THE EFFECTS OF EXERCISE INTENSITY ON DECISION MAKING PERFORMANCE OF EXPERIENCED AND INEXPERIENCED SOCCER PLAYERS

by

Fabio Eduardo Fontana

BS, Federal University of Parana, 1997

MS, University of Pittsburgh, 2004

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This dissertation was presented

by

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and approved by

Jean McCrory, PhD, Assistant Professor

Louis Pingel, PhD, Associate Professor

Robert Robertson, PhD, Associate Professor

Dissertation Director: Jere Gallagher, PhD, Associate Professor

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The aim of this study was to examine the decision making performance of experienced and inexperienced soccer players at four different exercise intensities: rest, 40% maximal aerobic power (moderate exercise I), 60% maximal aerobic power (moderate exercise II) and 80% maximal aerobic power (high intensity exercise). Following Easterbrook's theory, for the novice players it was predicted that the decision making accuracy and speed of decision making would show an inverted-U shape with increasing levels of exercise. For the experienced players, due to the automaticity of information processing, speed and accuracy of decision making were predicted to show no change in performance with increased exercise intensity. Thirty-two subjects, 16 experienced and 16 inexperienced adult male soccer players, participated in the study. Subjects were required to answer seven decision making questions at each exercise intensity. Level of soccer experience and level of exercise intensity were the independent variables while accuracy and speed of decision making were the dependent variables of this study. The data were analyzed using a 2 (experienced and inexperienced players) X 4 (exercise intensity level) multivariate analysis of variance with repeated measures on the last factor. The results indicated that exercise does not affect accuracy of decision making however there was a difference between experienced and inexperienced players. The effects of exercise intensity on speed of decision making for experienced and inexperienced players showed improved speed of decision making at moderately-high and high intensity exercise. Results of this experiment do not support the inverted-U hypothesis.

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PREFACE

I dedicate this dissertation to:

My advisor, Dr. Jere Gallagher, for the professionalism, kindness, and advices,

My friends, Oldemar Mazzardo, Comfort Mokgothu, and Ovande Furtado, for all the help along the way,

My family for all sacrifices,

My wife, Haydee Fontana, for the patience and Love.

1. INTRODUCTION

In sports, the remarkable skills of elite athletes draw the attention of a massive number of people around the world. The popularity of sports is largely due to the outstanding skills of professional athletes. Thus, it is difficult not to wonder how athletes develop skills to such high levels. Undoubtedly, genetics plays a role. However, it is deliberate practice that makes greatness. Deliberate practice refers to practice which is extensive and specifically designed to improve performance. Ericsson (1996) states that it takes at least 10 years of deliberate daily practice for an athlete to reach expertise. As a consequence, it is clear that physical education can not provide sufficient deliberate practice to transform all students into professional athletes. On the other hand, this is also not the purpose of physical education.

Instead of focusing on producing athletes, modern physical education focuses on promoting lifelong physical activity. There are many different ways in which people can be active in addition to playing sports and dance. Those include for example walking in the park with a dog or lifting weight at a local gym. However, for many people the best option is to be a member of a club or team playing a sport or dancing. Participation in sport and dance activities requires minimal levels of skill proficiency. By teaching students motor skills effectively, physical education is greatly enhancing the likelihood of students participating in physical activity for a lifetime.

Research on expertise in sports and dance assists physical education teachers by providing them with the knowledge to design better practices to help individuals acquire expertise. Extensive research on expertise in sport and dance in the last two decades has allowed researchers to have a deeper understanding of expertise. Not long ago, during the 1970's, few researchers would affirm that expert performance in sports depended so heavily on cognition.

Today, however, we know that in addition to motor skill execution, other elements of the information processing sequence are a critical component of expert performance. It is clear that expertise influences other elements of the information processing sequence including perception, thinking, knowledge base, and decision making. Based on the information processing model, 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. In fact, differences between experts and novices have been found in all elements of the information processing sequence. Several experiments were conducted on perception including Williams and David (1998) which indicated that in soccer, experts fixate their eyes on more relevant aspects of the environment. Several experiments were also conducted discriminating between experts and novices in knowledge base. In general, these experiments indicate that experts have a larger knowledge base compared to novices (Schneider, Bjorklund, Maier-Bruckner, 1996; Starkes, Caicco, Boutilier, Sevsek, 1990). Finally, experiments designed to measure the effects of expertise on decision making and motor skill execution indicate that experts make better and faster decisions, and execute better plays (Campos, 1993; McPherson, 1999).

However, although advantages in performance of experts over novices have been found for all elements of the information processing sequence, little is known about how these elements, perception, knowledge base, memory, decision making, and motor skill execution, respond to exercise. Interestingly, all phases of information processing in sports occur while subjects are exercising. Consequently, the purpose of this experiment is to examine the effect of exercise intensity on the decision making performance of experienced and inexperienced soccer players.

Two questions regarding the purpose are important: why investigate decision making and why select the sport of soccer. First, decision making was selected out of other possible elements of the information processing theory. Selection of decision making was based on its significance to open sports. In open sports, sports in which the environment is constantly changing, a large number of decisions must be made quickly and accurately.

It has already been indicated that experts make better and faster decisions than novices. However, due its critical role, a more detailed description of the effect of expertise on decision making becomes pertinent. Ripoll, Kerlirzin, Stein, and Reine (1995) found that adult experienced boxers reacted more accurately than intermediate and novice boxers respectively. Kioumourtzoglou, Kourtessis, Michalopoulou, and Derri (1998) found that water polo athletes were faster and more accurate than the novice physical education students. Although these two experiments were conducted in laboratory settings, other experiments replicating these findings were conducted using real world settings and task. In fact, McPherson (1999) and Nielsen and McPherson (2001) indicated that college tennis players make better decisions than novices for both serve and match play.

Second, among other sports, soccer was selected as the mechanism to study the effect of exercise on decision making due to the dynamics of the game. The game of soccer requires players to make quick and accurate decisions under physically demanding situations. Bangsbo, (1994), Chamari et al. (2005), and Stolen et al. (2005) indicated that the average exercise intensity in a game of soccer is approximately 75% of maximal oxygen uptake and 85% of heart rate. Evidence from these studies also indicated that about 10% of the game is also spent on high intensity activities that are predominantly anaerobic such as sprint or heading the ball. The exercise performed during soccer matches is of high intensity, consisting predominantly of aerobic running with periods of intense anaerobic exercise.

Results of research measuring decision making in soccer also follow the trend of experts being better sport specific decision makers than novices. Campos (1993) found that skilled youth players (8-14 years of age) make more accurate decisions than novices regardless of age. McMorris and Beazeley (1997) indicate that adult experienced players make more accurate and faster decisions in soccer.

Soccer has been commonly the sport used to investigate the influence of exercise on decision making (McMorris & Graydon, 1996a, 1996b, 1997, 1999). McMorris and Graydon examined the decision making performance of expert soccer players at three different exercise intensities: rest, 70% maximal power output (moderate exercise), and 100% maximal power output (maximum exercise). At each stage, two measures were recorded, accuracy of decision making (total number of accurate answers), and overall speed of decision making (total amount of time).

McMorris and Graydon hypothesized that performance on speed and accuracy of decision making would improve during moderate exercise and deteriorate during maximum exercise when compared to rest thus simulating an inverted-U shape. This hypothesis draws on the inverted-U theory (Yerkes-Dodson, 1908) of the effect of emotionally induced arousal on cognitive performance.

Although the inverted-U theory predicts the relationship between arousal and cognitive performance, it does not explain the mechanisms by which cognitive performance acquires an inverted-U shape as an effect of different levels of arousal. In 1959, Easterbrook attempted to explain this relationship by suggesting the cue utilization hypothesis. This hypothesis states that attention mediates the effect of arousal on cognitive performance. At low levels of arousal, individuals attend to too many cues present in the environment, some of which are irrelevant and impair cognitive performance. As the level of arousal increases, individuals are able to narrow their attention to only the relevant cues present in the environment. At this point, attention reaches an optimal level as does cognitive performance. However, if arousal continues to rise, individuals narrow their attention too much and important cues in the environment are missed.

However, the results of the series of experiments by McMorris and Graydon did not support the inverted-U theory. First, the results indicated that exercise does not affect decision making accuracy. The hypothesis for a decline in speed of decision making during maximal exercise was not supported as well, although speed of decision making improved significantly during exercise compared to when the participants were at rest.

Methodological limitations in the McMorris and Graydon studies might have masked the results. Methodological limitations are present in the decision making instrument, design of the experiment, and the exercise protocol used.

The decision making instrument had three shortcomings, test forms that were nearly identical, poor ecological validity, and the presence of only three forms of the test. The test forms of the decision making instrument used by McMorris and Graydon possessed soccer decision making situations that were identical except for the position of the situation on the field. The use of forms with identical situations might explain the lack of support to the hypothesized decision making performance. It is possible that decision making accuracy was not affected by exercise intensity because the subjects, noticing the situations were the same, chose the same answers. It is also possible that improvements in decision making speed were due solely to subjects repeating answers from one exercise condition to the next. The instrument chosen for this experiment uses test forms with completely different situations. Validity and reliability of the instrument used in this experiment have been extensively tested (Fontana, 2004).

