THE DEVELOPMENT OF A DECISION MAKING INSTRUMENT FOR SOCCER

by

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The goal of this project was to develop a reliable decision-making instrument with improved validity compared to other instruments used to date. A methodological design, consisting of two phases, was adopted to develop a valid and reliable instrument. In the first phase, 59 decision making video clips were developed. Content validity was assessed based on the review by expert soccer players. Finally, the basic format of the test was established based upon item discrimination, item-to-total correlation, and item difficulty index computed on 16 experts and 16 novices responses to the clips. Item discrimination and item-to-total correlation were used to exclude clips from the pool of clips. After clips were excluded, the 28 final clips were grouped in four forms based on level of difficulty. In phase two, the reliability of the four forms of the test was determined based on alternate forms reliability and coefficient alpha values. Six Pearson Product Correlations were computed. None of the correlations reached .7 indicating the forms could not be used interchangeably. Estimated internal consistency of each of the four forms based on Cronbach's alpha values was also low. More reliability information must be gathered before this instrument is used in actual experiments.

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PREFACE

I dedicate this thesis to

My adviser, Dr. Jere Gallagher, for all her incredible kindness and support,

Everyone that helped along the way: Wagner de Campos, Iverson Ladewig, Marilyn Ross, Carla Conradi, Adriana, Maura Polito, Jackie Harder, Ovande Furtado, Oldemar Mazzardo, Comfort Mokgothu, and Vitor Brito

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1. INTRODUCTION

Throughout the research literature, expertise has been defined as outstanding performance in a specific domain such as a sport, medicine, chess, or guitar playing. Research on expertise attempts to explain where in the performance experts excel over novices. By understanding what makes someone an expert, an effective learning environment can be created to help novices learn new skills.

In sports, the difference between experts and novices could exist anywhere in the continuum that represents the information processing sequence. The information processing sequence includes perception, thinking, knowledge base, decision making, and motor skill execution. Based on the information processing theory, before a sport movement can be executed, information present in the environment is perceived by the individual, processed by the central nervous system, the knowledge base accessed, and a decision made and executed. Research on expertise and sports indicate that experts perform better than novices in all components of the information processing sequence (Benguigui & Ripoll, 1998; Hyllegard, 1991; Campos, 1993; Starkes, Caicco, Boutilier, & Sevsek, 2001; Williams & Davids, 1998; French, Spurgeon, & Nevett, 1995; McPherson, 1999).

Among all the elements of the information processing sequence, decision making has received significant attention in the sport expertise literature due to its significance in open sports. Open sports are characterized by constantly changing environments. To meet environmental demands, a great number of accurate and quick decisions must be made. In contrast to the significant amount of research conducted on expertise in sports, particularly on decision making, little research has been conducted under situations in which the participants are exposed to different exercise intensities. In sports, however, players engage in exercise of various exercise intensities. Directing more attention to the effects of exercise intensity on decision making of expert and novice players should allow researchers to advance the understanding of the decision making processes during game play.

Besides being scarce, studies on decision making under conditions of physiological stress face methodological limitations. Many of these limitations are related to the data collection instruments used in conducting the experiments. Commonly, research on decision making has used instruments in which little or no evidence for validity and reliability was provided. Consequently, the goal of this project is to develop a reliable decision-making instrument with improved validity compared to other instruments used to date.

In order to develop the instrument, a review of the validity and reliability of instruments in decision making in sports is presented to support the need for the development of a new instrument. Following this discussion, the procedures taken to assess the validity and reliability evidence of the instrument proposed, including measurement, subjects, and data analysis, are described. Finally, the reliability and validity evidence accumulated during testing is discussed.

2. MEASUREMENT USED IN DECISION MAKING STUDIES

Most data collection instruments used to measure decision making in sports provide little or no evidence related to reliability and validity. Validity evidence and reliability of decision making tests is required in order for researchers to decide whether or not a test possesses characteristics that match their research purpose. Without appropriate reliability and validity evidence, it is difficult for researchers to ensure the outcome of the experiment reflects true performance of participants. Even though reliability and validity are related, they are presented separately for organizational purposes.

2.1. RELIABILITY

Although reliability evidence supporting the use of an instrument should always be provided before data collection, the reliability of the data collection instruments used in some studies in decision making, such as in Campos (1993) and Ripoll et al. (1995), was never provided. Campos used a test consisting of video clips of actual soccer games, and Ripoll used a test consisting of joystick responses to a video presented test. McPherson (1999) and Nielsen and McPherson (2001) have estimated scorer reliability. McPherson and Nielsen and McPherson had observers rate decision making performance during game play. In both experiments interrater and intrarater reliability ranging from .88 to 1 were reported. Equivalence among scores was adequate evidence in both experiments since more than one scorer was in charge of rating subjects. However, in addition to rater reliability, other types of reliability coefficients indicating the stability of scores over time or equivalence of performance criteria could have been examined.

Kioumourtzoglou et al. (1998) measured decision making for basketball and water polo. In water polo no reliability measures were reported. For basketball, decision making was assessed based on 23 items consisting of offensive basketball situations. All items had three options with one correct response. Kioumourtzoglou et al. reported the internal homogeneity reliability to be .95 estimated by the coefficient alpha. However, Kioumourtzoglou et al. did not describe the procedures used to estimate coefficient alpha reliability. Without knowing how the coefficient alpha reliability was reached by Kioumourtzoglou et al, the score is uninterpretable.

Similar to the test proposed in this study, McMorris and Graydon (1996a, 19967, 1997a, 1999), investigating the influences of exercise on decision making, used a test consisting of multiple forms. Three forms of the test were required due to the test being used to measured decision making under three different exercise conditions. Reliability among forms was determined based on intraclass correlations. The intraclass correlations for accuracy of decision and speed of decision for accurate responses were reported to be .94 and .79 respectively. Although high, these results were biased by the way the forms of the test were developed. Each form consisted of 10 questions. These 10 questions were the same for each form except for their location on the field. It is possible that correlations were high because subjects were just repeating the answers across forms.

McMorris and Beazeley (1997) developed a similar instrument to measure decision making in soccer. Only one form of the test consisting of 20 questions was developed. To measure the reliability of the instrument, the split-half method was used. The Spearman Brown Prophesy reported was .92 for speed and .84 for accuracy of decision. This was the only study found in decision making in which evidence in terms of equivalence of items was accurately reported. However, these results do not relate to the instrument proposed by this experiment because only one form of the test was developed.

In summary, reliability evidence for instruments used in decision making is scarce. Some studies in decision making used data collection instruments which were not tested for reliability (Campos, 1993; Ripoll, 1995). Others provided only scorer reliability when evidence about the equivalence of items was also critical (McPherson, 1997; Nielsen and McPherson, 2001). In the study of Kioumourtzoglou et al. (1998) equivalence of questions was provided, but information about how the reliability coefficient was achieved was missing. Directly related to this project are instruments used in investigating the effects of exercise on decision making. These studies provided reliability evidence that was biased by the use of different forms containing the same questions expect for location in the field. It is critical for researchers to dealing with test development to adequately measure the reliability of instruments.

Methodological limitations of instruments measuring decision making are not restricted to reliability. Validity evidence has not always been adequately reported. Limitations to validity are considered next.

2.2. VALIDITY

Methodological limitations related to validity are also evident in studies testing decision making. The more evidence provided about an instrument, the more equipped a researcher is in determining the appropriateness of the instrument for a specific research project. Different types of validity evidence can be provided including content evidence, internal structure evidence, external structure evidence, and ecological validity. From these and a number of other possible validity evidence that could be gathered, content validity is the only one consistently presented by researchers in the field of expertise in sports. Reference to ecological validity is also often made although ecologically validity instruments that measure performance in the actual sport environment are difficult to construct.

2.2.1. Content validity

Content validity is commonly the only type of evidence provided by studies on decision making. Invariably, content validity provided for decision making instruments is based on the examination of the test by a group of experts in the specific domain. Ripoll et al. (1995), for example, consulted one experienced French boxing coach. Campos (1993) consulted three soccer coaches, and Kioumourtzoglou et al. (1998) three basketball coaches. In deciding what plays to use McMorris and Beazeley (1997) also consulted a panel of experience soccer coaches. The number of coaches was not specified.

In McMorris and Graydon (1996a, 1996b, 1997, 1999), content validity evidence of the test was provided by a group of eight experienced soccer coaches. Three forms of the test were developed, one for each exercise condition: rest, moderate, and maximum exercise. However, as with reliability, content validity evidence might be biased by the way the forms of the test were constructed. The only difference between forms was in the position each question was set in the field. For each form, the same 10 questions were in different positions on the field. McMorris and Graydon justified the use of a single form of the test by stating that after the three versions of the test were applied to 18 expert soccer players, differences between forms in decision making time and accuracy were not found. However, it is possible that differences were not found because subjects realized the forms were the same and were merely repeating their answers.

Thus the results reported in their sequence of studies in decision making under conditions of physiological stress becomes questionable. If subjects noticed that they were tested on the same questions, they could have been choosing the same answer across exercise conditions. Thus, McMorris and Graydon's conclusions that accuracy of decision did not differ with increased exercise intensity is suspect. Results related to speed of decision are also questionable. Improvement in speed of decision from rest to moderate and maximum exercise could be due to the subjects already knowing the answer to the questions.

To produce a valid instrument containing multiple forms, not only the assessment of the instrument must be made by a panel of experts, but also forms of the test ought to have different decision making questions. If McMorris and Graydon had used forms of the test that were truly different from each other, results in line with their hypothesis might have been reached.

2.2.2. Ecological validity

Having experts assess the adequacy of decision making questions is important. In addition, it is also important to create data collection instruments that resemble as close as possible the natural sport environment. Tasks closely resembling the sport environment have high ecological validity. Investigations based on instruments with high ecological validity are more easily generalized to the actual world. Ideally all data collection instruments should possess high ecological validity. However, it is a difficult task to construct decision making instruments with high ecological validity because of the significant number of extraneous variables present in actual sport settings. Levels of motivation of athletes and the wide variety of situations present in sports are just some of these variables. Because of difficulties in controlling extraneous variables and constructing an objective test, often researchers have opted for more laboratory studies.

McPherson (1990), and Nielsen and McPherson (2001) were the only researchers investigating expertise not opting for laboratory instruments. Their instrument analyzed decision making during actual tennis matches. Although ecologically valid, the extent to which the instrument was able to control for extraneous variables is debatable. Some subjects, for example, could be more motivated to play tennis than others. Fatigue could also influence the results of the experiments. Subjects that were more fatigued could be limiting their decisions to plays that were less physically extraneous.

All other experiments discussed used less ecologically valid tests. These tests were better able to control for extraneous variables, but did not simulate two aspects of actual game play: number of decision making choices, and dynamics of sport play including the relation among perception, decision making, and action present in sports.

Number of decision making choices is considered first. None of the laboratory instruments had more than four possible decision making choices although a great number of decisions are made throughout open sports. Only four responses were possible even in the instrument used by McMorris and Graydon to test decision making under conditions of physiological stress in soccer. Questions in the instrument proposed in this study are presented in a form of video clips of actual soccer games. Since in video clips, only part of the game action is presented, only four decision making choices per question were developed.

Related to the number of decision making choices is how the choices are rated. In the experiments by McMorris and Graydon, only situations in which one optimal answer was present were included. This helps increase the objectivity of the test but reduces ecological validity. In sports, more than one decision can make a good play. Therefore, ranking of the decisions seems more appropriate. The data collection instrument proposed in this study ranks decisions by level of appropriateness. Ranking of decisions was conducted by three experienced soccer players.

In addition to the number of options and how they are rated, ecologically valid instruments must resemble the dynamics of sports. The extent to which decision making instruments are able to capture the dynamics of sport varies. Ripoll et al. were able to closely mimic the dynamics of French boxing by asking subjects to give a simple motor response to the actions of a taped boxer. The motor response consisted of pre-determined joystick movements. The experiment conducted by Campos was not as dynamic. The test consisted of segments of taped soccer games. Visual presentation of soccer problems allowed subjects to perceive how the situation develops.

All experiments testing decision making under conditions of physiological stress had more severe limitations in terms of how well they were able to mimic the dynamics of soccer. For these experiments (McMorris and Graydon, 1996a, 1997b, 1997, 1999), questions were presented to subjects as slides projected onto a wall. Slides do not capture the dynamics involved in soccer.

The discussion of ecological validity points out a dilemma in developing an instrument. Although instruments with high ecological validity are advisable, it is difficult to control extraneous variables in sport setting. During research planning, researchers need to decide on what is more important: developing an instrument with high ecological validity or controlling for extraneous variables.

2.2.3. Improvements made to the instruments proposed to this study

The purpose of this experiment is to provide reliability and valid evidence to the instrument proposed for testing the effects of exercise on decision making. Based on the instruments currently used, improvements in three major areas were attempted in developing the instrument proposed in this study.

