.9%
Overall range: P = 25.0% to 87.5%, C = 11.1% to 55.6%, A = 0 to 100%

4.4. Section 4: Domain knowledge

In this section, participants are tested on their knowledge of the rules and concepts of basketball. They are required to answer 10 multiple-choice questions (5 questions on rules and 5 questions on concepts) at each test sessions, with different questions for each session. Table 4 below shows the number of correct answers that each participant obtained.

Table 4. Domain knowledge scores for all participants

Participant no.	Test session 1		Test session 2		Test session 3	
	Rules	Concepts	Rules	Concepts	Rules	Concepts
A	3	4	5	3	5	4
B	3	3	3	5	3	5
C	4	3	3	2	3	4
D	3	3	5	5	4	5
E	4	4	4	4	3	4
F	4	5	2	5	4	5
G	5	5	5	5	5	5
H	1	3	3	4	4	3

Overall average: Rules = 3.67, concepts 4.08; Overall variance: Rules = 1.10, concepts = 0.86
ANOVA: F = 2.12, p-value = 0.15

4.5. Section 5: Learning

In the last section, participants are tested on their ability to learn set plays quickly. This section is split into two parts. The first part measures how fast and accurately is a participant able to recall and reproduce the set play that was presented to them. Table 5a shows the number of views of the set play video, the number of errors made by the participant in reproducing the set play, and the total time that they took to be able to reproduce the set play correctly. The second part measures how well the participant is able to recognize the set play in an actual game. The maximum score for this part is 8. Table 5b shows the number of times the participant is able to correctly identify whether the set play was run.

Table 5a. Results of part 1 of learning test

Participant no.	Test session 1			Test session 2			Test session 3		
	Views	Errors	Time taken (s)	Views	Errors	Time taken (s)	Views	Errors	Time taken (s)
A	2	1	271	2	0	123	3	0	325
B	3	2	367	4	0	442	5	9	817
C	6	0	597	5	0	256	10	1	707
D	4	2	411	5	0	315	3	0	332
E	7	0	1089	3	2	416	3	0	554
F	2	0	172	1	0	149	2	0	273
G	7	2	666	7	0	452	3	0	376
H	9	47	806	5	12	229	7	21	459

Table 5b. Number of correct answers for each participant in Learning test part 2

Participant no.	Test session 1	Test session 2	Test session 3
A	4	4	2
B	7	3	7
C	1	5	6
D	6	3	7
E	5	5	2
F	6	3	5
G	3	4	4
H	4	5	6

Overall average: Views = 4.5, errors = 4.1, time taken = 7.3 minutes, number of correct answers = 4.5

5. Discussion

This decision-making test was designed to measure the five components that affect a basketball player's decision making performance in a game of basketball. The previous section described the results of the test obtained by the eight research participants. From these results, we can see that the participants' test performance in all of the

sections varies across all three test sessions. Table 1 showed that the participants tend to experience higher cognitive anxiety than somatic anxiety as the highest score for cognitive anxiety was 31 and that of somatic anxiety was 26 across the three test sessions. This is similar to the results observed by Swain and Jones [19] as they got ten tertiary level basketball players to take the CSAI-2 questionnaires before six league matches. The highest cognitive anxiety score was 32 and the highest somatic anxiety score was 23.

In 2000, Kessels, Zandvoort, Postma, Kappelle and Haan [16] got 140 healthy adults to take the Corsi block-tapping task and found that most of them are able to get 40 squares correct. From Table 2, it can be seen that the number of correct squares ranged from 18 to 70 squares and all of the participants are able to get 40 or more squares correct in at least one of the test sessions. However, the participants in this experiment had an average of 27.0 to 52.3 squares correct, which is lower than the average of 55.7 observed by Kessels and colleagues. This may be due to the time pressure imposed on the participants in this experiment. Unlike Kessels's experiment where the participants are allowed to take as much time as they needed to recall the sequence, participants in this experiment were informed that their time taken for this task is recorded and that they should complete the task as quickly as possible. As such, some of them may have recalled the correct sequence, but they may have tapped on a wrong square when they are rushing through.

The last three sections of the test (situation awareness, domain knowledge, learning ability) are newly developed for this experiment. In order to develop the questions and answers for these sections, we interviewed 4 expert basketball coaches with more than 10 years of coaching experience. For the situation awareness section, they helped to identify the common scenarios in a basketball match and provided insights on the things that players need to be aware of in each of the scenarios. They also explained why it is important for the players to be aware of these things when in that particular scenario. From Table 3, it was noted that most of the participants are able to perceive at least half of the information needed for each scenario (an average 54.2% of information required), but most are unable to understand the reasons behind the need to perceive these information (average understanding of 33.3%). Although the participants were able to predict the correct moves about 46.9% of the time on average, they were least consistent with their anticipatory skills as their results can range from 0% to 100% over the three test sessions.

The same four coaches also helped to select the questions that are suitable for the domain knowledge section of this test. Williams, Davids and Williams [20] suggested using the declarative and procedural knowledge paradigm to study knowledge structures in a sports context. They cited the experiment done by French and Thomas in 1987, who used the declarative and procedural knowledge paradigm and found that performance on their knowledge test was related to the decision-making component of basketball performance. Therefore, in the domain knowledge section of our test, we have an equal number of questions that test for declarative (rules – what the game is about) and procedural (concepts – how the game is played) knowledge. In this experiment, the participants performed slightly poorer on the declarative component than on the procedural component of the test. However, a one-way ANOVA analysis revealed no significant difference ($p = 0.15$).

Lastly, the learning ability section of the decision-making test is split into two parts – recall and recognize. In 2001, Mulligan [21] suggested the use of set plays to study the ability of ice hockey players to learn them quickly. He explains that there are times when coaches get the players to run new set plays in the middle of a game and the players are required to learn these set plays and act them out immediately. Hence, it is important for players to be able to learn set plays quickly. From this experiment, we found that the participants took an average of about 7.3 minutes to be able to recall and reproduce the set play correctly. For the second part, the participants scored an average of 4.46 across all three test sessions.

6. Conclusion

In summary, this paper describes the decision-making test results obtained from just one group of research participants. More research needs to be done for a deeper understanding of the different cognitive components and their effect on game performance. As such, this experiment will be replicated for participants of different age groups (13 – 18 years old) and sexes. As such, we will then be able to compare the results of the different groups and investigate if there are any significant differences in the results due to age and sex. Furthermore, we have also identified the critical decision-making attributes that people use to judge a basketball player's decision-making performance. Therefore, the coaches will be able to rate each player on these critical attributes and we can also study if the results of the decision-making test are similar to that of the coaches' ratings.

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