Besides the use of forms with nearly identical questions, the decision making instrument used by McMorris and Graydon possessed poor ecological validity. It consisted of a tachistoscopic presentation of slides of soccer game situations made using model soccer players set on a tennis tabletop. Tachistoscopically presented tests have been criticized for poor ecological validity due to static presentation in contrast to the dynamic display of the actual game situations. The instrument chosen for the current experiment increases ecologically validity by simulating the complex and dynamic situations involved in soccer by using videotape segments taken from world-cup soccer matches. The advantage of video clips over slides is that it allows subjects to follow developing plays, and therefore provides a greater number of cues for subjects to determine the most appropriate action. Validity of research instruments, consisting of videotape segments taken from real soccer games, have been tested in previous experiments (Campos, 1993). The ideal scenario is to use an instrument in which decision making is measured during game play. In sports, however, the number of extraneous variables is so large and the ability to control the situation across trials so difficult that such instruments have yet to be developed.

Finally, in addition to using a decision making instrument with nearly identical forms and poor ecological validity, the decision making instrument used by McMorris and Graydon was also limited in terms of the amount of information it was able to collect. Their decision making instrument possessed only three forms, each used to measure decision making under a different exercise condition. The decision making instrument chosen for this experiment possesses four forms. The presence of four forms of the test allows for the addition of a fourth exercise condition. By the addition of an extra form and exercise condition, more information about the effects of increased exercise intensity on decision making can be gathered.

In terms of the design of the experiment, McMorris and Graydon did not test the decision making of inexperienced players other than in their first experiment. However, their experiment did not result in differences between inexperienced and experienced as expected probably because of the previously discussed methodological limitations. The design of this study, however, includes inexperienced players. The inclusion of inexperienced players is important because it allows the comparison between players with and without experience.

Although not as severe, limitations of the exercise protocol used by McMorris and Graydon may also have interfered with the results. Two limitations of the exercise protocol are the lack of randomization of exercise intensities and lack of control over exercise intensity.

In the McMorris and Graydon experiments, the exercise intensity manipulation always followed the same sequence. Subjects always answered the decision making questions first at rest, then at 70% maximal power output (moderate exercise), and finally at 100% maximal power output (maximum exercise). Increasing exercise intensity using the pattern from rest to maximum intensity only answers the question of whether increased exercise intensity affects decision making in soccer. However, during soccer matches the exercise performed by players varies greatly in intensity. This variability follows the requirement of the game and is random. As an example, a player might be running full speed at one moment, and the same player, several seconds later, might be slowly walking around the field. In this experiment, the order in which the subjects answered the questions was randomized, which allowed us to answer a much more appealing question of whether exercise of different intensities affects decision making in soccer.

A second limitation of the exercise protocol designed by McMorris and Graydon was that they did not control whether the power outputs selected, 70% and 100% maximal power output, were evoking intended exercise intensities. The prediction of the resistance of the cycle ergometer to provide the target power output was based on a pre-test of the aerobic capacity of the subjects. However, without any controlling measure such as heart rate or oxygen consumption, it is impossible to determine whether the predictions were accurate. In this experiment, heart rate and oxygen consumption were used to control exercise intensity.

All methodological improvements derived from the use of a refined decision making instrument and exercise protocol should help clarify what the effects of exercise on decision making performance are.

1.1 HYPOTHESIS

Three hypotheses were tested in this experiment. First, it was hypothesized that experienced soccer players would show faster and more accurate decision making performance than inexperienced soccer players across exercise conditions. The other two hypotheses were set to test the effects of exercise on decision making performance. It was hypothesized that exercise would affect the decision making performance of inexperienced and experienced players differently. Following Easterbrook's theory, for the inexperienced players it was hypothesized that accuracy and speed of decision making would show an inverted-U shape with increasing levels of exercise. For the experienced players, due to the automaticity of information processing, speed and accuracy of decision making were predicted to show no change in performance with increased exercise intensity.

2.0 METHODS, DESIGN AND PROCEDURES

2.1 SUBJECTS

2.1.1 General Characteristics

Thirty-two subjects, 16 experienced and 16 inexperienced college male soccer players participated in the study. It was important to restrict the sample to male college students since the Decision Making Instrument has only been validated for male students. In addition, male and female soccer players compete in separate leagues. Including both genders in the study would have increased within group variability thus increasing the difficulty of interpreting the results. No exclusion criteria were based on race, ethnicity, or HIV status. All participants signed the IRB consent forms and completed a soccer experience questionnaire prior to the start of the experiment.

2.1.2 Inclusion/Exclusion Criteria

All subjects were male college students. Inexperienced soccer players were on average 21.1 years of age (SD = 1.6), and experienced players were 19.5 years of age (SD = 1.1). Selection of subjects was based on their soccer experience. Two groups with distinctive soccer experience were formed as follows:

- Experienced players group (16 players): The experienced players were selected based on two criteria. First, they need to be members of the University of Pittsburgh Panthers soccer team. Second, all experienced players selected were required to demonstrate extensive soccer experience. Only players with 8 or more years of competitive experience were selected to be part of the expert players group.
- Inexperienced player group (16 players): the inexperienced players were college students with a minimum of 1 and a maximum of 4 years of soccer experience but had not played soccer for their high school team or played competitive soccer since leaving high school. It was important that inexperienced players had some minimal experience with soccer since individuals without any experience are likely to choose the answers at random. Choosing answers randomly is likely to mask the effects of exercise on decision making.

Finally, subjects would have been excluded from this research study if they reported, during the health screening conducted over the phone interview, having any physical problems that would place them at high risk for non-physician supervised exercise testing according to the American College of Sports Medicine. Physical problems included orthopedic, cardiovascular, and/or metabolic problems such as coronary artery disease, prior myocardial infarction, peripheral vascular disease, chronic obstructive pulmonary disease, and diabetes mellitus. Health screening was based on the Physical Activity Readiness Questionnaire (PARQ). None of the subjects answered yes to any question, so none of the subjects interviewed were excluded from the study.

2.1.3 Recruitment procedures

Signs were posted around recreational facilities of the University of Pittsburgh. Interested participants contacted one of the investigators by phone or e-mail. Subjects were screened for soccer experience and health screened by one of the investigators via phone. For a complete description of recruitment procedures see Appendix B.

2.1.3.1 Soccer Experience Screening Procedures

Upon contacting the researcher, participants were screened via the phone in order to determine whether they met the criteria for one of the two soccer experience groups to qualify to participate in the experiment. Qualification criteria have been previously described. Upon meeting the soccer experience criteria, participants were asked to answer the PAR-Q questionnaire.

2.1.3.2 Health Screening Procedures:

During the phone interview, subject's health was screened based on the Physical Activity Readiness Questionnaire - PARQ. The Physical Activity Readiness Questionnaire is designed to collect information about any health related condition that might place the subject at risk during participation in this study. A potential subject would have been excluded from participation if he answered yes to any of the PARQ questions. None of the subjects were excluded from participation in the study.

The telephone screening during which the soccer experience and PAR-Q questionnaires were administered occurred prior to the potential subject signing the informed consent.

2.2 DESIGN

The design of this experiment was 2 (expert and novice players) X 4 (exercise intensity level) with repeated measures on the last factor. The dependent variables are accuracy and speed of soccer decision making.

2.3 DECISION MAKING INSTRUMENT

The soccer decision making instrument, developed as a master's thesis at the University of Pittsburgh, was used for data collection. Detailed procedures used to acquire validity and reliability information are provided in the thesis (Fontana, 2004). A brief description is provided next.

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 with more than twenty years of soccer experience. Finally, the basic format of the test was established based upon item discrimination, item-to-total correlation, and item difficulty index computed on the responses of 16 college soccer players and 16 novices to the clips. Exclusion of clips was based on negative item discrimination and item-to-total correlation lower than .2. After clips were excluded, a final pool of clips contained 28 clips. The 28 final clips were grouped in four forms based on level of difficulty.

With the basic format of the test developed, a second phase of the experiment was conducted to determine the reliability of the four forms of the test. Thirty-two subjects categorized into four groups, novices, intermediate-novices, intermediate-experts, and experts, were tested during this phase. Reliability was determined based on alternate forms reliability. Six Pearson product-moment correlations were computed. All correlations were significant at the .01 level and greater than .5 indicating the forms could be used interchangeably. In addition, based on the results of a 4 (experienced level of subjects) X 4 (alternate forms) analysis of variance with repeated measures on alternate forms, the main effect of forms ($F_{3,84}$=.435; p= .729) was not significant (see Table 1 for means and standard deviations). This analysis also showed a main effect for groups ($F_{3,28}$=9.749; p< .01). College soccer players were more accurate than any of the other three groups, intermediate-experts, intermediate-novices, and novices.