First, four different forms were developed. Test forms used by McMorris and Graydon possessed questions that were identical except for position of the play in the field. The test forms proposed here will have complete different items. Aside from that, McMorris and Graydon only used three forms of the test. Development of four forms of the test allow for the addition of a fourth exercise condition which permits more information about the effects of increased exercise intensity on decision making be gathered.

A second improvement is that answers will be ranked by level of correctness. Ranking answers by level of correctness resembles more closely what happens during actual matches. In soccer, more than one decision can turn out a good play.

The last improvement is related to ecological validity. It was decided not to develop an instrument with high ecological validity. Decision was based on how difficult it is to control for extraneous variables. Besides, if the effects of exercise on decision making are to be measured in actual games, a protocol to measure exercise intensity during actual games would also have to be created. However, improvement to ecological validity compared to tests used to measure decision making under conditions of physiological stress was made by using videotape segments taken from real soccer matches. Although not as dynamic as actual soccer matches, videotaped segments are more dynamic than slides. Research instruments, consisting of videotape segments taken from real soccer games, have been found to be valid instruments in testing expertise in sports since previous research using videotaping has been able to demonstrate differences between experts and novices in decision making ability (Campos, 1993). Although the video clips are still shown in the laboratory, improvements made to the test should accurately capture the effects of exercise on decision making.

3. PHASE ONE

The aim of the first phase of this experiment was to establish the basic format of the test and determine content validity. The format of the final test required four forms with seven questions each. The four forms are required due to the fact that the final instrument will be used to test decision making under four different exercise conditions, rest, 30%VO_{2max}, 70%VO_{2max}, and 100%VO_{2max}. The number of questions is set to seven because of the amount of time a subject is able to maintain a pre-determined exercise intensity.

Three major steps were completed in this phase of the experiment (Table 1). The first step refered to the development of the questions. Questions in this experiment consisted of video clips of critical decision-making situations found in soccer matches. Based on an extensive review of the soccer coaching literature, three experienced soccer coaches and colleagues in doctoral studies developed and revised 59 decision-making clips. The second step consisted of establishing content validity of the clips based on the assessment of experienced soccer players. Finally, the last step consisted of asking expert and novice soccer players to answer the items in order to calculate the item discrimination index, the item-to-total correlation score, and the item difficulty index. As explained later, all these measures were used to eliminate clips that did not meet item discrimination and item-to-total score correlation requirements and to structure the remaining clips into four alternate-forms based on item difficulty index.

Table 1

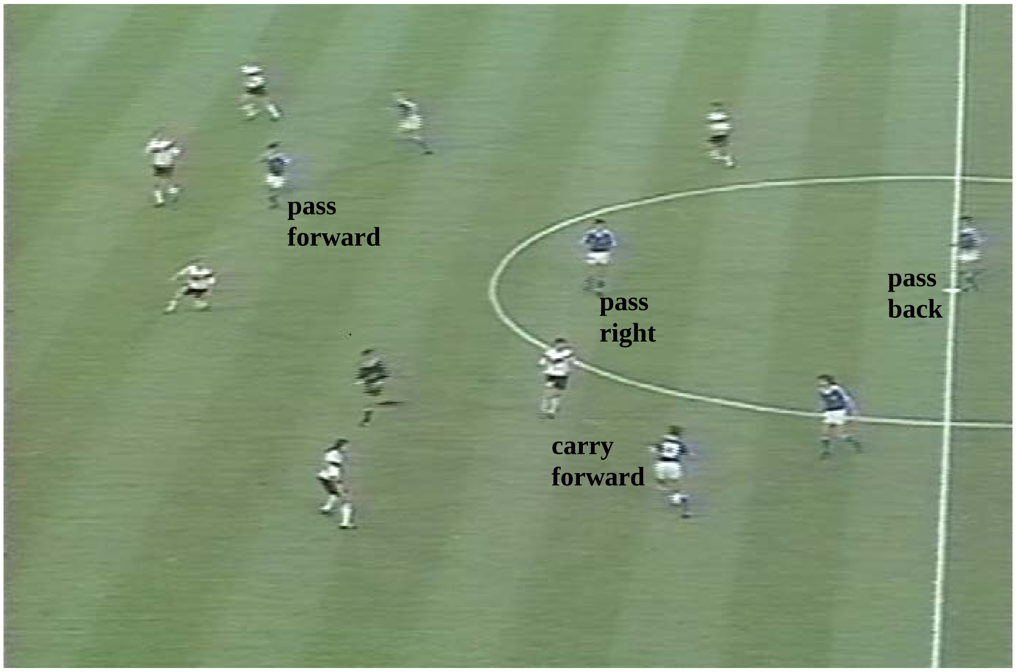
Major steps completed in the first phase of the experiment

1st step:	
	Development of 59 videoclips containing critical soccer decision making situations
2nd step:	
	Content validity assessment based on the review of the clips by experts
3rd step:	
	Decision making test basic format established based on experts and novices responses to the clips a. drop clips that do not discriminate experts from novices b. drop clips with low item-to-total correlation c. rank remaining clips in order of difficulty d. group clips in 7 levels of difficulty e. within each level of difficulty, randomly assign clips to forms

3.1. STEP ONE

Based on an extensive review of the soccer coaching literature, three experimenters developed 59 decision-making videoclips consisting of critical decision-making situations found in soccer matches. Each clip was 12 seconds and consisted of a segment of a real soccer match taken from the 1986 or 1990 World Cup. After 12 seconds, the clip freezes and four possible decisions are displayed on the screen (Figure 1).

Figure 1



The decisions were stated in the form of decision sentences. Each decision sentence consisted of a simplified two-word phrase which characterized the meaning of the decision. Seven decision sentences were used throughout the first phase of this experiment including, “shoot goal”, “pass direction”, “dribble around”, “carry forward”, “kick direction”, “cross direction”, “control ball”.

3.2. STEP TWO

3.2.1. Methods

In step two, assessment of content validity was conducted by three experienced soccer players each with an average of 39 years of soccer years. All players are still active in the City of Pittsburgh soccer senior leagues. Players reviewed the clips independently, ranking the decisions from least to most appropriate. Three points were associated with the most appropriate action, two with the second, one with the third, and zero with the least appropriate action. Ranking of decisions by level of correctness was appropriate since in soccer most plays possess a great number of actions with some resulting in better consequences. A wrong decision seldom exists. All reviewers ranked each clip independently of other reviewers and subsequently shared their answers. If agreement was not reached by all reviewers, discussion of the play, moderated by the lead investigator, followed. If after discussion, agreement was still not reached, that play was discarded from the pool of clips. If more than 8 clips were discarded, additional plays were to be developed. A minimum of 50 clips was needed for step three.

3.2.2. Results

For four clips, agreement among reviewers in the ranking of decisions by levels of appropriateness was not reached even after a discussion mediated by the main investigator. These four clips were eliminated from the study. In the opinion of reviewers, these clips in general had two or more decisions that were considered to be very similar deserving to be at about the same level of appropriateness. A clip for example could consist of the following decisions: pass right, cross left, shoot goal, and dribble around. If pass right and shoot goal were considered equally appropriate or inappropriate by the reviewers, the play was eliminated from the study. A total of 55 plays were left in the pool of clips.

3.3. STEP THREE

The purpose of this third step was to select 28 clips that would comprise the four forms of the test. To do so, the third step required experienced and novice subjects view the clips and respond to the decision making situations.

3.3.1. Methods

3.3.1.1. Subjects

The subjects for this step were thirty six male college students, 18 experienced and 18 novice soccer players. Novice soccer players were college students with some previous soccer experience but had not played soccer for their high school team nor had they played competitive soccer during their high school years. Experts were college soccer players.

3.3.1.2. Procedures

The pool of clips containing 55 clips was projected onto a wall in front of participants using a LCD projector. All participants were tested using the same LCD projector (Proxima DP 6155). The projection size had a width of 166cm and a height of 87.5cm from the floor. Participants were seated in a chair positioned 245 cm from the LCD screen. Each clip lasted 12 seconds. When each clip was finished, the clip froze, and four possible decision sentences containing two words such as “kick goal” or “pass right” were projected on the screen. Subjects were told what each sentence meant as follows:

- “Shoot goal” means the player will possession of the ball will shoot to the goal, the sentence
- “Pass direction” means that the player in possession of the ball will pass to a teammate that is on that side of the field (right, left, forward, or back);
- “Dribble around” means that the player in possession of the ball will advance with the ball by dribbling around an opponent;
- “Carry forward” means that the player in possession of the ball will just dribble the ball forward without dribbling an opponent ;
- “Kick direction” means that the player in possession of the ball will clear the ball away from defense on the that side of the field;
- “Cross direction”: cross is just a longer pass, and direction is the same (right, left, forward, or back);
- “Control ball” means that the player in possession of the ball will stop the ball and protect it before he does any other actions.

Although speed of decision was not of concern in this phase of the experiment, the subjects were asked to select the most appropriate action for the player in possession of the ball as quickly and as accurately as possible. This was important to avoid a speed-accuracy trade-off. A video camera was used to measure speed of decision (Panasonic VHS – AG 188). The camera focused on a clock positioned on the right side of the screen. Subjects were told that the camera was used to record the decision making time. Accuracy of decision was measured by the points associated with the selected decisions. Three points was associated with the most appropriate action, two to the second, one to the third, and zero to the least appropriate action.

3.3.1.3. Data analysis

Experts and novices responses to the clips were used to compute the item discrimination score. The item discrimination score helped to ensure that the final version of the test contained only clips able to differentiate expert from novice players. The item discrimination scores were calculated based on the difference between the average score of the experienced group on the clip and the average score of the novice group on the clip divided by the range of possible clip scores (Equation 1 – Nitko, 2001). All clips with negative item discrimination score were discarded from the pool of clips. Because a score of three was given to the most appropriate answer and a four was given to the least appropriate answer, a higher score referred to a better performance.

Equation 1

The equation below illustrates how item discrimination scores were computed

$$D^* = \frac{\text{average score of experts on the item} - \text{average score of novices on the item}}{\text{maximum possible item score} - \text{minimum possible item score}}$$

Complementary to the item discrimination score, the item-to-total score correlation, was also a source of clip elimination. The item-to-total score correlation is a measure of how well an item correlates to the total test score. The item-to-total correlation is also a discrimination measure. Clips that are correctly answered by most novices and incorrectly by most experts should have a low item-to-total correlation score. Clips with item-to-total score correlation lower than .2 were eliminated from the pool of clips. The item-to-total score correlation was computed using SPSS v12.

Ranking of the clips by level of difficulty, based on item difficulty index, is important to insure that the four test forms have equivalent levels of difficulty (Equation 2 – Nitko, 2001). Based on this ranking, clips were grouped into seven levels of difficulty. Within each level of difficulty, clips were assigned to one of four alternate forms so that item difficulty index averages as well as item-to-total correlation and item discrimination score averages were as similar as possible.

Equation 2

Equation used for computing the item difficult index.

$$p^* = \frac{\text{average score for the item}}{\text{maximum possible item score} - \text{minimum possible item score}}$$

Before the forms of the test were exposed to the next phase of the experiment, a pilot study was conducted to determine whether the assignment of clips produced similar test forms in terms of item difficulty index, item-to-total correlation, and item discrimination score. A total of 10 people were tested during the pilot study. Four participants were classified as novices, three as intermediate, and three as experienced players. The statistics used to measure form similarities were mean score for novices, experts, overall mean (novice, experts, and intermediated combined) and the mean difference between novices and experts. Reassignment of clips was possible if the results from the pilot study indicated that the forms of test were different from each other in any of the measures. Reassignment of clips was only done for clips from the same group of difficulty.

If reassignment occured, item difficulty index, item discrimination score, and item-to-total correlation was recomputed based on the answers provided by the 16-novice and 16-expert soccer players. The new forms were compared to the forms created before the pilot study was conducted. If the new forms were more similar than the ones created before the pilot study, this last arrangement of forms wereconsidered the final version of the test.

3.3.2. Results

After all 55 clips were answered by the expert and novice soccer players, item-to-total correlation and item discrimination scores were computed (Table 2). From all 55 clips, 31 clips passed both criteria, item-to-total correlation higher than .2 and negative item discrimination score. All other 24 clips were eliminated from the study.

Table 2

Clips in bold met pre-established criteria. Other clips were eliminated from pool of clips.