Table 1: Equivalence of test forms

	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 final product of the previously described development procedures was a soccer decision making instrument containing four equivalent test forms. Each form consisted of 7 decision making videoclips. Each clip lasts 12 seconds and consists of a critical decision making segment of a real soccer match. When the decision point is reached, the video freezes. Four possible decision sentences are provided on the screen (e.g., pass right, shoot goal, cross left, and dribble forward). To avoid the habituation effect, forms were presented randomly for each exercise intensity condition.

2.4 PROCEDURES

The testing occurred over two sessions: fitness testing and decision making testing. All procedures, except for the initial screening phone interview took place at the Human Energy Laboratory, located in Trees Hall at the University of Pittsburgh.

2.4.1 Fitness Testing

The purpose of this first session, fitness testing, was to determine the subject's fitness level using the Bruce treadmill protocol (for a complete description of see Appendix C). In the Bruce protocol, participants walked/ran on a Trackmaster TMX 425C until they were tired and unable to continue. Prior to starting the Bruce protocol the subject's body height and weight were measured using a standard physician's scale. This was then entered into the computer that controls the testing protocol. The Bruce protocol consists of 5 stages lasting 3 minutes each. For each stage, the workload is increased by the combination of the speed and the grade of the treadmill as follows: Stage 1 – 2.73km/hr at 10% grade; Stage 2 - 4.03km/hr at 12% grade; Stage 3 - 5.47km/hr at 14% grade; Stage 4- 6.76km/hr at 16% grade; and Stage 5 – 8.05km/hr at 18%. During the Bruce protocol test, VO_2 and heart rate were recorded every 30 seconds. Heart rate (beats/min) was measured with a Polar Monitoring System (Woodbury, NY). An open-circuit respiratory metabolic system (True Max 2400, Parvo Medics, Salt Lake City, UT) was used to measure maximal aerobic capacity (VO_2). During the last minute of each 3-minute stage, the subject was asked to answer the OMNI Scale. The limits on the scale are zero, referring to exercise that feels extremely easy, and 10, referring to the exercise that feels extremely hard. The pictures and words positioned close to the number help subjects rate perceived exertion. The OMNI Scale was viewed by the subject who pointed to his RPE on the OMNI Scale. Ratings were taken for the overall body (RPE-overall), the peripheral perceptions in the legs (RPE-legs), and for breathing perceptions in the chest (RPE-chest). Test termination criteria was any of the following: (a) a change in VO_2 of <2.1 $ml{\cdot}kg^{-1}{\cdot}min^{-1}$ with increasing exercise intensity; (b) a Respiratory Exchange Ratio (RER) of ≥ 1.10 (defined as ratio of $[CO_2]:[0_2]$ (c) heart rate +/- 5 beats per min^{-1} of the age predicted maximum at the end of the exercise test, (d) volitional termination due to exhaustion or (e) termination at the subject's request for any reason. After completion of the test, subjects cooled-down at 2.0 $miles{\cdot}hr^{1}$ and 0% grade for three minutes or until heart rate decreased to <110 $beats\ {\cdot}min^{-1}$.

The data derived from the fitness session were used to predict treadmill speed and grade associated with exercise intensities 40%, 60%, and 80% VO_2max. Prediction was done by calculating separate simple linear regression equations (for an example see Appendix E). For each analysis, speed and grade scores were the dependent variables and VO_2 scores were the independent variable. Corresponding target VO_2 scores were also computed. The target VO_2 scores consisted of percentages of the total VO_2 reached by subjects during the Bruce protocol. Target VO_2 was used to assure that subjects had reached the predicted exercise intensity before answering the decision making instrument.

Once the fitness test was complete, subjects answered eight decision making questions similar to the ones they faced during the decision making session. These questions took approximately 3 minutes to complete. These questions served the purpose of acquainting the participants with the decision making instruments as well as clarifying any questions participants might have.

2.4.2 Decision Making Testing

Three to eight days following the aerobic fitness testing, a second testing session measured decision making while exercising at different intensities (see Appendix D). The Decision Making Instrument was projected onto a wall in front of the treadmill using an LCD projector (In focus LP 70+). Projection was located right in front of the treadmill 1.50m away and 1.80m high from the ground. Once the video froze, 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. One form of the Decision Making Instrument was used on each predetermined exercise intensity: rest (0%), 40%, 60%, and 80% VO_2max. The exercise conditions chosen represented the different points of the arousal curve including the two extremes, a condition where subjects are not exercising and another in which the subjects have to exercise at very high intensity, and two intermediate arousal points, a moderate-low and a moderate-high exercise conditions.

The rest condition functioned as a control variable and was always tested first. During the rest condition, participants answered one form of the Decision Making Instrument while standing on the treadmill.

After being tested at rest, treadmill grade and speed were set to match one of the predetermined exercise intensities (40%, 60%, and 80% VO_2max). All four predetermined exercise intensities were administered during a testing session. To better simulate exercise in soccer, exercise intensities were counterbalanced (see Appendix F).

Within each exercise condition, a habituation period of two minutes was provided to allow subjects to reach the target VO_2 level. It was considered that the subject had reached target, if his VO_2 at the end of the second minute was within +/-3 percentage points of the target scores. For example, for the 40% condition, VO_2 scores within the range 37% to 43% VO_2max were accepted. An open-circuit respiratory metabolic system (True Max 2400, Parvo Medics, Salt Lake City, UT) was used to measure VO_2 during the first two minute habituation period. After reaching the target VO_2 at the end of the habituation period, subjects disconnected the open-circuit respiratory metabolic system by removing the mouth piece and handed it to the researcher as they continued to walk. The heart rate associated with the second minute mark of each exercise condition was used to control exercise intensity during the decision making phase. After reaching the target intensity, the decision making testing began and the subjects responded to the soccer video clip with the best response for the player in control of the ball.

If the subject was below or above +/-3 percentage points of his target VO_2 score at the two minute mark, an extra one minute adjustment period was provided. Slight alterations in speed during the adjustment period were made so that each participant exercised at the predetermined aerobic power. Alterations were only made on speed. At the beginning of the second minute, speed was decreased or increased as necessary based on the equation: Speed Increment = 5 X slope of the line[1]. The slope of the line was based on the regression equation calculated with data of the first session for the speed of treadmill. Upon reaching target VO_2 at the end of the third minute, the decision making testing began. If the target VO_2 was not achieved at the end of the third minute, that exercise condition was terminated. Upon termination, the subject received a 10-minute break. The subject restarted the same condition

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[1] The rules for alterations in speed had been tested during pilot work.

after a 10 minute break if his heart rate was below 100 beats per minute. An adjustment of the speed was conducted on the speed increment equation previously described. However, the adjustment was relative to speed of the treadmill at the end of the adjustment period (3rd minute mark).

The heart rate associated with the second minute mark of each exercise condition (or when adjustments were necessary the third minute) was used to control exercise intensity as subjects answered the decision making instrument. As previously described, there are two 6-second breaks in the decision making instrument. Slight alterations in speed during these breaks were made so that each participant exercised at the predetermined exercise intensity throughout the decision making phase. Alterations were based on heart rate. If heart rate was within +/- 5 beats per minute of its initial value, no alterations were made. If heart rate was between +/- 5 and +/- 7 beats per minute, speed was modified based on the equation Speed Increment = 3 X slope of the line. If heart rate was above or below +/- 7 beats per minute, speed was modified based on the equation Speed Increment = 5 X slope of the line.

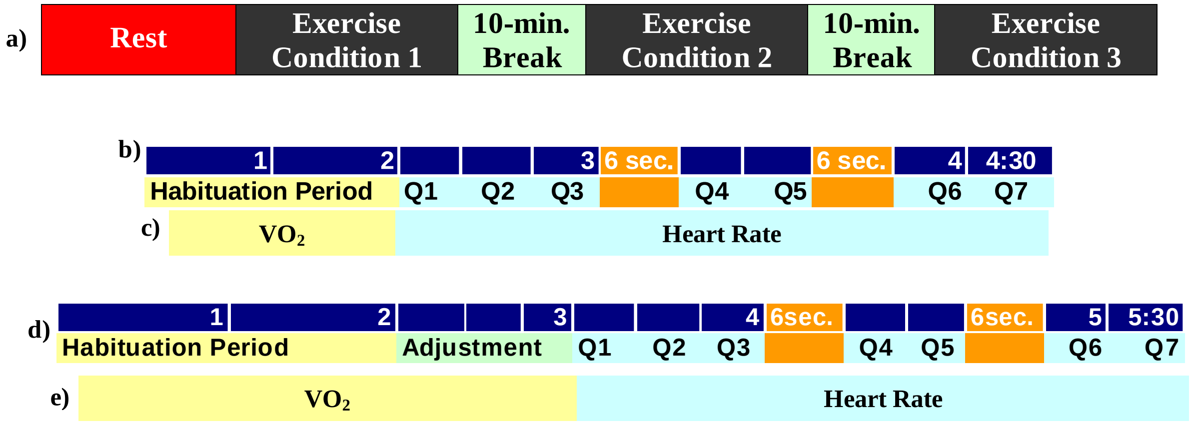

Figure 1: Sequence of events for the decision making session: a) overall sequence; b) sequence of events during each exercise condition; d) sequence of events during each exercise condition when an adjustment period is necessary; c and e) measure used to control exercise intensity

Between exercise conditions, there was a 10-minute rest period. Before another condition was started, heart rate of the subject had to be below 100 beats per minute. The same procedure applied to the subsequent two counterbalanced exercise intensities.