Clips	Item-to-total correlation	Item discrimination score
22	0.73	+0.50
2	0.62	+0.30
1	0.6	+0.39
53	0.59	+0.20
13	0.48	+0.37
20	0.42	+0.19
25	0.41	+0.09
33	0.41	+0.17
47	0.4	+0.31
12	0.36	+0.17
18	0.36	+0.13
7	0.35	+0.35
32	0.35	+0.17
38	0.35	+0.13
27	0.34	+0.09
48	0.34	+0.07
26	0.33	+0.13
31	0.33	+0.07
30	0.31	+0.17
23	0.3	+0.26
6	0.29	+0.17
9	0.28	+0.11
5	0.27	+0.13
4	0.25	+0.09
15	0.25	+0.04
40	0.25	+0.09
37	0.24	+0.07
39	0.24	+0.50
51	0.24	+0.30
19	0.21	+0.39
34	0.21	+0.20

Clips	Item-to-total correlation	Item discrimination score
35	0.19	+0.11
49	0.17	+0.07
46	0.16	+0.04
41	0.15	-0.02
16	0.1	+0.09
29	0.1	-0.00
36	0.1	-0.00
50	0.08	+0.13
28	0.07	-0.00
54	0.07	-0.06
10	0.05	+0.20
11	0.04	+0.15
44	0.04	+0.02
55	0.03	+0.17
14	0.02	+0.02
17	0.02	-0.07
52	-0.02	+0.02
24	-0.04	+0.15
8	-0.14	-0.00
21	-0.18	-0.02
45	-0.18	-0.04
42	-0.24	-0.17
43	-0.26	-0.11
3	-0.44	-0.37

Following the elimination of clips, the difficulty index scores of the remaining 31 clips were computed. Since only 28 clips were required for the final experiment, clips 18, 23, and 33 were eliminated. Decision for item elimination was based on equating the four forms of the test in terms of item difficulty index. Item 18, 23, 33, were the most extreme clips. Item 23 was the easiest item, and clips 18 and 33 were the most difficult clips.

Table 3
Clips 23, 33 and 18 in bold were eliminated from the final pool of clips. Other clips were divided in groups based on level of difficulty.

Clips	Item-to-total correlation	Item discrimination score	Item difficulty index	Groups of clips	Groups of clips ranked by level of difficulty
23	**0.3**	**+0.06**	**.006**		
38	0.35	+0.17	0.08	Group 1	Easiest Group Of Clips
26	0.33	+0.13	0.10		
31	0.33	+0.09	0.10		
34	0.21	+0.09	0.10		
12	0.36	+0.17	0.12	Group 2	
27	0.34	+0.17	0.12		
37	0.24	+0.09	0.12		
40	0.25	+0.11	0.13		
51	0.24	+0.13	0.16	Group 3	
25	0.41	+0.09	0.18		
20	0.42	+0.19	0.19		
5	0.27	+0.17	0.19		
9	0.28	+0.07	0.20	Group 4	
30	0.31	+0.07	0.22		
4	0.25	+0.17	0.25		
39	0.24	+0.04	0.26		
47	0.4	+0.28	0.27	Group 5	
2	0.62	+0.30	0.28		
13	0.48	+0.37	0.28		
7	0.35	+0.31	0.29		
32	0.35	+0.13	0.29	Group 6	
15	0.25	+0.26	0.30		
22	0.73	+0.50	0.32		
48	0.34	+0.35	0.32		
19	0.21	+0.07	0.33	Group 7	Hardest Group Of Clips
6	0.29	+0.13	0.34		
1	0.6	+0.39	0.36		
53	0.59	+0.20	0.36		
33	**0.41**	**+0.04**	**0.41**		
18	**0.36**	**+0.37**	**0.59**		

One item of each group was assigned to each form until all four forms contained seven clips each. The averages for item difficulty index, item-to-total correlation, and item discrimination scores for each form were compared. In order to make the forms as similar as possible, reassignment of clips was conducted until it was believed that no more improvement could be made to these averages by switching any other clips (Table 4). Clips were only switched between forms if they were grouped in a similar level of difficulty.

Table 4

Item-to-total correlation, item discrimination score, and item difficulty index averages within forms

Forms of the Test	Item Level of Difficulty	Clips	Item-to-total Correlation	Item Discrimination Score	Item Difficulty Index
Form 1	1	31	0.33	0.09	0.10
	2	37	0.24	0.09	0.12
	3	20	0.42	0.19	0.19
	4	30	0.31	0.07	0.22
	5	47	0.4	0.28	0.27
	6	15	0.25	0.26	0.30
	7	53	0.59	0.20	0.36
	Averages		**0.363**	**0.169**	**0.222**
Form 2	1	34	0.21	0.09	0.10
	2	12	0.36	0.17	0.12
	3	51	0.24	0.13	0.16
	4	39	0.24	0.04	0.26
	5	13	0.48	0.37	0.28
	6	22	0.73	0.50	0.32
	7	19	0.21	0.07	0.33
	Averages		**0.353**	**0.196**	**0.225**
Form 3	1	38	0.35	0.17	0.08
	2	27	0.34	0.17	0.12
	3	5	0.27	0.17	0.19
	4	9	0.28	0.07	0.20
	5	2	0.62	0.30	0.28
	6	48	0.34	0.35	0.32
	7	6	0.29	0.13	0.34
	Averages		**0.36**	**0.193**	**0.221**
Form 4	1	26	0.33	0.13	0.10
	2	40	0.25	0.11	0.13
	3	25	0.41	0.09	0.18
	4	4	0.25	0.17	0.25
	5	7	0.35	0.31	0.29
	6	32	0.35	0.13	0.29
	7	1	0.6	0.39	0.36
	Averages		**0.363**	**0.190**	**0.228**

Before the beginning of the second phase, a pilot study was conducted to test whether assignment of clips produced balanced test forms (Table 5). Two major discrepancies among forms were recognized. First, the overall mean for the second form of the test, which was 1.686, was lower than any other form of the test (Form 1 = 1.8; Form 3 = 183; Form 4 = 193). Secondly, the difference between novices and experts in test forms 3 and 4 (difference score =

.2556 and .163 respectively) were much lower than forms 1 and 2 (Form 1 = .66, and Form 2 = .74).

Table 5

Overall mean, novice group mean, expert group mean, and expert-novice difference score for data collected during the pilot study.

Forms of the test	1	2	3	4
Overall mean	1.8	1.685714	1.828571	1.928571
Novice group mean	1.988889	1.927778	1.922222	1.972222
Expert group mean	1.333333	1.190476	1.666667	1.809524
Difference score	0.655556	0.737302	0.255556	0.162698

Based on these two discrepancies, another reassignment of clips was conducted. Clips were only switched among forms if they came from the same level of difficulty group. The rearrangement of clips produced test forms that were similar to each other across measures.

Table 6

Overall mean, novice group mean, expert group, and difference score for modified forms constructed based data collected during the pilot study.

Forms of the test	1	2	3	4
Total score	1.81	1.79	1.8	1.842857
Novice average	2.071429	2.107143	2.142857	2.178571
Expert average	1.47619	1.52381	1.428571	1.571429
Discrimination score	0.595238	0.583333	0.714286	0.607143

More important than being similar in pilot study measures, the rearranged forms needed to be compared in terms of item-to-total correlation, item discrimination scores, and item difficulty index. For that, a new set of averages for these measures were computed using the answers by the 16 novice and 16 expert players. The new rearrangement of clips with the pilot data produced greater similarity of forms (Table 7). Consequently, this last arrangement of forms was considered the final version of the test.

Table 7

Item-to-total correlation, item discrimination score, and item difficulty index averages within forms for the final test forms

Forms of the Test	Item Level of Difficulty	Clips	Item-to-total Correlation	Item Discrimination Score	Item Difficulty Index
Form 1	1	31	0.33	0.09	0.10
	2	40	0.25	0.11	0.13
	3	20	0.42	0.19	0.19
	4	30	0.31	0.07	0.22
	5	47	0.4	0.28	0.27
	6	15	0.25	0.26	0.30
	7	53	0.59	0.20	0.36
	Averages		**0.364**	**0.172**	**0.224**
Form 2	1	38	0.35	0.17	0.08
	2	12	0.36	0.17	0.12
	3	25	0.41	0.09	0.18
	4	39	0.24	0.04	0.26
	5	13	0.48	0.37	0.28
	6	48	0.34	0.35	0.32
	7	19	0.21	0.07	0.33
	Averages		**0.341**	**0.18**	**0.225**
Form 3	1	34	0.21	0.09	0.10
	2	27	0.34	0.17	0.12
	3	5	0.27	0.17	0.19
	4	9	0.28	0.07	0.20
	5	2	0.62	0.30	0.28
	6	22	0.73	0.50	0.32
	7	6	0.29	0.13	0.34
	Averages		**0.36**	**0.191**	**0.224**
Form 4	1	26	0.33	0.13	0.10
	2	37	0.24	0.09	0.12
	3	51	0.24	0.13	0.16
	4	4	0.25	0.17	0.25
	5	7	0.35	0.31	0.29
	6	32	0.35	0.13	0.29
	7	1	0.6	0.39	0.36
	Averages		**0.337**	**0.193**	**0.22**

Before the test was finalized, ordering clips within each form was completed. Ordering of clips was done based on the level of difficulty grouping. In all forms, the sixth easiest item came first, followed by the second, fourth, fifth, first, seventh, and third respectively.

3.3.3. Discussion

Decision making plays a significant role in performance of sports. Although it has been studied extensively, little is known about how exercise affects decision making during game play. Consequently, the focus of this project to construct a reliable and validity instrument to test decision making in situations in which the subjects are exposed to increased exercise intensity.

In phase one, the basic format of the test was established. In doing so, three steps were taken. In the first step, 59 videoclips containing critical soccer decision making situations were developed by three experimenters. In the second phase, content validity information was gathered based on assessment of the clips by a group of expert soccer players. Reviewers ranked plays for each clip based on level of appropriateness. Four clips were eliminated from the experiment since ranking agreement was not reached.

In step three, the basic format of the test was established based on experts and novices responses to the clips. The final number of clips required for the final test was 28 divided in four forms with 7 clips each. Consequently, clips needed to be dropped. Dropping of clips was based on item discrimination and item-to-total correlation scores. It was important for clips to discriminate between experts and novices. Twenty-seven clips did not reach pre-established criteria for item discrimination and total correlation scores and were excluded from the pool of clips. For the remaining 31 clips, item difficulty index was computed. Since only 28 clips were required, three more clips were excluded from the experiment based on extreme discrimination scores. Clips were then assigned to different forms of the test. Reassignment of the clips occurred until item difficulty index, item discrimination score and item to total correlation were as similar as possible across forms.

Before moving on to Phase Two, a pilot study was conducted to verify equivalence among forms. Based on the pilot study, forms were rearranged. The forms produced based on the pilot study had more similar scores for item difficulty index, item discrimination, and item-to-total score. Consequently, these forms were considered the final version of the test.

4. PHASE TWO

4.1. Methods

The aim of the second phase of this experiment is to establish the reliability of the instrument. Alternate-forms reliability was used to show equivalence among the four forms created in Phase I. In addition, internal consistency of each form was also measured based on the coefficient alpha reliability. The coefficient alpha reliability indicates the homogeneity of clips within forms.

In addition to establishing the reliability of the instrument, this phase of the experiment expanded the validity evidence provided in Phase I. For that, it is expected that the groups will perform differently from each other in decision making accuracy with advantage to the groups with more expertise. The forms and forms by group interaction are not expected to be significant thus providing evidence that the forms are equivalent.

4.1.1. Subjects

Thirty two male college students of varying soccer skill levels participated in this phase of the experiment. To ensure a wide range of soccer skill in the sample of subjects, selection of subjects was based on their soccer experience. Four groups of 8 students each were formed as follows:

- Novices: students with no competitive soccer experience (less than 3 months of soccer experience);

- Intermediate-novices: students with some previous soccer experience, more than 3 months and less than 4 years, which have not played for their high school team nor have they played competitive soccer during high school;
- Intermediate-experts: students who played for their high school team or played competitive soccer during high school;
- Experts: college soccer players. Players needed to be listed in the roster of soccer university varsity team.

4.1.2. Procedures

The procedures were similar to Phase One of this experiment except that instead of 55 clips, subjects answered to 28 clips divided into four forms containing 7 clips each. The clips were projected onto a wall in front of participants using a LCD projector. All participants were tested using the same LCD projector (Proxima DP 6155). Testing procedures are the same as described in phase I. Participants were seated in a chair positioned 245 cm from a LCD screen. All participants were tested in a completely dark room. When each clip was finished, the videotape froze. Four possible decision sentences containing two words such as “kick goal” or “pass right” were projected onto the screen. Although speed of decision was not of concern in this phase of the experiment, the subjects were asked to select as quickly and as accurately as possible the most appropriate action for the player in possession of the ball. A video camera was used to measure speed of decision (Panasonic VHS – AG 188). The camera focused on a clock positioned on the right side of the screen. Accuracy of decision was measured by the points associated with the selected decision. Three points were associated with the most appropriate action, two to the second, one to the third, and zero to the least appropriate action.

The forms were presented to the subjects in different sequences. Form sequence was determined based on the Latin Square procedure with two restrictions. First, in the same sequence forms could not be repeated. Second, across sequences forms could not follow in the same spot in the Latin Square. A table of random numbers was used to determine the placement of each form in the Square. Four different sequences were adopted as follows:

Table 8

Four sequences of the test were established based on the Latin square procedure

	FORMS OF THE TEST			
SEQUENCE 1	1	2	4	3
SEQUENCE 2	3	4	2	1
SEQUENCE 3	4	1	3	2
SEQUENCE 4	2	3	1	4

4.1.3. Data analysis

Three analyses were performed in this phase of the experiment. For the alternate forms reliability, the total score for each of the forms of the test was used to calculate the Pearson Product Moment Correlation. Six correlation coefficients were computed. Higher correlation coefficients between forms indicate higher reliability. For all forms to show good reliability, correlations should be higher than .7. With a .7 correlation the amount of total variance attributed to true variance is the same as variance attributed to error variance. For each form, the coefficient alpha was calculated as an indicator of within forms consistency. As with the alternate forms reliability, high consistency depended upon high coefficient alpha estimation.

Finally, to increase support for the test, the data was also analyzed using a 4 (groups) X 4 (alternate forms) analysis of variance with repeated measures on the alternate forms of the test. Coherent with the purpose of the test, this analysis should indicate that groups are different from each other. The more experienced groups should have better performance in accuracy of decision. In order to show equivalence among forms, this analysis should also indicate that forms and form by group interactions are not significant. The dependent variable is accuracy of decision. All calculations will be performed using the SPSS v12.

4.2. Results

Alternate forms reliability evidence was achieved based on Pearson Product Moment Correlation among the total scores for each form of the test (Table 1). All six correlations between forms were moderate ranging from .31 to .56. All correlations, except correlation between forms 1 and 4, are significant at the .05 level. Correlation between forms 1 and 4 is .31 (p-value = .084).

Table 9

Pearson product moment correlations among forms of the test

		Form 1	Form 2	Form 3	Form 4
Form 1	Pearson Correlation	-	.508*	.436*	.310
	Sig. (2-tailed)		.003	.013	.084
	N		32	32	32
Form 2	Pearson Correlation		-	.555*	.383*
	Sig. (2-tailed)			.001	.030
	N			32	32
Form 3	Pearson Correlation			-	.436*
	Sig. (2-tailed)				.013
	N				32
Form 4	Pearson Correlation				-
	Sig. (2-tailed)				
	N				

The Cronbach's alpha was also calculated for the entire test as well as for each form of the test. Although the alpha values for all forms were low, the alpha value for the entire test was moderately high. Table 2 presents a complete list of alpha values.

Table 10

Cronbach's alpha values for each form of the test and for the entire test.

	N of clips	Cronbach's Alpha
Form 1	7	.212
Form 2	7	.576
Form 3	7	.104
Form 4	7	.517
Entire test	28	.738

In addition to the correlations between forms and the Cronbach's alpha, means and standard deviations were also computed for each form of the test in order to show equivalence of forms. Means and standard deviations were similar to each other.

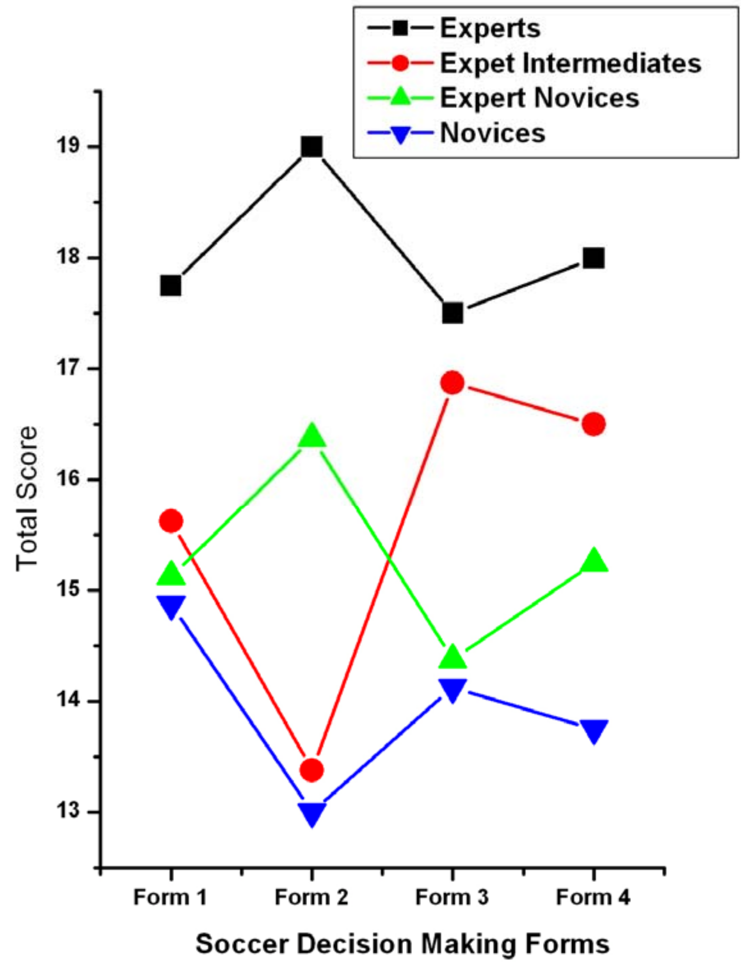
Table 11

Means and standard deviations for test forms across groups

	Mean	Std. Deviation	Sample size
Form 1	12.2	2.9	32
Form 2	12.5	3.8	32
Form 3	12.5	2.8	32
Form 4	11.9	2.9	32

The results of a 4 (experienced and inexperienced players) X 4 (alternate forms) analysis of variance with repeated measures on alternate forms shows a main effect for groups ($F_{3,28}$=9.749; p= .000). College soccer players were more accurate than any of the other three groups, intermediate-experts, intermediate-novices, and novices. The main effect of forms ($F_{3,84}$=.435; p= .729) was not significant. The interaction between forms and groups ($F_{9,84}$=2.033; p= .045) was significant. The interaction was likely due to poor performance of the intermediate-expert group in Form 2 of the test.

Figure 2


Experts
Expet Intermediates
Expert Novices
Novices
Total Score
19
18
17
16
15
14
13
Form 1
Form 2
Form 3
Form 4
Soccer Decision Making Forms

5. DISCUSSION

The purpose of this experiment was to construct a test to examine the effects of increased exercise intensity (rest, moderate low, moderate, and maximum exercise) on decision making of experts and intermediate novice soccer players. Four forms of the test were created during the Phase One, but before they are used in data collection further investigation of their reliability and validity were required. Phase Two of the experiment aimed at establishing the validity and reliability of the test.

Validity evidence for the use of the test was provided based on comparison between group means. The results indicated that experts were more accurate decision makers than any of the other three groups, intermediate-experts, intermediate-novices, and novices. Due to the purpose of the test, discriminating between the group of expert and intermediate novice players provided substantial evidence for the use of the test.

On the other hand, reliability information collected was insufficient to support the use of the test. The only evidence supporting the reliability of the test was based on the main effect for test forms. Test forms were not significantly different from each other. However, because the interaction between test forms and groups was significant, equivalent among forms can not be supported.

The correlation between forms of the test also indicated that forms of the test can not be used interchangeably. First of all, correlation between Forms 1 and 4 was not significant. Most importantly, all correlations were only moderate and below .7. Moderate correlations and lack of significance on the correlation between Forms 1 and 4 are potentially due to sample size and to the number of items. Each form had only seven items (clips). The number of items can not be increased due to limitations in how long subjects can be kept at the same exercise intensity. Consequently, to show stronger reliability evidence, increasing the number of subjects tested is advisable.

In the same line with correlations, estimated reliability of the test based on Cronbach's alpha values was also low. The Cronbach's alpha indicated that item responses did not correlate well with each other and with the total form score. This is specially true for forms 1 and 3. Low alpha values suggest that clips within forms are not consistent. Individual subject performances are likely not accurate due to the sample of clips used within each form.

In summary, some of the validity evidence provided during the first and second phase of the experiment suggests that the instrument proposed is adequate for measuring decision making accuracy in soccer for college population. In the first phase, validity was demonstrated by consulting a panel of experienced soccer players. Validity of the instrument was also evidenced by item-to-total correlation and the item discrimination scores. Only clips that correlated well with each other and that were able to discriminate between experts and novices became part of the test. The instrument was also able to differentiate experts from novice soccer players. However, the importance of all the results supporting the validity of the test was diminished by the reliability measures.

The reliability information collected is insufficient to show that the test is reliable. This was evident based on moderate correlations between forms, low coefficient alpha within forms, and the significant interaction between forms and groups. The first step in gathering more information should be increasing sample size. The sample size used in this experiment was small. If reliability measures are not improved by increasing sample size, rearrangement of forms, decreasing the number of clips per form, or decreasing the number of forms are possible alternatives to increase the reliability of the test.

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APPENDIX A. Review of Literature

Expertise refers to outstanding performance in a specific domain and is a function of innate capabilities and the amount and quality of experience. Spanning the last two decades, understanding what makes someone an expert has been a major focus of research in motor behavior. By understanding the phenomenon of expertise, physical educators will be better able to comprehend what makes experts better performers and subsequently help novices learn new motor skills effectively.

Experiments investigating differences between experts and novices are usually based on the information processing theory. The information processing theory postulates that information is sequentially processed from perception, to attention, thinking and integrating, incorporating knowledge base, making decisions, and finally executing motor skills. This sequence includes cognitive and motor skills. Differences favoring experts have been found in all elements of the information processing sequence. Compared to novices, experts possess better perceptual and decision making skills, and a richer knowledge base, in addition to more effective motor skills in their specific domains (McMorris & Beazeley, 1997; Radlo, Janelle, Barba, and Frelich, 2001; Williams & Davids, 1998; McPherson, 1999).

Because of the importance of decision making to open sports, decision making has received significant attention in the sport expertise literature (Ripoll, Kerlirzin, Stein, & Reine, 1995; Kioumourtzoglou, Kourtessis, Michalopoulou, & Derri, 1998; McPherson, 1999; McPherson, 1999). In open sports, sports in which the environment is constantly changing, a large number of decisions must be made quickly and accurately. Although research on the effects of expertise on sport performance is quite substantial, seldom has research been conducted under situations in which the participants are exposed to physiological stress. Sports however are played under conditions of physiological stress. Directing more attention to the effects of exercise intensity on decision making skills of expert and novice players should allow researchers to advance the understanding of the decision making process in actual sport settings.

Besides being limited in terms of number of studies, studies on decision making under conditions of physiological stress face methodological limitations including lack of ecological validity and reliability. Measurement instruments with high ecological validity are difficult to construct because of difficulties in controlling extraneous variables such as the diversity in situations involved in open sports. Also, the reliability scores of the testing instruments have often not been reported. Consequently, the goal of this project is to develop a reliable decision-making instrument with improved ecological validity compared to other instruments used to date.

Consistent with this goal, a discussion of the literature on expertise becomes imperative. With the exception of decision making, the information processing sequence is followed. Decision making is the last component of the information processing sequence discussed here due to its emphasis in this study. Discussion of the data collection instruments used to test decision making under conditions of physiological stress is also included.

Expertise in sports

Throughout the research literature, expertise has been defined as outstanding performance in a specific domain such as a sport, medicine, chess, or guitar playing. In sports, the difference between experts and novices could exist anywhere in the continuum that represents the information processing sequence. The information processing sequence includes perception, thinking knowledge base, decision making, and motor skill execution. Based on the information processing theory, before a sport movement can be executed, information present in the environment is perceived by the individual, processed by the central nervous system, the knowledge base accessed, and a decision made and executed.

Reviewing the research on expertise, differences between experts and novices have been found in all components of the information processing sequence. In perception, for example, experts discriminate among plays and fixate their eyes on more relevant aspects of the environment (Hyllegard, 1991; Benguigui and Ripoll, 1998). Knowledge base also discriminates between experts and novices. Experts display a larger knowledge base compared to novices (Campos, 1993; Williams & Davids, 1998; Starkes, Caicco, Boutilier, & Sevsek, 2001). In addition to perception and knowledge base, as expected, experts make better decisions and execute better plays (French, Spurgeon, & Nevett, 1995; McPherson, 1999).

A more detailed discussion on how expertise affects each component of the information processing sequence follows. Components are presented based on their order in the information processing sequence. The only topic presented out of its sequencing order is decision making. Decision making is the last topic presented due to its essential role in this paper which is constructing a testing instrument to investigate the decision making skills of expert and novice soccer players at different exercise intensities.