Speed of Decision Making was measured in milliseconds of a second. The answer was spoken into a microphone positioned in front of the treadmill (Blue Snowball Microphone). The microphone was connected to a computer (Power Mac G5). The voice of the subject was recorded by the software Final Cut Express 2 on the computer. The wavelength of the answers recorded by Final Cut Express 2 were used to determine speed of decision making. Accuracy of Decision Making was measured by the sum of total number of points associated with the selected decision for each of the exercise conditions. Four points were associated with the most appropriate action, three to the second, two to the third, and one point to the least appropriate action. Answers were recorded by a video camera. Only the investigators listed on this protocol had access to the data recorded by the Final Cut Express 2.

2.5 DATA ANALYSIS

2.5.1 Fitness Level

A one-way ANOVA with experience level as the independent variable (inexperienced and experienced players) was computed on the dependent variable maximal aerobic capacity (VO_{2max}). Maximal aerobic capacity was determined based on the Bruce Treadmill protocol.

2.5.2 Exercise Intensity

Analyses were performed for providing support for the differentiation of exercise conditions and maintenance of exercise intensity within each exercise condition.

2.5.2.1 Differentiating Exercise Conditions

A 2 (inexperienced and experienced players) X 4 (Exercise intensity) ANOVA with repeated measures on the last factor was computed to show that the exercise conditions (Rest, 40%, 60%, 80% VO_2max) were different from each other. The dependent variable was heart rate.

2.5.2.2 Exercise Intensity Within Each Exercise Condition

Descriptive statistics on heart rate including means and standard deviations were used to show that subjects maintained target exercise intensities for each exercise condition. Means and standard deviations were computed based on average deviation scores. Deviation scores were based on the difference between target and actual heart rate. Deviation scores were computed for each subject. Then, they were averaged across exercise conditions. Deviations scores close to zero and small standard deviations would suggest subjects maintained exercise intensity within each exercise condition.

2.5.2.3 Carry-over Effect

The carry-over effect was analyzed using a 2 (experience level) X 3 (exercise intensity level) multivariate analysis of variance with repeated measures on exercise intensity. The exercise condition rest was not included in the analysis. The dependent variables were accuracy and speed of decision making. Follow-up ANOVAs were calculated where appropriate.

2.5.3 Decision Making

The speed and accuracy of decision making data were analyzed using a 2 (experience level) X 4 (exercise intensity level) multivariate analysis of variance with repeated measures on exercise intensity. The dependent variables were accuracy and speed of decision making. Follow-up ANOVAs were calculated where appropriate.

Expected results include:

- Interaction between levels of physiological stress (rest, 40%, 60%, and 80% VO_2max) and experience level (experienced and inexperienced players): the presence of a significant interaction may support the hypothesis that the effects of physiological stress are different across experience levels. For novices, exercise is expected to produce a decision making performance resembling an inverted-U shape. For experts, exercise is not expected to affect decision making;
- Main effects of accuracy and speed of decision making: significant main effects show that experienced players make better and faster decisions than novices.

Sample size for the 2 (experience and inexperienced players) X 4 (alternate forms) multivariate analysis of variance with repeated measures on the alternate forms of the test was determined based on a power analysis using as parameters a large effect size of .8, a power of .7, and an alpha of .05 (Cohen, 1988).

3.0 RESULTS

The results are organized into three sections: fitness level, exercise intensity, and decision making. In the fitness level section, a description of whether level of fitness was a factor is presented. In the exercise intensity section, two questions are addressed. First, whether manipulation of exercise intensity produced exercise conditions that were clearly different from each other is discussed. Secondly whether subjects exercised at the pre-determined exercise intensity within each exercise condition is examined.

The decision making section evaluates three main research questions. The first question evaluated was whether inexperienced and experienced players differed in terms of accuracy and speed of decision making. The other two questions evaluated the effect of exercise on decision making ability in terms of accuracy and speed of decision making for inexperienced and experienced players. Each of the two questions had different hypotheses for inexperience and experienced players. For inexperience players, decision making accuracy and speed of decision making were predicted to show an inverted-U shape with increasing levels of exercise. For the experienced players, speed and accuracy of decision making were predicted to show no change in performance with increased exercise intensity.

3.1 FITNESS LEVEL

The fitness level of the subjects was determined using the Bruce Treadmill Protocol. The resultant VO_{2max} scores were used to compare the fitness level of inexperienced and experienced soccer players. A one-way ANOVA with experience level as the independent variable was computed on the dependent variable VO_{2max}. Results indicated that the fitness level of inexperienced players was not significantly different from the fitness level of experienced players ($F_{(1,31)} = 3.93$; $p = .057$). Although not significant (see Table 2), the p-value almost reached significance (observed power = .484). However even if significant, the fitness level of the subjects was not expected to have influenced the results of this experiment since subjects exercised at percentages of their own maximal aerobic capacity (VO_{2max}). Subjects only started answering the decision making instrument if their VO_2 scores were within the target range (+/- 3%) at the end of the habituation period.

Table 2: Means (SD) for aerobic capacity across experience level

	Aerobic Capacity
Inexperienced	55.1 ml/kg/m (13.1)
Experienced	62.6 ml/kg/m (7.6)

3.2 EXERCISE INTENSITY

Three questions are answered in this section. The first is whether the exercise conditions were clearly different from each other. The second is whether subjects maintained the required exercise intensity throughout each exercise condition while the third question addresses carry-over effect.

3.2.1 Differentiating Exercise Conditions

The purpose of this section is to show that the exercise intensity manipulation in fact produced four exercise conditions (Rest, 40%, 60%, 80% VO_2max) that were different from each other. Analysis was based on a group x exercise condition ANOVA with repeated measures on the last factor. Heart rate was the dependent variable. This repeated measures analysis violated the sphericity assumption, consequently, the F-values obtained were evaluated based on adjusted degrees of freedom using the lower-bound correction procedure.

The results revealed a significant main effect for exercise intensity ($F_{(1,30)} = 693.8$; $p< .0005$). The main effect for experience level was not significant ($F_{(1,30)} = .865$; $p= .36$). Least Square Difference (LSD) post hoc analysis showed that heart rates at Rest (M = 81 bpm; SD = 10.3), 40% (M = 126 bpm; SD = 11.7), 60% (M = 152bpm; SD = 11.5), and 80% VO_2max (M= 175 bpm; SD = 8.9) were all significantly different from each other at $p < .0005$ (See Table 3). The interaction between exercise intensity and level of experience was not significant ($F_{(1,90)} = .433$; $p= .850$).

Table 3: Means (SD) for heart rate scores across experience level and exercise intensity

	Rest	40% VO_2max	60% VO_2max	80% VO_2max
Inexperienced	82.75 (11.1)	127 (12.1)	152.3 (9.3)	177.2 (8.0)
Experienced	79.3 (9.5)	124.6 (11.5)	151.7 (13.7)	173.6 (9.6)

3.2.2 Exercise Intensity Within Each Exercise Condition

Before the subjects started answering the decision making instrument, each subject went through a 2- to 3-minute habituation period. The habituation period served to allow the subjects to reach the target VO_2 level. The heart rate associated with the end of the habituation period was used to control exercise intensity as subjects answered the decision making instrument. Slight alterations on speed were made if the heart rate of the subjects was outside of a pre-specified range. Adjustment of heart rate was based on how far out of range it was. If heart rate was between +/- 5 and +/-7 beats per minute outside of the range as determined based on pilot study, speed was modified based on the equation Speed Increment = 3 X slope of the line (i.e. 0.2mph). If heart rate was above or below the target by +/- 7 beats per minute, speed was modified based on the equation Speed Increment = 5 X slope of the line (i.e. 0.3mph).

The purpose of the alterations on speed was to maintain the target exercise intensity. Consequently, in order to determine whether the subjects were exercising at predetermined exercise intensities, it was imperative to evaluate the variation of heart rate measures at each exercise intensity level (see Table 4). This was done by calculating average deviation scores. Deviation scores were based on the difference between target and actual heart rate. Deviation scores were computed for each subject. Then, they were averaged across exercise intensities.

Table 4: Means (SD) for deviation scores across experience level and exercise intensity

	40% VO_2	**60% VO_2**	**80% VO_2**
Inexperienced	-0.1 (2.4)	1.5 (2.3)	5.2 (2.6)
Experienced	-1.6 (1.8)	0.5 (2.6)	4.4 (2.3)

Average deviations for inexperienced and experienced players were small for the 40% and 60% maximal aerobic intensity conditions suggesting that subjects were in fact exercising at their predetermined exercise intensities.

At the 80% maximal aerobic intensity, average deviations for inexperienced and experienced groups across decision making questions were slightly larger. This was expected since the subjects were exercising above the anaerobic threshold. Average deviations suggest that subjects were exercising at a slightly higher capacity than predicted specially by the end of the Decision Making Instrument. This is supported by the average deviations for each of the questions (See Table 5). Average deviations for each question suggest that subjects were exercising at a slightly higher capacity than predicted specially by the end of the Decision Making Instrument.