Perception

Perception, the first component of the information processing sequence, is a critical component in sports. In closed sports, such as gymnastics or diving, sport participants rely mostly on information about how their body is moving in space. In open sports, perception of current events in the environment becomes more important. In baseball, for example, batters rely on visual information from the pitcher's behavior, the speed and early trajectory of the ball. In fact, baseball players even rely on the seams of the ball to discriminate among different pitches (Hyllegard, 1991).

Regardless of the type of sport, open or closed, studies on perception have mostly concentrated on visual discrimination skills and visual search patterns. Visual discrimination refers to accurately identifying information present in the environment while visual search patterns refer to ways the individual searches for the most relevant aspects of information present in the environment. Although the most frequently researched, visual discrimination and search are not the only elements of perception examined in the expertise literature. Coincidence timing accuracy, referring to the action of intercepting a moving object by coordinating limb movements, has also been examined. Lastly, perception in expertise has been indirectly studied by measuring attention allocation. Studies comparing perceptual skills of experts and novices usually indicate that experts outperform novices in the domain of expertise.

An advantage of experts over novices in sports might be that experts can more quickly and accurately identify relevant information in the environment. Goulet, Bart, and Fleury (1989) investigated visual discrimination differences in tennis. Results demonstrated that experts identify serves more accurately (flat, top-spin, and sliced) than novices. Hyllegard (1991) investigated visual discrimination in baseball. Results, in Hyllegard's experiment, indicated that expert players were able to identify more pitches than novices. Finally, Radlo, Janelle, Barba, and Frelich (2001), compared advanced to intermediate baseball batters, instead of novices as in the previous studies, and found, as well, that advanced batters were faster and more accurate in visual discrimination of fast and curved balls. These experiments suggest that, in general, experts are able to identify contextual information more precisely than novices.

The pattern of visual search of experts also differs from novices. During the execution phase of the serve, experts focus mostly on the racquet of the server while novices focus mostly on the ball (Goulet et al., 1989). Patterns of visual search was also studied by Williams and Davids (1998). After a series of four experiments in which subjects were exposed to different soccer situations (1 on 1, 4 on 4), the authors concluded that in general, experts show a more efficient pattern of visual fixation than novices usually fixating their eyes on more relevant aspects of the environment and showing greater reliance on peripheral vision. Obviously, by using a more effective visual search strategy, experts have more and better options to choose from when making decisions.

In addition to visual discrimination and visual search skills, coincidence timing accuracy has also been used to evaluate perception of experts and novices in sports. Coincidence timing accuracy certainly plays a major role in sports that require interception of moving objects such as tennis, football and karate. Benguigui and Ripoll (1998) examined the coincidence timing accuracy of 7-, 10-, 13-year-olds and adults. Participants were asked to synchronize a button press response to the arrival of a moving object at the end of a runway. Benguigui and Ripoll found that tennis experience accelerated the development of coincidence timing accuracy. The 7-

year-old tennis players reached a level of coincident timing accuracy similar to adults, while the same levels were just reached by novices at age 10.

Radlo et al. (2001) further explored the perceptual advantages of experts in sports indirectly by measuring attention of the participants. The authors examined the perceptual processes associated with batting in baseball. Two groups were tested, intermediate and advanced baseball batters. It was hypothesized that the perceptual advantage of advanced batters should enable them to allocate less attention to the pitches compared to the intermediate batters. Attention allocation was measured by studying subjects' brain wave patterns during their perceptual decision period, specifically the P300 component. The P300 component is the third in a series of waves that occurs between 300 and 1000/ms after stimulus presentation. Studies on P300 show that this wave is related to the time for a stimulus to be evaluated. As expected, measures of the amplitude of the P300 component showed that advanced batters produced a smaller P300 component. The smaller P300 component found for the advanced batter suggests that they are actually allocating less attention to processes of identifying different pitches.

All studies described so far indicate that perception is a fundamental part of expert performance. Thinking about how important perceptual skills can be to the acquisition of expertise, Abernethy, Wood, and Parks (1999) studied whether anticipatory skills in squash could be learned by novices. Three groups were tested: a perceptual training group, a placebo group, and a control group. Training for the first two groups consisted of 20 minute sessions, 5 times a week for 4 weeks. The perceptual training group worked four times a week on videotape-based prediction tasks and one time a week on physical practice. The placebo group worked four times a week on reading magazines about tennis and one time on physical practice. Finally, the control group was limited to one physical practice a week for four weeks. Results from this experiment indicate that training of perceptual skills isolated from physical practice can be learned by novices. Whether these results can be transferred to game performance still requires further investigation, nonetheless it is encouraging to know that such an important part of expertise might be trained in the absence of physical activity.

The results previously discussed support the notion that experts in sports perceive things differently from novices. Experts identify information present in the environment faster and more accurately. When compared to novices, experts also focus on the most relevant aspects of the environment. Another difference favoring experts is in coincidence timing accuracy. Experts are better at intercepting moving objects than novices. Finally, experts do not have to allocate as much attention in the identification of in relevant information present in the environment as do novices.

Differences in perception at different levels of expertise suggest that differences in other components along the information processing sequence exist. It is expected that knowledge base influences what is perceived by an individual by directing attention to the crucial information present in the environment. It is also expected that extracting information from the environment more efficiently help sport participants make fast and more accurate decisions to execute optimal plays.

Knowledge base

Information processing theorists believe that cognitive skills are as important as motor skills. For perception, it was demonstrated that experts possess better perceptual skills than novices. Knowledge base is another cognitive skill that has been extensively studied. Knowledge base also strongly affects sport performance. A richer knowledge base allows the performer to anticipate upcoming plays, choose the best strategy to deal with a variety of situations present in sports, and quickly react to environmental demands. In general, experts in sports possess richer knowledge bases compared to novices.

In a classical study, Chase and Simon (1973), examining the nature of knowledge of chess masters, found that chess masters organize individual chess pieces in chunks which represent meaningful game relationships. Besides the advantage in knowledge organization, by combining individual pieces in chunks, chess masters have also stored in memory an estimated 50,000 chess chunks (Simon & Gilmartin, 1973), and the respective 50,000 appropriate actions to the chunks (Newell & Simon, 1972). Chase and Simon's chess research indicates that experts are able to organize knowledge in a very efficient manner which gives them the ability to store in memory extensive amounts of information.

In addition to the experiments in chess, experiments in other domains have shown that experts possess more specific knowledge than novices. Comparing child experts and novices in two age levels (8-10 and 11-12 years of age) in basketball, French and Thomas (1987) demonstrated that experts in basketball have more declarative knowledge than novices. Declarative knowledge in this study referred to rules, player positions, and terminology. In a similar vein, comparing child experts and novices in soccer for two age levels (8 -10 and 12 – 14 years of age), Campos (1993) demonstrated that experts in soccer have more knowledge about rules, technique, terminology, and strategy than novices regardless of age. Age was a factor only within the novice group. Older child soccer novices performed better on the soccer knowledge tests than younger novice children.

Investigating knowledge base in baseball, French, Nevett, Spurgeon, Graham, Rink, and McPherson (1996) also found differences between youth experts and novices. Experts possessed greater sport knowledge than novices of similar age. This was shown in 3 out of 5 baseball problems presented to the players. Although experts exhibited statistically significant more advanced solutions to the problems, the authors, analyzing the less advanced solutions and errors in the solutions concluded that even the experts were at the beginning stages of learning.

Along the same lines, research on expertise in memory provide support the findings from research on knowledge base. Studies integrating memory differences between experts and novices determine the ability to recall domain specific information from knowledge base. Comparing high skilled soccer players (5 professionals/7 semiprofessional players) with low skilled soccer players (physical education majors), Williams and Davids (1998) demonstrated that high skilled players have superior anticipatory, recall and recognition performance of soccer specific actions compared to low skilled players. Thus, when contrasted to novices, experts make faster decisions, recall more information from play-to-play, and more accurately recognize different tactical patterns. Improvement in recall of information, and quickness and accuracy of decision are only possible due to the richer and better organized knowledge base of experts.

Similar to the results in sports, experts outperform novices in motor recall of dance sequences (Starkes, Caicco, Boutilier, & Sevsek, 1990). Interestingly, there is a distinction on what dancers can recall depending upon their dance experience. Starkes et al. demonstrated that ballet dancers outperform novices only for structured sequences; whereas, dancers with experience in creative modern dance outperform novices in both structured and unstructured routines. The different results are probably due to the specificity of each dance. Ballet is more structured than creative modern dance. In sum, the study by Starkes et al. suggests that even though experts are better in recall than novices, what individuals remember is highly related to what they practice. Since recall of information is highly related to how much and how well organized the information in the knowledge base is, Starkes et al research also indicates that experts possess more and better organized knowledge than novices.

Knowledge base is so critical in determining expertise that it can overcome other measures of intelligence. Schneider, Bjorklund and Maier-Bruckner (1996) compared experts and novices in soccer with low and high cognitive aptitudes on a text recall task. Experts and novices were identified through a short version of a 45-item soccer questionnaire initially developed by Pentenrieder (as cited in Schneider et al., 1996). Within the groups of soccer experts and novices, children with high and low cognitive aptitude were identified through their scores on a verbal aptitude test for fourth graders. All participants were presented with a story dealing with an important match in the life of a young soccer player. The authors indicated that in the recall of this soccer story, experts in soccer outperformed novices independent of cognitive ability. In other words, these findings demonstrate that experience was able to eliminate the effects of cognitive abilities. This study shows how powerful the acquisition of expertise is on overcoming developmental ability differences. Expertise was found to be a more critical determinant of superior knowledge base performance than cognitive measures such as IQ.

Three main pieces of evidence were discussed in the experiments on expertise. First, it has been demonstrated that experts differ from novices in knowledge base. Differences, invariably favoring experts, have been demonstrated in chess, dance, and in a great number of sports. Second, research indicates that knowledge acquisition is experience dependent. The third piece of evidence probably ratifies the importance of the first two. Knowledge base was supported to be a powerful cognitive measure of expertise. In fact, so powerful that it is capable of overcoming IQ measures.

Naturally, decision making should be the next component discussed. In sports, specifically in open sports, players are required to meet environmental demands that are constantly changing. Throughout a game, a player is required to execute a great number of plays. Each execution is based on the player’s perception of the environment, knowledge base, decision making and motor execution. Based on the information processing theory, the sequence just presented contains the exact order in which information is processed. So far, this paper has followed this order of information processing. However, due to its central role in this research, decision making is presented only after the discussion on motor skill execution.

Motor skill execution

Thus far, perception and knowledge base have been argued as critical elements of sport performance. Experts have been described to possess better perceptual skills and a larger knowledge base than novices. Motor skill execution is another critical element of sport performance. As with perception and knowledge base, research also indicates that in general experts execute motor skills more effectively than novices.

Very often, the studies on motor skill execution have focused on cognitive domains as well with the purpose of showing that cognitive and motor skills are highly developed in experts. With the exception of the experiment conducted by French, Spurgeon, and Nevett (1995), research points out cognitive advantages of experts over novices. Another important characteristic of studies on motor skill execution is the high ecological validity. Rarely observed in investigations on the other components of the information processing sequence, studies on motor execution have usually been conducted during actual game play. Discussion on differences between experts and novices in motor skill execution follow a brief discussion of studies which used motor skill execution as a criterion for subject selection.

Subject selection based on motor skills has been done on studies investigating youth populations. Distinction between experts and novices in youth populations is not always as clear as in adult populations. As players age, because of increased experience and body changes, experts become more proficient in sports compared to novices. Often, to separate experts from novices, researchers use coaches' or parents' ratings or even years of competitive experience of subjects. In addition to these criteria, to increase the validity of the assignment of youth subjects to different levels of expertise, motor skill execution is sometimes tested.

Campos (1993) and French Spurgeon, and Nevett (1995) are among the authors who used motor skill execution as a criterion to separate youth experts from novices. The former tested youth soccer players, ages 8-10 and 11-12 years old, while the later authors tested youth baseball players, ages 7-, 8-, 9-, and 10-years-old. Campos administered the wall volley and soccer dribble test combined with a parental questionnaire to classify players into skilled and unskilled. French et al. (1995) first assigned participants to three levels of expertise, high, average, and low, based on coaches' ratings. Then to increase validity of assignment, they tested players' ability to perform a baseball throw for distance. As expected, high skilled children, ranging from 7- to 10-years-of-age, performed the throw for distance better than average and low skilled players. The baseball throw for distance is supported in the literature as a valid discriminator of baseball skill (Kelson cited in French et al. 1995).

After separating experts from novices, measurement of motor skill execution of players in their respective sports was made. Campos measured motor skill execution based upon videotaped performance of players during 20 minutes of actual play. Conclusions indicated that experts, independent of age, possessed more highly developed passing, receiving, kicking, and dribbling soccer skills. In the experiment conducted by French et al. (1995) a minimum of five regular season baseball games were videotaped. Analysis of the tapes by experienced baseball raters indicated that throwing force, batting average, batting contact, and catching were important discriminators of expertise.

French and Thomas (1987) were also among authors investigating motor skill performance. Youth basketball players, ages 8-10 and 11-12 years old, were tested. Dribbling and shooting skills were measures of motor execution during non-game situations. Conclusions indicated that experts possessed better shooting skills than the novice players. Surprisingly, no difference was found for dribbling skills.

Measures of motor skill performance have also been conducted with adults. Nielsen and McPherson (2001) compared the motor skill performance of adult experts and novices during tennis matches. Experts in this study were defined as professional players with a mean of 17.3 years of experience while novices were defined as players with no tournament experience and only a mean of 5.3 years of tennis experience. Shot and serve of participants were assessed on control and execution. Control of the shot and serve were coded as successful or unsuccessful by expert tennis coaches based on court position, ball contact and footwork. Execution of shot and serve were coded as forceful, nonforceful, netted, and long or wide. As with the youth populations, results of this experiment demonstrated that adult experts possess more developed motor skills than novices. Experts made more controlled and forceful shot and serve execution than novices. For efficient performance in tennis, controlled and forceful executions are desired.

Performance advantages of experts on perception, knowledge base and motor skill execution suggest that all three components taken together contribute to successful performance in sports. A component of information processing sequence not discussed so far is decision making. Since the purpose of this project is to create a reliable and valid instrument to test decision-making in sports, a detailed review of decision making in sports becomes imperative and will be the next topic covered.

Decision making in sports

According to the information processing theory, perception of information present in the environment, comparison to knowledge base, decision making, and motor execution complete the sequence of events for action production. So far, perception, knowledge base, and motor execution have been discussed. The next component to be discussed is decision making. In terms of the information processing sequence, decision making should have been discussed after knowledge base. However, because of its central role in the present study, decision making is purposefully presented out of context in the information processing sequence.

It has been previously stated that, in general, experts outperform novices in perception, knowledge base, and motor skill execution. The idea of the information processing theory sequence is that information from each component is integrated and synthesized in working memory in order to make a decision. In fact, a decision of what action to execute in a certain sport situation is based on current environment information perceived by the sport participant in relation to the knowledge base. Therefore, the presence of differences in perception and knowledge base already suggest that experts differ from novices in decision making. Experts also perform better than novices in decision making skills.

Most studies on decision making in sports have been done using open sports. In open sports such as tennis, boxing, and soccer, the environment is constantly changing. To meet environmental demands, open sport participants are required to constantly make quick and accurate decisions. In boxing, for example, boxers have to continually make decisions about which kind of punch to throw and how to defend their opponent's attacks.

Ripoll, Kerlirzin, Stein, and Reine (1995) investigated decision-making in simulated French boxing situations across three levels of expertise, novice, intermediate and expert. French boxing is a modality of boxing in which arm and leg strokes are legal. In this experiment, French boxing scenarios were acted out by an expert boxer. The taped clips were presented to the subjects. The task of the subjects consisted of joystick reactions to maneuvers of the taped boxer. The authors found that experienced boxers reacted more accurately than intermediate and novice boxers respectively. However, no differences were found in decision making time. Since in French Boxing deciding quickly is critical to successful performance, the lack of significance in decision making time might have been due to limitations of the decision making instrument used in this experiment. Limitations include lack of reliability and low ecological validity. It is possible that with improvements in the measurement instrument differences for decision making time would be found.

Even though Ripoll and collaborators failed to find differences in decision making time, Kioumourtzoglou, Kourtessis, Michalopoulou, and Derri (1998) found differences in both accuracy and speed of decision making. Kioumourtzoglou and collaborators compared athletes from the Greek water-polo national team to a group of novice players formed by physical education majors. The results favored the athletes which were faster and more accurate than the novice physical education students.

In the second experiment in the study, decision making in basketball was also measured but differences across expertise levels were not found. Experts in this study referred to members of the Greek national team while novices referred to physical education students. The authors attributed the findings to the fact that basketball is very popular in Greece and so the situations chosen might have been too easy even for the group of novices thus creating a floor effect. The findings could also be attributed to the lack of real world features in the instrument used. It is possible that the use of a decision making instrument with a higher ecological validity would have overcome the problems related to the popularity of basketball in Greece.

As reviewed so far, ecological validity is a common limitation of experiments in decision making. Controlling all the variables that are invariably present in a real life situation is a difficult task. In one of the few experiments testing decision making during actual matches, McPherson (1999) investigated the decision making accuracy skills of experts and novices in tennis, ages 10-11, 12-13, and collegiate adults. Players were asked to play a set of tennis, but only the first six games were filmed. McPherson analyzed the decision making of subjects according to a pre-determined protocol for the serve and game play situations. As expected, the results of this experiment indicated that experts in tennis, regardless of age, make better decisions than novices for both serve and match play.

Using the same protocol, Nielsen and McPherson (2001) compared professional instead of elite collegiate players to novices in tennis. Similar to the elite collegiate players in the McPherson (1999) study, professional tennis players showed higher percentages of tactical serve and shot selections than novices. Comparing the data obtained in both studies, the authors pointed out that professional tennis players make better serve and shot selections than elite collegiate players. Differences between these two groups were attributed to higher levels of expertise acquired through practice.

The research conducted in decision making in sports indicates that, in general, experts make better and faster decisions than novices, although sometimes there is a trade-off with experts only doing better on either accuracy or speed of decision making. It is rare to find experiments conducted in sports in which no differences exit in decision making between experts and novices. This emphasizes the point that experts develop not only more effective motor skills but also other elements of the information processing sequence. However, limitations on studies dealing with decision making in sports exist. The most common being ecological validity. As previously stated only a few studies (McPherson, 1999; Nielsen, & McPherson, 2001) used an instrument with high ecological validity. These high ecologically valid studies however did not measure decision making time. Other problems commonly cited with studies testing decision making are the lack of internal validity and reliability. Due to the fact that the goal of this project is to develop an instrument that captures decision making in soccer, the next section of this paper reviews experiments dealing exclusively with decision making in soccer.

Decision-making in soccer

Research on decision making has frequently used soccer as one of its greatest tools to test decision making in sports. Soccer, an open sport, is characterized by a great number of tasks that occur simultaneously. In fact, even players that do not have possession of the ball are constantly performing different skills. Running and attending to teammates and opponent positions are just some of these tasks. Controlling the ball, passing, dribbling, or kicking to the goal are examples of tasks performed during a game when a player has possession of the ball.

Obviously with so many tasks involved, the number of potential choices is large, as is the number of decisions a player has to make during a game. As an example, a player with possession of the ball has to decide whether to pass the ball to a teammate, dribble an opponent, run forward with the ball, kick to the goal, or perhaps even make a different decision. For each task, for example passing the ball to a teammate, there still are many more specific decisions to be made such as to whom among 10 teammates to pass the ball and which passing technique is the most appropriate for the given situation. Impressively, with so many options available, expert players usually make very accurate and fast decisions.

In testing decision making in soccer, as in other open sports, both accuracy and speed of decision have almost invariably been measured. Measuring both accuracy and speed of decision serves two purposes: creating testing environments that best mimic real soccer situations and controlling for the speed-accuracy trade-off. The former is related to the way soccer is played. In soccer, both quickness and accuracy of decision are critical to the dynamics of soccer. A player needs to make quick and accurate decisions based upon current environmental information. Not making quick decisions usually means losing the opportunity to create a good play or even loosing possession of the ball, whereas not making accurate decisions usually means losing the opportunity to initiate the optimal play for that situation. The later purpose is related to possible emphasis subjects might put on either decision speed or accuracy. If subjects are told that decision making time is not an important variable, subjects might allocate attention exclusively to accuracy, and by doing so differences between experts and novices might be eliminated.

Studies on decision-making in soccer have predominantly focused on discriminating between experts and novices. These studies show that experts possess better decision making skills than novices. In some of these studies it was found that experts, compared to novices, make more accurate decisions, and in others both more accurate and faster decisions. They also show that experience is a determinant factor in the acquisition of expertise. Differences between expert and novice adults in decision making are more easily identified in adult populations than between expert and novice youth populations.

An experiment testing decision making skills of skilled and unskilled youth soccer players in two age levels (8 – 10 and 12 – 14 years) was conducted by Campos (1993). Subjects were presented a videotape with 12 separate segments of a soccer game. After viewing the tape for 20 seconds, the tape was frozen and the subjects were to decide the most appropriate play using a forced four choice option. The results of this study indicate that skilled children make more accurate decisions than novices regardless of age, and unskilled older children make more accurate decisions than unskilled younger children. On the other hand, although quick decision making is a crucial element of actual soccer games, there was no difference in decision-making time between skilled and unskilled or older and younger children. The lack of significant difference in decision-making time might have been due to the fact that even the older skilled players in Campos experiment were still young children.

The second part of Campos' experiment investigated decision making skills during game play. Each subject was filmed playing soccer for 25 minutes. Decision making was analyzed based on intention of the player executing a pass, dribble, or kick, and also based on the outcome of the performed skill. Campos demonstrated that experts in soccer make more appropriate decisions during game play than novices. Due to its high ecological validity, results of this experiment are important in elucidating differences in decision making between experts and novices during actual soccer matches. However, precaution should be taken before generalizing these results to other situations since the testing instrument designed to measure the decision making skills of the players was measuring more than one dimension of soccer performance; the measure incorporated decision making based on the individual's skill level. It is possible that another set of results could have been reached if decision making was the only dimension tested.

As in the first part of the experiment conducted by Campos (1993), McMorris and Beazeley (1997) also compared decision making skills of expert and novice soccer players. In both experiments, quickness and accuracy of decision making were tested. However, whereas McMorris and Beazeley tested college level subjects, Campos tested children ranging from 8- to 14-years-of-age. In addition, although Campos was unable to capture differences between experts and novices in decision making time, the results of the experiment conducted by McMorris and Beazeley indicate that experienced players were not only more accurate in making soccer decision but also made faster decisions than inexperienced players. The difference between younger experts and novices in decision making time were not as high as the difference between older experts and novices. Taken together, results of both experiments suggest that experience plays a key role in the acquisition of expertise. It can be speculated that these results were achieved because the amount of experience across expertise level is clearly distinct for adults, but not so for younger players. As players age, due to a greater exposure to a wide variety of decision making situations, experts become more accurate and faster soccer decision makers.

Besides being a consequence of experience, the difference in decision making time and accuracy between experts and novices found by McMorris and Beazeley could be due to the quality of the testing instrumentation used. The decision making test used in their experiment had good reliability and internal validity. Its ecological validity, however, was not high. The situations included in the test were not dynamic since they were presented to the subjects as slides projected onto a screen.

In general, research on decision making in soccer shows that experts invariably possess better decision making skills than novices. Although studies have tested both decision making time and accuracy, differences in decision making time have not always been found. These studies also suggest that experience is a determinant factor in the acquisition of expertise. However, up to this point, none of the research discussed has tested decision making under conditions of physiological stress. Actually, only a few studies in decision making have been conducted in situations in which players are exposed to different exercise intensities. Conversely, it is well known that players are rarely at rest during a game, and they undergo exercise of different intensities throughout the game. More scientific information on how the decision making process of players respond to exercise is pertinent.

Decision making under conditions of physiological stress

Expanding the literature to how decision making is impacted by exercise intensity is crucial for a better understanding of decision making in sports. Sports are generally played under conditions of physiological stress. Bangsbo et al (1991) found that, for example, players in the Danish premier soccer league spent only about 17.1% of a match standing. Soccer games are characterized by exercise bouts that vary in intensity. Again, Bangsbo showed that players of the Danish soccer league walk for about 40.4% of the time, run in low intensity for 35.1% of the time, and run in high intensity for 8.5% of time.

On the other hand, although sports are very physically demanding and decision making is an important component of performance, to date research investigating the effects of exercise intensity on decision making is limited. The leading researchers on decision making under conditions of increased exercise intensity are McMorris and Graydon. Two articles on exercise intensity and decision making published prior to 1966 (Marriott, Reilly, & Miles, 1993; Tenenbaum et al., 1993) were criticized by McMorris and Graydon (1996a) for lacking reliability scores, not examining possible learning effects, and not testing speed of decision.

McMorris and Graydon (1996a, 1996b, 1997, 1999) have conducted a series of experiments focusing on the effects of exercise on decision-making performance of experienced players in soccer. Surprisingly, McMorris and Graydon tested the decision making of novice players only in their first experiment. Considering the importance of understanding the effects of exercise on decision making for populations that are just starting to learn soccer, the inclusion of a group of inexperienced players could have been fruitful.