Table 5: Means (SD) for deviation scores at 80% VO_2max

	Inexperienced	Experienced
Question 1	3.0 (2.3)	2.0 (2.1)
Question 2	3.9(2.7)	3.4 (2.2)
Question 3	5.3 (3.1)	3.9 (2.2)
Question 4	5.6 (3.4)	4.8 (2.5)
Question 5	6.3 (3.5)	5.1 (2.9)
Question 6	5.8 (3.2)	5.8(3.3)
Question 7	6.2 (3.6)	5.8 (3.0)

3.2.3 Carry-order Effect

Based on the group x order of exercise intensity multivariate analysis of variance with repeated measures on the last factor, the main effect of order of exercise intensity was not significant ($F_{(4,27)}$ = 1.29; p= .303). In congruence with the MANOVA, the results for the univariate analyses for accuracy ($F_{(2,60)}$ = .456; p= ..636) and speed of decision making ($F_{(4,27)}$ = 1.29; p= .303) were not significant.

3.3 DECISION MAKING

Based on the group x intensity multivariate analysis of variance with repeated measures on the last factor, the construct decision making was significantly affected by level of experience ($F_{(2,29)}$ = 14.7; p< .0005) and exercise intensity ($F_{(6,25)}$ = 14.7; p= .009). These results suggest that both level of experience (inexperienced and experienced) and exercise intensity (Rest, 40% VO_2max, 60% VO_2max, 80% VO_2max) have an effect on the ability of participants to make decisions. The interaction between exercise intensity and level of experience was not significant ($F_{(6,25)} = .433$; $p = .850$).

3.3.1 Level of Experience

As expected, the level of soccer experience of the subjects was an important factor in explaining the difference in accuracy and speed of decision making. Experienced soccer players were significantly more accurate ($F_{(1,30)} = 16.6$; $p < .0005$) and made faster decisions ($F_{(1,30)} = 6.5$; $p = .016$) than their less experienced counterparts (See Table 6).

Table 6: Means (SD) for accuracy and speed of decision making across experience level

	Accuracy of Decision*	Speed of Decision*
Inexperienced players	22.4 (2.5) N = 16	1707 ms (612) N = 16
Experienced players	24.4 (2.0) N = 16	1299 ms (413) N = 16

* $p < .05$

3.3.2 3.3.2 Exercise Intensity

In congruence with the results for the MANOVA, the interactions between exercise intensity and level of experience for accuracy ($F_{(3, 90)} = .488$; $p = .692$) and for speed of decision making ($F_{(3, 90)} = .627$; $p = .600$) were not significant.

Although the levels of exercise intensity significantly affected the construct decision making, when accuracy and speed of decision were considered separately, accuracy did not vary as a function of exercise intensity ($F_{(3, 90)}$= 1.32; p= .273).

Table 7: Means (SD) for accuracy of decision making across experience levels and exercise intensity

	Rest	40% VO_2max	60% VO_2max	80% VO_2max
Inexperienced	22.3 (2.8)	22.6 (2.6)	21.9 (1.8)	22.7 (2.9)
Experienced	23.8 (2.5)	24.9 (1.5)	24.4 (2.1)	24.6 (1.7)

As with the MANOVA, the univariate analysis revealed that speed of decision making was affected by exercise intensity ($F_{(3, 90)} = 7.12$; $p < .0005$). LSD post-hoc analysis indicated that speed of decision making improved significantly at 60% and 80% maximal aerobic capacity compared to rest for both groups (See Table 8). Except for the comparison of the two highest exercise intensities to rest, all other comparisons were not significant.

Table 8: Means (SD) for speed of decision making across experience levels and exercise intensity

	Rest	40% VO_2max	60% VO_2max	80% VO_2max
Inexperienced	1950 ms (472)	1726 ms (702)	1612 ms* (489)	1538 ms* (505)
Experienced	1430 ms (692)	1307 ms (486)	1269 ms* (340)	1190 ms* (332)

* p < .05 compared to speed of decision making during the Rest condition

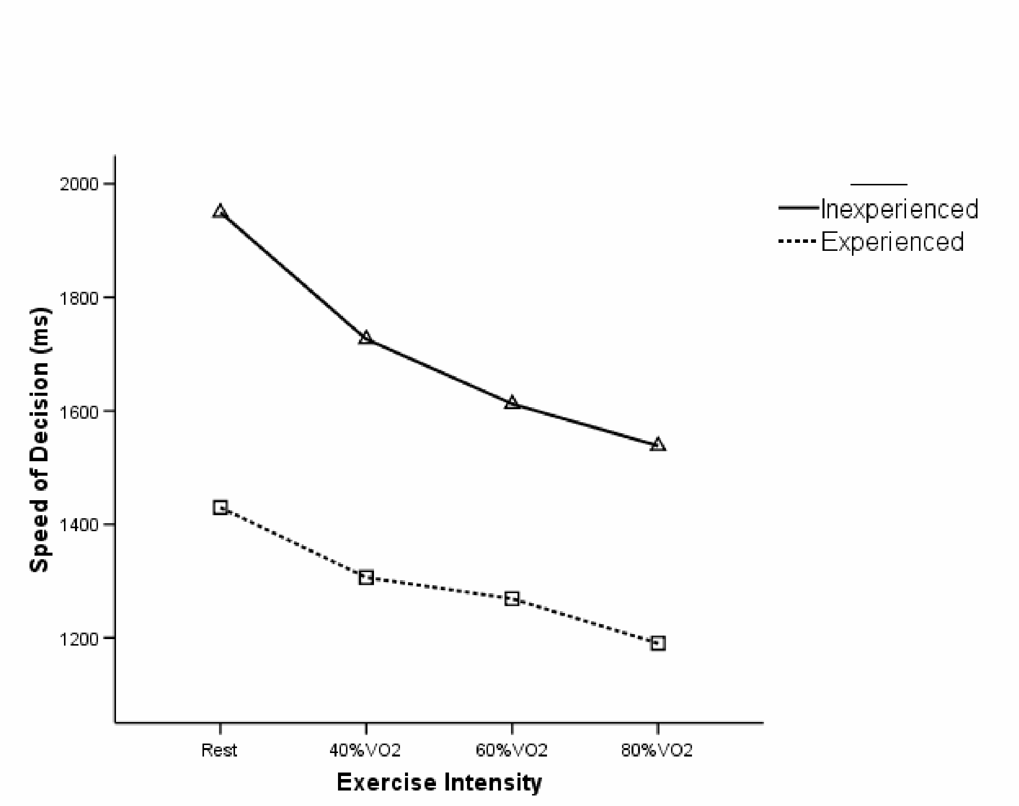

Figure 2: shows improvements in speed of decision making performance as exercise intensity increases. It is important to emphasize that differences in speed of decision making were only significant between the rest condition and the two highest exercise intensities (60% and 80% maximal aerobic capacity).

4.0 DISCUSSION

Current research on expertise indicates that many factors ranging from perceptual skills, to knowledge base, decision making, and motor skills strongly influence sport performance (McMorris & Beazeley, 1997; Williams & Davids, 1998). Although research on the effects of expertise on sport performance is quite substantial, almost no research has been conducted under situations in which the participants are exposed to exercise of various intensities. To date, the research on cognitive function during exercise has tested the assumption that cognitive performance shows an inverted-U shape as exercise intensity increases.

The few studies conducted on the topic have not provided significant support of the inverted-U theory for exercise and cognitive performance (McMorris & Graydon, 1996a, 1996b, 1997, 1999). In McMorris's and Graydon's experiments, accuracy of decision making was not affected by exercise while speed of decision making improved from rest to moderate exercise but no deterioration of performance was found with maximal exercise. However, these results might have been biased by methodological limitations.

In this experiment, methodological improvements were made to correct the limitations in McMorris's and Graydon's experiments. All these improvements should help clarify whether or not the inverted-U theory can be used to explain the effects of exercise on decision making performance**.** Thus, the purpose of this study was to examine the decision making performance of inexperienced and experirenced soccer players at four different exercise intensities: rest, 40%, 60%, and 80% maximal aerobic power

Before we discuss the effects of exercise intensity on decision making in soccer for inexperienced and experienced players, it becomes imminent to point out that the manipulation of exercise intensity produced four exercise conditions (rest, 40%, 60%, and 80% VO_{2max}) that were clearly different from each other. It is also critical to state that subjects exercised at the predicted exercise intensities throughout each exercise condition except for the 80% VO_{2max}. Deviations from target intensity at 80% VO_{2max} were expected since at this intensity subjects are using anaerobic metabolism. Manipulations of exercise intensity were effective.

It is also important to briefly state that the fitness level of the subjects was not likely to have interfered with any of the results of this experiment. First, it is important to point out that the subjects were exercising at percentages of their own aerobic capacity. Second, the aerobic fitness level of experienced players was not significantly different from that of inexperienced players. This was not an expected result. Experienced players were expected to show better fitness. A possible reason for lack of significance includes the fact that testing occurred after the season was over. It is also possible that the recruitment procedures used might have produced a group of inexperienced players with an unusually high aerobic capacity. Recruitment was done through signs posted on fitness centers around the university. Finally, it is possible that the aerobic capacity of two of the inexperienced subjects with an unusually high aerobic capacity might have interfered with the results (VO_{2max}= 71.3 and 81.7ml/kg/m). The large standard deviation for the inexperienced group corroborates this assumption (see Table 6).

The most critical results of this dissertation are the ones that answer the research hypotheses. Three hypotheses were tested. The first hypothesis stated that experienced soccer players would show faster and more accurate decision making performance than inexperienced soccer players across exercise conditions. Following Easterbrook's theory, the second hypothesis predicted that the decision making accuracy and speed of decision of inexperienced players would show an inverted-U shape with increasing levels of exercise. The third hypothesis was set specifically for the experienced players. Due to the automaticity of information processing, speed and accuracy of decision making of experienced players were predicted to show no change in performance with increased exercise intensity.

The first hypothesis was the only hypothesis fully supported by the results of the experiment. Experienced players in fact made faster and more accurate decisions. These results agree with the majority of the results testing differences in decision making performance between inexperienced and experienced players (Kioumourtzoglou et al., 1998; McMorris and Beazeley, 1997; McPherson, 1999; Nielsen and McPherson, 2001).

Decision making comparisons usually use open sports to make comparisons between inexperienced and experience players. In open sports such as basketball and soccer, the environment is constantly changing. To meet environmental demands, players in these sports are constantly required to make quick and accurate decisions. The comparison between inexperienced and experienced players ability to make quick and accurate decisions shows that experience is a major factor in improving the ability of players to become better decision makers. The results also show that this difference in the ability to make decisions is independent of the intensity of the exercise performed. Experienced players performed better than inexperienced players during rest, moderate and highly intense exercise.

The first hypothesis compared decision making performance across experience levels. The other two hypotheses were designed to describe what would occur to decision making performance as a result of the exposure to exercise of different intensity. One of these hypotheses was designed specifically for inexperienced players, and it was based on literature about the effects of exercise on cognitive performance, including the series of experiments conducted by McMorris and Graydon (1996a, 1996b, 1997, 1999). Based on the literature, it was hypothesized that speed and accuracy of decision making performance would improve during exercise performed at moderate intensities and deteriorate with further increase in exercise intensity. If that were the case, then decision making performance would demonstrate an inverted-U shape as theorized by the Yerkes and Dodson law developed in 1908. Easterbrook (1959) made improvements to this law by providing a link between arousal and cognitive performance. For Easterbrook, attention was the mediator between the effects of arousal and cognitive performance. Currently, the effect of arousal on performance is commonly known as the inverted-U hypothesis.

However, variations in accuracy and speed of decision making performance across exercise intensity in this study do not corroborate the inverted-U hypothesis. The accuracy for inexperienced players did not significantly change as a result of the manipulation of exercise intensity. For speed of decision making, inexperienced players did make faster decisions during moderate-high (60% VO_{2max}), but as the exercise became more intense (80% VO_{2max}), speed of decision making performance did not significantly improve any further.

The third hypothesis was designed exclusively to explain the effects of exercise on decision making performance of experienced players. It was initially predicted that exercise would not affect the decision making ability of experienced players. This was based on the assumption that the soccer experience acquired throughout years of practice would allow the college players to make decisions more automatically than their inexperienced counterparts.

After all, throughout several years of soccer experience, college players were likely to have been extensively exposed to similar decision making situations. In terms of speed of decision making, the results from this experiment did not support this hypothesis. As occurred for the inexperienced players, compared to rest, speed of decision making improved for the exercise conditions performed at the moderately-high and high intensities.

The accuracy of decision making results provided support for the hypothesis for the experienced players. Differences in accuracy of decision making across exercise conditions were not found. At first glance, these results suggest that the knowledge base acquired across several years of experience is so stable that exercise intensity does not impact decision making accuracy of performance. However, when the results for accuracy of decision making of inexperienced and experienced are analyzed together, it is clear that level of expertise can not explain the lack of influence of exercise on accuracy of experience players. Accuracy of decision making of inexperienced players was also not affected by manipulations in exercise intensity. A more plausible conclusion for this experiment is that, independent of level of experience, exercise-induced arousal does not affect accuracy of decision making performance.

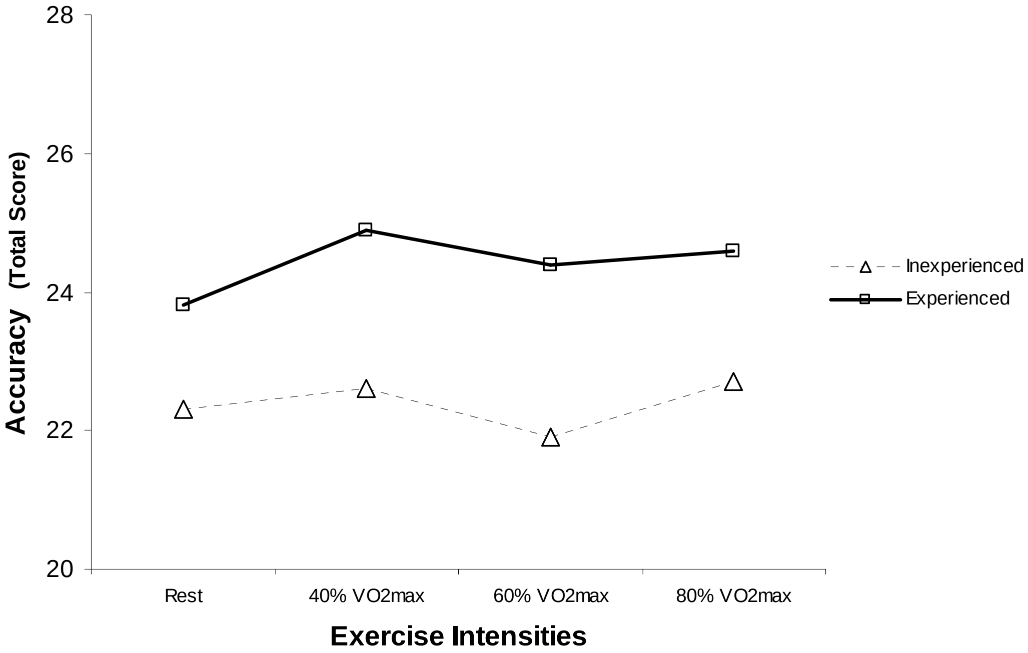

Figure 3: depicts the effects of exercise intensity on accuracy of decision making. Independently of exercise intensity, exercise intensity had no effect on accuracy of decision making.

The effects of exercise intensity on speed of decision making for experienced and inexperienced players are so similar that they need to be discussed together. Both groups, inexperienced and experienced players, showed improved speed of decision making at moderately-high and high intensity exercise. Taken together the results for speed and accuracy of decision making for experienced and inexperienced players, it is plausible to assume that exercise only affects speed of decision making. Also, for the effects on speed of decision making to become evident subjects must be exercising at least at moderately high (60% VO_{2max}) exercise intensities, but further increments on exercise intensity do not produce deterioration in speed of decision making performance.

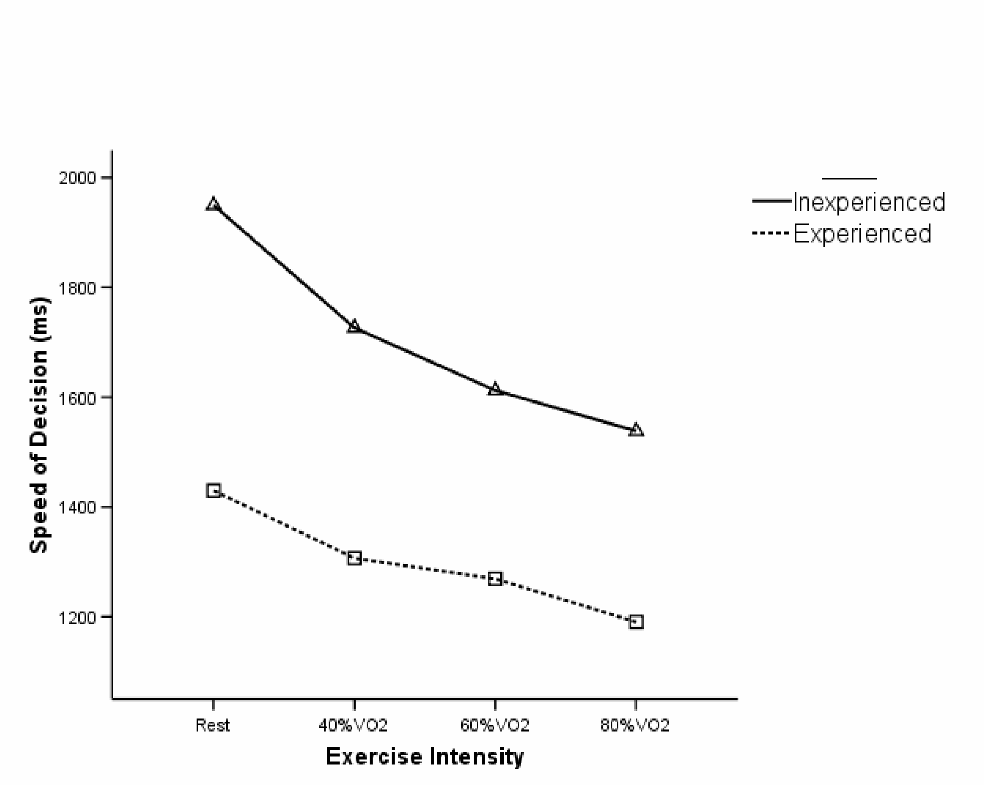

Figure 4: depicts the effects of exercise intensity on decision making. Independently of experience levels, subjects made faster decisions at the two highest intensities.