The experiments conducted by McMorris and Gradyon were designed to test Easterbrook's (1959) theory of perceptual narrowing. The perceptual narrowing theory attempts to explain cognitive performance across different levels of arousal. This theory states that levels of arousal are related to changes in the attention capacity in an inverted-U manner. At low levels of arousal, individuals attend to relevant and irrelevant cues present in the environment. As the levels of arousal increase, individuals are able to narrow their attention to only the relevant cues present in the environment. At this point, attention reaches an optimal level. However, if arousal continues to rise, individuals narrow their attention too much thus missing relevant environmental cues. Consequently, based on the perceptual narrowing theory, McMorris and Graydon hypothesized that performance on speed and accuracy of decision would improve during moderate exercise and deteriorate during maximum exercise when compared to rest thus simulating an inverted-U shape.

The series of studies conducted by McMorris and Graydon on decision making were developed following similar methodological procedures. Decision-making performance was tested at three different exercise intensities: rest, 70% maximal power output (moderate exercise), and 100% maximal power output (maximum exercise). At each stage, three measures were taken, accuracy of decision (total number of accurate answers), overall speed of decision (total amount of time) and speed of decision for accurate responses (total amount of time for accurate answers only). The task consisted of 10 attacking situations selected by experienced soccer coaches. The situations were set up on a tennis tabletop and slides were made of these situations. Subjects had to answer as accurately and as fast as possible whether the player in possession of the ball should execute one of the following plays: pass, run, dribble or shoot. Speed of decision was measured using a tachistoscopic voice activated device.

In the first experiment, McMorris and Graydon (1996a) examined the effect of exercise on decision-making performance of experienced and inexperienced soccer players at three different exercise intensities. The results of this experiment, however, did not support McMorris' and Graydon's hypothesis. First, performance in decision-making accuracy for both groups, experienced and inexperienced soccer players, did not improve with moderate exercise or deteriorate with maximum exercise. Second, for speed of decision, performance of experienced players improved with moderate exercise, but there was no deterioration with maximum exercise. This was explained by the authors as a result of the experts' better knowledge base which made the task less cognitively demanding. Finally, the results of the inexperienced players for the speed of decision were actually the opposite of what the authors were expecting, no improvement with moderate exercise but improvement with maximum exercise.

McMorris and Graydon failed to support their hypothesis, specifically in relation to the accuracy of decision which did not differ with increased levels of exercise. McMorris and Graydon (1996b) contended that the task, a 4-choice decision making test based on the player with possession of the ball, was too simple, and therefore did not challenge accuracy in decision-making. Their assumption about the simplicity of the task came from the fact that even the inexperienced players had high scores. Consequently, a follow-up experiment using a more complex task was designed.

In the follow-up experiment, a group of 20 experienced players were tested on a simple and a complex task under the same three exercise levels: rest, moderate exercise, and maximum exercise. The simple task consisted of the same 4-choice decision-making task based on the player in possession of the ball while the complex task referred to a task in which subjects had to make a decision for a forward player who was not in possession of the ball. The results of this experiment in fact demonstrated that the complex task was more difficult since subjects had poorer scores on the complex task. Concerning decision making skills of players, although improvements in the testing instrument were made, results were not different from those achieved in the previous experiment. Speed of decision making improved from rest to the moderate exercise condition as predicted. However, no deterioration in speed of decision was seen with maximal exercise. Also, exercise once again had no effect on accuracy of decision.

McMorris and Graydon (1996b) believed that another possible explanation of lack of significance for the accuracy results is the speed/accuracy trade-off effect. The authors believed that because the players were asked to answer as quickly and as accurate as possible, some players were choosing accuracy over speed. Based on that, the authors developed a second experiment, in which one of the groups was asked to answer the decision making problems as fast as possible while the other group was told that speed of decision was not a critical factor. Although the group tested only on accuracy of decision was significantly slower than the group tested on speed and accuracy, again, accuracy of decision was not affected by exercise, even for the accuracy only group.

Results of the experiments discussed so far indicate that exercise has no effect on accuracy of decision-making. Differences in decision making accuracy across exercise intensities were not captured even when players were told that speed of decision was not a factor or tested using a complex decision making task. Finally, speed of decision once again improved from rest to the exercise conditions, but deterioration of decision time from moderate to maximal exercise, as hypothesized, was not found.

Up to this point, the authors focused on describing the influence of exercise on decision-making in general. However, due to a series of unexpected results, the focus of investigation in their next experiment (McMorris & Graydon, 1997) was switched to understanding why speed of decision was affected by exercise while accuracy was not. The authors thought that it was possible that exercise does not affect the entire decision making sequence from perception to performance. It could be that the only components of the cognitive process affected by exercise are encoding and attention. If this were the case, the results from speed of decision are explained. For the simple task, speed of decision improved as a result of improvements in the search time for finding the player with possession of the ball. For the complex task, improvements in speed of decision were exclusively a result of improvements in the search time for the player without possession of the ball marked by an X. Consequently, the next experiment in the series was set to test whether only search time is affected by exercise.

To test this assumption, instead of testing decision making, McMorris and Graydon tested reaction time of college soccer players at rest, 70% and 100% maximal power output using a visual search task. The task involved two sets of 15 situations. One set involved 15 game situations, 10 with and 5 without the ball. The other set involved 15 non-game situations. The participants were supposed to state as quickly and accurately as possible if the ball was present or absent in each situation. The results indicated that, for both game and non-game displays, speed of decision was faster during maximal exercise than at rest but moderate exercise did not affect visual search performance. Consequently, since visual search reaction time did not improve during the moderate exercise condition as happened in previous experiments, the argument that visual search would account for improvements in decision-making speed under physiological stress was weakened.

With their initial argument weakened, the second part of this experiment was set to test the contention that the information processing sequence as a whole, not only visual search, was facilitated by exercise. McMorris and Graydon combined the design used for the first part of this experiment, which consisted of three versions of 10 situations in which the ball was present and 5 in which it was not, with the design used in their previous research. Each version was administered during one of the three exercise conditions: rest, moderate, or maximal exercise. Subjects were supposed to first answer as quickly and accurately as possible whether the ball was or was not present, and then what course of action the player in possession of the ball should take: run, shoot, pass, or dribble. The results indicated that visual search was not affected by either exercise condition. Based on that, the authors' argument, that the only component of solving decision-making tasks influenced by exercise was visual search, was weakened even further. In fact, the results indicate that other component(s) of information processing may have a greater impact on decision-making speed than visual search.

In their most recent experiment, McMorris and collaborators (1999) tested the decision making performance of college soccer players at rest and while exercising at their adrenaline threshold and at maximal exercise. The authors saw the use of adrenaline threshold instead of moderate exercise as an improvement from their previous experiments since the adrenaline threshold is supported in the literature as being a more accurate measure of central nervous system arousal. To support this claim, McMorris and collaborators cited studies (Cooper, 1973; Chmura et al., 1994) in which increases in exercise intensity induced increases in the concentration of adrenaline central nervous system which induced increases in arousal and cognitive performance.

Although McMorris and collaborators used a more refined measure of CNS arousal, their findings were similar to their previous studies. As in the previous studies, accuracy of decision during the rest condition did not differ significantly from the two exercise conditions, and speed of decision was significantly faster for the two exercise conditions compared to rest. With the use of the adrenaline threshold, the authors were expecting to find difference in speed of decision between the adrenaline threshold condition and the maximal exercise condition, which was not the case. McMorris and collaborators speculated that it could be that increases in adrenaline above the adrenaline threshold are irrelevant for this particular task or that the adrenaline threshold and maximum power output represent only moderate CNS arousal. To support the latter assumption, the authors stated that maybe exercise does not produce the same effects as emotional arousal since the physiological changes associated with exercise are used to keep the body in homeostasis while physiological changes produced by emotional arousal disturb homeostasis.

In their series of experiment, McMorris and Graydon (1996a, 1996b, 1997, 1999) never fully supported their hypothesis. If the results were to support the inverted-U hypothesis, accuracy and speed of decision performance should have improved from rest to moderate exercise and then declined again to rest levels during maximal exercise conditions. In fact, the only portion of their hypothesis that was supported by their findings was that speed of decision decrease from rest to moderate exercise. The authors also claimed that there is no change in speed of decision as exercise intensity progresses from moderate to maximal exercise. McMorris and Graydon claimed that decision making accuracy was not affected by exercise, which was evident even when complex tasks were used.

Although never mentioned in their experiments, the problem with this research might have been the data collection instruments which lacked ecological validity. Both the simple and the complex decision making tests consisted of attacking situations chosen by experienced coaches set up on half of a table tennis tabletop. These attacking situations were photographed and transformed into slides which were then projected onto a wall in front of the subjects while they exercised. Clearly, these tests do not simulate the relation among perception, decision making, and the action present in the game of soccer.

Measurement used in decision making studies

Most tests used to test decision making in sports face methodological difficulties including reliability, and internal and ecological validity. Reliability and validity evidence of data collection instruments should be provided so that researchers are able to decide on whether or not the instrument possesses characteristics that match their research purpose. Reliability refers to the consistence of results obtained by the same measurement instrument over time. Reliability has actually an impact on validity. As reliability scores become lower, the researcher is less confident that the results are valid.

Although reliability of an instrument should always be measured before data collection, some studies in decision making did not measure the reliability of the data collection instrument used. Others estimated scorer reliability, but did not estimate the stability of instrument over time. Finally, some studies, including all studies in decision making under conditions of physiological stress, accurately reported the reliability of the test. Campos (1993) and Ripoll et al. (1995) never reported measuring reliability. Interestingly, in both studies differences between experts and novices in decision making accuracy were found, but not for decision making time. Interrater and intrarater reliability ranging from .88 to 1 were measured in McPherson (1990) and Nielsen and McPherson (2001). However, in addition to rater reliability, a measure of scores over time should have been used. In Kioumourtzoglou et al. (1998) and in McMorris's experiments, including the experiments measuring decision making under conditions of physiological stress, reliability of the instrument used to measure decision making was accurately reported. Kioumourtzoglou et al. reported reliability to be .95 estimated by the coefficient alpha measure. McMorris and collaborators used the split-half method to test the reliability of the scores. In McMorris studies, the reliability was reported as .92 for speed and .84 for accuracy of decision. Reliability was a limitation in two studies, in another study it was questionable, all other studies had tests with good reliability.

Methodological limitations related to validity can also be pointed out in studies testing decision making. Validity refers to the extent to which an empirical measure reflects the real value associated with a specific construct. Two types of validity are relevant for decision making tests: internal and ecological validity. Internal validity is defined as the degree to which testing clips measure the specified construct. In constructing decision making tests, internal validity is improved by consulting a group of experts in the specific domain. The test used in the experiment conducted by Ripoll et al. was developed by only one experienced coach. More experts should have been included in the development of the test.

McMorris and Graydon provided internal validity evidence based on assessment of their instrument by a group of 8 experienced soccer coaches. When conducting the experiments however, McMorris and Graydon used basically only one form across exercise conditions. The only different between forms used for the different exercise conditions was in the position each problem was set in the field. For each exercise condition (rest, moderate, or maximal exercise), the same 10 problems were used in different positions of the field. The validity of the results reported in their sequence of studies in decision making under conditions of physiological stress becomes questionable. It is possible that subjects noticed that the same plays were being used and consequently chose the same answer across exercise conditions. Indeed, McMorris and Graydon concluded that there were no differences in accuracy of decision with increased exercise intensity.

Actually, results related to speed of decision might also be explained by bias in the way the measurement instrument was used. In decision making experiments, it is expected that subjects weigh and compare the options present in each decision making situation to their knowledge base. If subjects notice the same plays are used across exercise conditions, the decision making process is substituted by simple recall of information from a previous condition. If able to recall answers, subjects were likely to reduce the time to make decisions for the first to the second condition. In fact, this is the pattern of response for speed of decision in McMorris and Graydon experiments. Subjects were able to improve speed of decision from rest to moderate exercise. As exercise intensity increased from moderate to maximal exercise no deterioration was found in decision making time. It is possible that lack of deterioration in speed of decision time was due to subjects repeating the answers from moderate to maximal exercise. By using different forms of the test, as is the case for the instrument proposed by this study, results in line with McMorris and Graydon hypothesis might be reached.

The other type of validity, ecological validity, is defined as the degree of generalization of score interpretations. In sports, the more similar the test is to the measured sport, the higher the ecological validity. Ecological validity is important for generalization of results to practical situations. Ideally all tests should be rated high in ecological validity. However, it is a difficult task to construct decision making tests with high ecological validity because of the great number of extraneous variables present in actual sport settings. Levels of motivation of athletes and the wide variety of situations present in sports are just some of these variables. Because of difficulties in controlling extraneous variables and constructing an objective test, often researchers have opted for more laboratorial studies.