An unexpected finding was that the results in this study were an almost perfect reflection of the results reached throughout the experiments of McMorris and Graydon (1996a, 1996b, 1997, 1999). Accuracy was not affected by the varying levels of exercise, however, speed of decision making improved from rest to moderate exercise, but deterioration in performance from moderately-high to the high intensity exercise condition did not occur. The only discrepancy among the results of the different studies was that in this experiment improvements in speed of decision making performance were noticeable during moderate exercise for inexperienced players while in McMorris and Graydon (1996a) improvements in speed of decision making were only apparent at 100% maximal exercise output.

It is remarkable that very similar results were reached even after several methodological improvements were made to the current experiment. Improvements were made to the decision making instrument and exercise protocol. Improvements to the decision making instrument included adding an extra form of the test and designing forms with similar levels of difficulty but using different decision making situations. McMorris and Graydon used identical forms except for the position in which the situations were placed on the field. Improvements to the exercise protocol included randomizing exercise intensity to control for order-over effects and to better simulate exercise performed during soccer matches. In the McMorris and Graydon experiments, the exercise intensity manipulation always followed the same sequence. A second improvement was made to the exercise protocol by controlling exercise intensity using VO_2 scores during the habituation period and heart rate thereafter.

Results from this study, combined with those provided by McMorris and Graydon, provide strong evidence that the effects of exercise on decision making performance during soccer can not be explained by the inverted-U hypothesis. A possible explanation for the lack of deterioration of speed of decision making performance from moderate to high intensity could be that the exercise intensity used (80% VO_{2max}) is not at a high enough level to produce performance decrements. This explanation was provided by McMorris and Graydon in the discussion of their 1997 experiment. Manipulations requiring subjects to exercise at intensities above 80% are difficult to create since it is difficult to maintain the subject at intensities above the anaerobic threshold even for the relatively short periods of time required for the completion of the decision making testing.

This assumption that exercise performed at an intensity of approximately 80% of maximal aerobic capacity does not produce the extreme arousal levels necessary for performance detriments might be useful to explain the speed of decision making, however it would not explain why moderate exercise failed to affect accuracy of decision making for experience, especially for the inexperienced players. It is possible that improvements in speed and lack of improvement in accuracy of decision making were due to the effects of exercise on one of the elements of the information processing sequence that occurs prior to decision making, potentially perception.

In one of their experiments, McMorris and Graydon investigated this hypothesis by measuring speed of decision making using a visual search task. The results did not support the hypothesis of a possible effect from visual search. The visual search task however was very simple and only required the subjects to state whether a ball was present or not in the display. Visual search during decision making situations are much more complex. In addition to involving more elements, in decision making situations subjects must extract a massive amount of information such as the direction the player is running or how far from the goal he is located before making a decision. This assumption deserves more research before it is discarded.

A third possible explanation is that physiologically-induced arousal produces different effects on cognitive performance than psychologically-induced arousal. This experiment did not find that the inverted-U hypothesis explained physiological-induced arousal as it has psychologically-induced arousal. A more appropriate paradigm to explain the results of physiologically-induced arousal reached in this experiment and in the series of experiments conducted by McMorris and Graydon (1996a, 1996b, 1997, 1999) explains the effects of exercise on cognitive performance using a new perspective. Based on this new paradigm, exercise is predicted not to affect accuracy of decision making but to affect speed of decision making. Speed of decision making however also does not show an inverted-U shape with increased levels of exercise intensity. In fact, although not predicted to improve with increased exercise intensity, speed of decision making did improve until 80%.

It is clear that the inverted-U hypothesis is not useful in explaining the results of this experiment. However, regardless of the theoretical explanation provided, the findings provide some interesting information for teachers and coaches. First, when open sport participants make bad decision late in the game, teachers and coaches will know that those decisions were not directly affected by how fatigued the players were. Maybe after an intense bout of exercise a player misses a set play that had been repeatedly practiced during training. This wrong decision is not a function of poor accuracy of cognitive functioning. It could be that this specific player did not learn the task well during training sessions or that he took into consideration his fatigue level in order to decide which action to make.

As an example, after an intense bout of exercise during a game a player receives the ball and has a clear chance of carrying the ball forward as practiced during training sessions. However, this player decides to pass the ball to a teammate that is closely guarded who consequently looses the ball. Based on the results of this experiment, the teacher/coach can assume that the wrong decision was not impacted by the player’s ability to make decisions accurately. It is possible that lack of conditioning at the moment in the game made the option of passing the ball better than carrying forward, or that the player did not learn the play well in order to carry it out. Understanding that exercise intensity does not directly affect the process of decision making allows coaches to eliminate accuracy of decision processing as a possible cause of poor decision making performance which may simplify somewhat the reasoning of the teacher/coach to understand the causes of poor decisions during game play.

Second, warm-ups gain importance when you can show players that they are not only useful to prevent injuries but it can also boost cognitive performance. Only speed of cognitive performance is affected by exercise intensity. However, in games such as soccer in which quick decisions are critical for optimal performance, warming up prior to games at a moderate intensity of about 60% aerobic capacity can be crucial to players to start games at the optimal cognitive performance level. Even though they might make a correct decision, it was not made in time to make a difference.

Sports are a complex phenomenon, and more research is encouraged to increase our understanding of how different factors, such as exercise intensity, affect performance.

4.1 FUTURE RESEARCH

Few studies have been conducted to measure the effects of exercise intensity on decision making performance in sports. To better clarify the topic, research efforts must be extended. Some guidelines for future research follow:

- None of the experiments conducted so far used ecologically valid tests. It is possible that decision making processing in game situations is affected by exercise differently from what this and previous studies suggest. Experiments in actual settings are difficult to conduct because of the number of extraneous variables that must be controlled. In addition, decision making instruments and exercise protocols to be used during actual soccer matches are not currently available. Development of these instruments is a difficult task. However, ecologically valid experiments have clear advantages in terms of the generalizability of results. For further advancements in the area of expertise, it is critical that our endeavors focus on developing the procedures able to control extraneous variables during actual game play and new data collection instruments.

- The results of the multivariate analysis of variance indicated that the “decision making construct” was significantly affected by exercise intensity. A fruitful line of research would involve creating an instrument measuring the construct decision making instead of two separate variables, speed and accuracy of decision making. Overall scores for the decision making construct would probably be a compiled score extracted from the decision making accuracy and speed. This is a complex problem to solve, but one that would provide very useful information for the area of expertise.
- More recently, task complexity, induced psychological arousal, and subject’s anxiety trait level have all been linked to variation in cognitive performance as a result of manipulations in arousal levels (Schmidt & Wrisberg, 2004). Laboratory research investigating the effects of these factors on cognitive performance for a fixed level of exercise intensity is also encouraged. Since this research dissociated the effects of psychological and physiological arousal, manipulation of psychological arousal seems especially promising. The fixed level of exercise must be of at least moderately-high intensity.

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APPENDIX A:

EXTENDED REVIEW OF LITERATURE

1.0 INTRODUCTION

There are some people so good at what they do that it is difficult not to wonder how they mastered certain skills. After you try swinging a golf ball, it is quite apparent the task is difficult. Watching Tiger Woods swing a golf ball, one questions how he makes it look so effortless. The answer for Tiger Woods golf performance is expertise. Expertise refers to outstanding performance in a specific domain. Expertise is a function of innate capabilities, and the amount and quality of experience experts acquire through life. Although innate capabilities can not be changed, there are components that can be acquired through experience that can be used to more quickly improve skill performance. By understanding the phenomenon of expertise, physical educators and coaches will be better able to comprehend what makes experts better performers and subsequently help novices learn new motor skills effectively. Through successfully learning motor skills, participation in physical activity for a lifetime is enhanced.

Thus, the purpose of this experiment is to expand the expertise knowledge base. Within the realm of expertise, this research will specifically examine whether exercise performed at various intensities affects the decision making performance of experienced and inexperienced soccer players. Little is known about the interaction between exercise and decision making in sports.