In testing decision making in tennis, McPherson (1990), and Nielsen and McPherson (2001) used instruments with high ecological validity. Their protocol analyzed decision making during actual tennis matches. All other experiments discussed used more laboratory tests. The tests used in the decision making research discussed does not simulate three aspects of actual game play: number of decision making choices, dynamics of sport play, and the relation among perception, decision making, and the action present in sports.

A great number of decisions are made throughout open sports. For each decision players face, there are a great number of possible choices present. However, none of the laboratory tests had more than 4 possible decision making choices. Only 4 responses were possible even in the instrument used by McMorris and Graydon to test decision making under conditions of physiological stress in soccer. In these experiments, only situations in which one optimal answer was present were included. This helps increase the objectivity of the test. On the other hand, it reduces ecological validity of the test. In sports, more than one decision can turn out to be a good play. Ranking of the decisions seems more appropriate. In the instrument proposed by this study, decisions will be ranked by level of appropriateness by three experienced soccer players.

Decision making problems present in sports generally possess a large number of possible solutions. In addition, sports are very dynamic. The extent to which decision making tests were able to capture the dynamics of sports varies. Ripoll et al. were able to closely mimic the dynamics of French boxing by asking subjects to give a simple motor response to the actions of a taped boxer. The motor response consisted of pre-determined joystick movements. The experiment conducted by Campos was not as dynamic. The test consisted of segments of taped soccer games. Visual presentation of soccer problems allowed subjects to perceive how the situation developed. All experiments testing decision making under conditions of physiological stress had more severe limitations in terms of how well they were able to mimic the dynamics of soccer. For these experiments, problems were presented to subjects as slides projected onto a wall. Slides do not capture the dynamics involved in soccer.

The purpose of this experiment is to construct a reliable and internally valid decision making test. The test should also have improved ecological validity compared to tests used to test decision making under conditions of physiological stress. Use of an ecologically valid instrument is debatable in this situation. Constructing an ecologically valid instrument that controls for extraneous variables and at the same time is objective is very difficult. Besides, if the effects of exercise on decision making were to be measured in actual games, a protocol to measure exercise intensity during actual games would also have to be created. An improvement from current research on decision making under conditions of physiological stress can be made by using videotape segments taken from real soccer matches. Although not as dynamic as actual soccer matches, videotaping is more dynamic than slides. Research instruments, consisting of videotape segments taken from real soccer games, have been found to be a valid instrument in testing expertise in sports since previous research using videotaping has been able to demonstrate differences between experts and novices in decision making ability (Campos, 1993).

In summary, the instrument developed in this research will possess three major improvements compared to instruments currently used in research comparing decision making and physiological stress. First, a total of four different forms, one for each condition, will be developed. Forms will be tested for level of difficulty. Second, answers will be ranked by level of correctness. Finally, videotaping will be used instead of slides.

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APPENDIX B. ANSWER KEY BASED ON EXPERTS RANKING OF PLAYS PHASE ONE

Play 1 - Comfortmovie 1

Shoot goal	Pass forward	Pass left	Carry forward
4	1	3	2

Play 2 - Comfortmovie 2

Pass left	Dribble around	Pass center	Pass right
4	2	3	1

Play 3 - Comfortmovie 3

Pass right	Carry forward	Pass forward	Pass left
1	2	4	3

Play 4 - Comfortmovie 5

Shoot goal	Pass right	Carry forward	Pass back
1	4	2	3

Play 5 - Comfortmovie 6

Pass right	Carry forward	Pass back	Pass forward
1	3	4	2

Play 6 - Comfortmovie 7

Pass forward	Dribble forward	Pass left	Pass right
1	3	4	2

Play 7 – Fabioextramovie

Carry forward	Pass right	Pass forward	Pass left
2	3	4	1

Play 8 – Fabiomovie100

Pass back	Pass Left	Dribble around	Pass forward
4	2	1	3

Play 9 – Fabiomovie1000

Pass right	Pass forward	Carry forward	Pass left
3	1	2	4

Play 10 – Fabiomovie1001

Pass right	Shoot goal	Pass left	Pass forward
2	1	4	3

Play 11 – Fabiomovie101

Dribble around	Shoot goal	Pass back	Pass right
3	4	1	2

Play 12 – Fabiomovie200

Pass right	Pass left	Shoot goal	Pass back
1	3	2	4

Play 13 – Fabiomovie201

Cross right	Pass forward	Carry forward	Pass right
4	2	3	1

Play 14 – Fabiomovie202

Pass forward	Shoot goal	Pass right	Pass back
4	2	3	1

Play 15 – Fabiomovie204

Pass forward	Pass left	Pass right	Carry forward
1	2	4	3

Play 16 – Fabiomovie251

Carry forward	Pass right	Pass left	Shoot goal
2	3	4	1

Play 17 – Fabiomovie252

Pass left	Control ball	Pass forward	Pass back
4	1	3	2

Play 18 – Fabiomovie253

Shoot goal	Pass left	Pass forward	Carry forward
2	4	1	3

Play 19 – Fabiomovie50

Pass back	Pass right	Pass forward	Pass left
1	4	2	3

Play 20 – Fabiomovie51

Pass right	Dribble around	Pass forward	Pass left
4	3	2	1

Play 21 - lastplay

Shoot goal	Pass forward	Pass right	Carry forward
1	4	3	2

Play 22 – movie1

Kick outside	Pass goalkeeper	Dribble right	Pass side
3	1	2	4

Play 23 - movie 12

Carry forward	Pass right	Shoot goal	Pass back
1	2	3	4

Play 24 – movie 13

Carry forward	Pass back	Pass left	Cross right
3	2	4	1

Play 25 – movie 14

Pass back	Cross right	Pass right	Carry forward
4	3	1	2

Play 26 – movie 15

Dribble around	Pass right	Pass left	Pass back
2	1	3	4

Play 27 – movie 16

Pass forward	Pass left	Carry forward	Pass right
1	2	3	4

Play 28 – movie 17

Carry forward	Cross right	Pass right	Pass forward
3	4	2	1

Play 29 – movie18

Control ball	Pass left	Pass forward	Pass right
1	2	3	4

Play 30 – movie 19

Carry forward	Pass right	Pass back	Pass forward
3	1	2	4

Play 31 – movie 2

Pass back	Dribble around	Cross forward	Pass right
4	1	3	2

Play 32 – movie 22

Throw-in Left	Center	Right	Back
1	3	4	2

Play 33 – movie 23

Shoot goal	Pass forward	Pass left	Pass right
4	2	1	3

Play 34 – movie 26

Pass forward	Kick forward	Cross left	Pass goalie
2	1	3	4

Play 35 – movie 27

Cross right	Pass right	Pass back	Carry forward
3	1	4	2

Play 36 – movie 28

Cross right	Pass forward	Pass right	Carry forward
3	4	1	2

Play 37 – movie 29

Pass right	Pass back	Pass left	Cross right
2	3	4	1

Play 38 – movie 3

Carry forward	Pass right	Pass left	Pass goalkeeper
3	2	1	4

Play 39 – movie 30

Kick outside	Dribble around	Pass side	Pass forward
3	1	2	4

Play 40 – movie 31

Pass back	Cross left	Pass right	Carry forward
3	4	2	1

Play 41 – movie 32

Pass left	Pass forward	Carry forward	Pass right
3	1	2	4

Play 42 – movie 4

Kick outside	Pass left	Pass forward	Dribble around
3	4	1	2

Play 43 – movie 6

Pass back	Dribble forward	Pass left	Pass right
3	2	4	1

Play 44 – movie 7

Shoot goal	Dribble forward	Pass left	Cross right
4	2	1	3

Play 45 – movie 9

Pass right	Pass forward	Pass left	Carry forward
3	4	1	2

Play 46 – oldemarmovie1

Pass back	Pass forward	Carry forward	Pass right
4	2	1	3

Play 47 – oldermarmovie10

Shoot goal	Cross right	Pass forward	Pass right
4	2	1	3

Play 48 – oldemarmovie2

Pass forward	Pass left	Pass back	Dribble around
2	1	3	4

Play 49 – oldemarmovie3

Dribble around	Pass left	Pass right	Pass forward
3	1	4	2

Play 50 – oldeamarmovie4

Dribble around	Pass left	Pass forward	Shoot goal
4	3	1	2

Play 51 – oldemarmovie5

Pass left	Cross right	Pass forward	Carry forward
3	4	1	2

Play 52 – oldemarmovie6

Shoot goal	Cross right	Pass back	Pass left
3	4	2	1

Play 53 – oldemarmovie7

Carry forward	Pass right	Pass back	Pass forward
3	2	4	1

Play 54 – oldemarmovie8

Carry forward	Pass overhead	Shoot goal	Pass left
4	3	2	1

Play 55 – oldemarmovie9

Carry forward	Cross right	Pass forward	Pass left
3	1	4	2

APPENDIX C. ANSWER KEY – SECOND PHASE

Name: ___________________________________
Group: __________________________________
Tape number: _______________________________

TEST:

Demonstration

Demo1 - Play 18 – Fabiomovie253

Shoot goal (2	Pass left (4	Pass forward (1	Carry forward (3

Demo2 - **Play 33 – movie 23**

Shoot goal (4	Pass forward (2	Pass left (1	Pass right (3

Demo3 - **Play 23 - movie 12**

Carry forward (1	Pass right (2	Shoot goal (3	Pass back (4

Demo4 - **Play 35 – movie 27**

Cross right (3	Pass right (1	Pass back (4	Carry forward (2

Demo5 - **Play 49 – oldemarmovie3**

Dribble around (3	Pass left (1	Pass right (4	Pass forward (2

Experts ra1nking of plays
TEST: ______

Form 1

1. Play 47 – oldermarmovie10

Shoot goal	Cross right	Pass forward	Pass right
4	2	1	3

2. Play 37 – movie 29

Pass right	Pass back	Pass left	Cross right
2	3	4	1

3. Play 53 – oldemarmovie7

Carry forward	Pass right	Pass back	Pass forward
3	2	4	1

4. Play 20 – Fabiomovie51

Pass right	Dribble around	Pass forward	Pass left
4	3	2	1

5. Play 30 – movie 19

Carry forward	Pass right	Pass back	Pass forward
3	1	2	4

6. Play 31 – movie 2

Pass back	Dribble around	Cross forward	Pass right
4	1	3	2

7. Play 15 – Fabiomovie204

Pass forward	Pass left	Pass right	Carry forward
1	2	4	3

Experts ra1nking of plays
TEST: ______

Form 2

1. Play 13 – Fabiomovie201

Cross right	Pass forward	Carry forward	Pass right
4	2	3	1

2. Play 12 – Fabiomovie200

Pass right	Pass left	Shoot goal	Pass back
1	3	2	4

3. Play 19 – Fabiomovie50

Pass back	Pass right	Pass forward	Pass left
1	4	2	3

4. Play 51 – oldemarmovie5

Pass left	Cross right	Pass forward	Carry forward
3	4	1	2

5. Play 39 – movie 30

Kick outside	Dribble around	Pass side	Pass forward
3	1	2	4

6. Play 34 – movie 26

Pass forward	Kick forward	Cross left	Pass goalie
2	1	3	4

7. Play 22 – movie1

Kick outside	Pass goalkeeper	Dribble right	Pass side
3	1	2	4

Experts ra1nking of plays
TEST: ______

Form 4

1. Play 7 – Fabioextramovie

Carry forward	Pass right	Pass forward	Pass left
2	3	4	1

2. Play 40 – movie 31

Pass back	Cross left	Pass right	Carry forward
3	4	2	1

3. Play 1 - Comfortmovie 1

Shoot goal	Pass forward	Pass left	Carry forward
4	1	3	2

4. Play 25 – movie 14

Pass back	Cross right	Pass right	Carry forward
4	3	1	2

5. Play 4 - Comfortmovie 5p

Shoot goal	Pass right	Carry forward	Pass back
1	4	2	3

6. Play 26 – movie 15

Dribble around	Pass right	Pass left	Pass back
2	1	3	4

7. Play 32 – movie 22

Throw-in Left	Center	Right	Back
1	3	4	2

Experts ra1nking of plays
TEST: ______

Form 3

1. Play 2 - Comfortmovie 2

Pass left	Dribble around	Pass center	Pass right
4	2	3	1

2. Play 27 – movie 16

Pass forward	Pass left	Carry forward	Pass right
1	2	3	4

3. Play 6 - Comfortmovie 7

Pass forward	Dribble forward	Pass left	Pass right
1	3	4	2

4. Play 5 - Comfortmovie 6

Pass right	Carry forward	Pass back	Pass forward
1	3	4	2

5. Play 9 – Fabiomovie1000

Pass right	Pass forward	Carry forward	Pass left
3	1	2	4

6. Play 38 – movie 3

Carry forward	Pass right	Pass left	Pass goalkeeper
3	2	1	4

7. Play 48 – oldemarmovie2

Pass forward	Pass left	Pass back	Dribble around
2	1	3	4