Decision making is just one of the elements of the information processing sequence where differences between expert and novice players have been found. The information processing sequence also includes perception, thinking, knowledge base, and motor skill execution. Based on information processing theory, before a 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; Starkes, Caicco, Boutilier, & Sevsek, 2001; Radlo, Janelle, Barba, & Frelich, 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. All studies dealing with the effects of exercise on cognitive performance in sports have focused on decision making. This increased interest in decision making is 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. For these reasons, this experiment is also focusing exclusively on decision making.

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 experienced and inexperienced players should allow researchers to advance the understanding of the decision making processes during game play.

To date, the research on cognitive function during exercise has tested the assumption that cognitive performance follows an inverted-U pattern as exercise intensity increases. This assumption is drawn on Easterbrook's (1959) hypothesis of the effect of emotionally induced arousal due to the fact that the physiological effects of arousal induced by exercise, such as increased plasma adrenaline, heart rate and blood pressure, are similar to those induced by emotional stress. For example, improvement in cognitive performance increases as arousal increases up to a point after which deterioration in cognitive function with further increases in arousal occurs (Easterbrook, 1959).

Research however has not provided significant support of the inverted-U theory for exercise and cognitive performance (McMorris & Graydon, 1996a, 1996b, 1997a, 1999). In McMorris's and Graydon's experiments, accuracy of decision was not affected by exercise while speed of decision improved from rest to moderate exercise but no deterioration of performance was found with maximal exercise. However, other than in their first experiment, McMorris and Graydon did not test inexperienced players. In addition, methodological limitations of the data collection instrument, including repeated use of the same static soccer game situations across forms of the test might have interfered with the findings. Following Easterbrook's theory, it is possible that, for experienced and inexperienced players, accuracy and speed of decision making shows an inverted-U shape with increasing levels of exercise.

Due to the fact that sports are generally played under conditions of physiological stress and little is known about the effects of physiological stress on decision making, a better understanding of how information-processing skills are affected by physiological stress becomes necessary. Therefore, there is a clear need to study the effect of exercise on the decision making performance of experienced and inexperienced soccer players.

A review of literature organized in four main sections opens this paper. Section one describes the literature on expertise in sports in great detail. Chapter two makes the case for studying the effects of exercise on decision making by describing the physiological demands of soccer. Section three describes experiments in which the relationship between exercise and cognitive performance is explored. Finally, because other experiments investigating the same topic have already been conducted, section four justifies replicating studies on the effects of exercise on decision making in soccer by critiquing the methodology used in previous experiments.

1.1 HYPOTHESIS

In this dissertation, it is hypothesized that exercise will affect the decision making performance of novice and experienced players differently. Following Easterbrook's theory, for the novice players it is predicted that the decision making accuracy and speed of decision will show an inverted-U shape with increasing levels of exercise. For the experienced players, due to the automaticity of information processing, speed and accuracy of decision are predicted to show no change in performance with increased exercise intensity. It is also hypothesized that experienced soccer player will show faster and more accurate decision making performance than inexperienced soccer players across exercise conditions.

1.2 LIMITATIONS OF THE STUDY

Only a few studies have been conducted to investigate the effects of exercise on decision making in sports. All of which have been conducted in soccer (McMorris & Graydon, 1996a, 1996b, 1997, 1999). These studies possess several methodological limitations that may have greatly impacted the results. In the current experiment, the methods have been refined to better capture the causal relationship of exercise on decision making in soccer.

Although the methods have been greatly improved, the current experiment still has limitations worth a discussion. First, the decision making instrument selected has questionable ecological validity. It consists of videotape segments from real soccer matches. Videotape segments allow subjects to follow developing plays which therefore provides a greater number of cues for subjects to determine the most appropriate action. The ideal scenario is to use an instrument in which decision making is measured during game play. Sports, however, are very dynamic. So many extraneous variables influence match performance including tactics of the team, condition of the field, importance of the game, whether, and motivation of players. The ability to control the sport environment across trials is so difficult that an instrument to measure decision making during game situations has yet to be developed.

A second limitation of the current experiment refers to the restricted number of exercise intensities included in the design. The current experiment contains only four exercise intensity, rest, 40%, 60%, and 80% maximal intensity. Although the intensities selected represent a range from low to high intensity, it is not possible to determine what happens to decision making for exercise intensities not selected.

Finally, this experiment faults on gender and sport specific. This experiment onl focuses on male soccer players. It is possible that the effects of exercise on decision making might be different for other open sports as well for females. However, these limitations are easier to overcome, and one could expect research on expertise broadening to other sports and to females fairly soon.

1.3 DEFINITIONS OF TERMS

Arousal refers to the current state of the individual under an intensity continuum that varies from very low to very high excitement

Expertise refers to outstanding performance on a specific domain.

Information processing model refers to the study of movement in which the human is viewed as a processor of information, focusing on storage, coding, retrieval, and transformation of information" (Schmidt and Lee, 1999)

Reliability refers to the extent to which the same results are obtained when responses are measured using different sample of items or raters, or measured at different times.

Validity "always refers to the degree to which empirical evidence and theoretical rationales support the adequacy and appropriateness of interpretations and actions based on test scores" (Messick, 1993). Variety of evidence can be used to establish the validity of interpretations of scores from a test or survey.

Content validity refers to the type of validity evidence supporting content representativeness and relevance of the construct being measured

Ecological validity refers to the degree to which the test simulates a situation in its actual environment.

Maximal oxygen consumption (VO2 max) maximum amount of oxygen one can consume while exercising at maximal capacity.

2.0 REVIEW OF LITERATURE

2.1 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.

2.1.1 Perception

Perception, the first component of the information processing sequence, is critical 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. Finally, 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 focus and pattern of visual search of experts also differs from novices. During the execution phase of the serve, experts focus mostly on the server's racquet 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-, and 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. Finding indicated 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 not reached by novices until 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 brain 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, suggesting that they are actually allocating less attention to the identification of 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 than 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.

2.1.2 Knowledge base

For perception, experts possess better skills than novices. Perceiving the environment more effectively gives experts a great advantage. Perception and knowledge base are related. The knowledge base offers guidance to what an individual perceives in the environment. As with perception, 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 at 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 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, 1999). 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 knowledge base. 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.

Following the information processing sequence, 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.

2.1.3 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.

French and Thomas (1987) investigated motor skill performance of youth basketball players, ages 8-10 and 11-12-years-old. 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.

The experiment conducted by French and Thomas has low ecological validity. However, studies on motor skill execution have usually been conducted during actual game play. Rarely observed in investigations on other components of the information processing sequence, only evidence derived from ecologically valid experiments is provided next.

Campos (1993) measured motor skill execution of youth soccer players separated in two groups, 8-10 and 11-12-years-old. Analysis of motor skill execution was 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.

Youth players, ages 7-, 8-, 9-, and 10-years-old, were also tested in the experiment conducted by French, Spurgeon, and Nevett (1995). Expert and novice players were defined based on years of baseball experience and on coaches' ratings of baseball skill. Motor skill performance was based on baseball skills. For each player participating in the experiment, a minimum of five regular season 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. As in Campos experiment, independent of age, experts possessed better motor skills than novices.

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. The shot and serve of participants were assessed on control and execution 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 executions than novices.

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 yet 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 is the next topic covered.

2.1.4 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 environmental 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 years, and collegiate adults. Experts in this experiment were division 1A collegiate players with outstanding tennis records, and novices were college students enrolled in a beginner tennis class with limited tennis experience. 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 the more cognitive 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.

2.1.5 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, there still are many more specific decisions to be made for example when passing the ball to a teammate, one needs to decide to whom among 10 teammates should the ball be passed 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 losing 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 at 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. In McMorris and Beazeley, the difference between younger experts and novices in decision making time was 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 summary, 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. Before we discuss these studies, a discussion of the physiological demands of soccer is pertinent.

2.2 PHYSIOLOGICAL DEMANDS OF SOCCER

Soccer is a team sport played by 11 players per team. The field in professional and collegiate soccer is approximately 68 meters wide and 105 meters long. The game of soccer is played in 2 periods of 45 minutes each with 15 minutes halftime. During a game, players make a massive number of decisions. For instance, a player in possession of the ball must decide whether to pass the ball, dribble another player, shoot to the goal, or cross the ball to a player across the field. For each of these decisions, others follow. If the player decides to pass the ball, he still needs to decide what type of skill he will use to make the pass for each player he will pass the ball to. Adding complexity, the decisions are made under different exercise intensities during a soccer game. Therefore, the purpose of this section is to describe the physiological demands of the game of soccer.

Physiological demands of soccer are multifactorial. They depend, for example, on the position of the player on the field, tactics of the team, and the score of the match. In addition, the physiological demands of soccer vary markedly during match-play. In fact, Mohr, Krustrup, and Bangsbo (2005) stated that there is a change in activity level every four to six seconds. Activities performed during a game of soccer range from low energy demanding tasks such as standing and walking to high energy demanding tasks such as dribbling, running, and jumping (Bangsbo, 1994; Mohr, Krustrup, & Bangsbo, 2005; Tumilty, 1993). The physiological demands of soccer show great variability. Inferences about the physiological demands of soccer are best determined based on the combination of different methods. Description of the distance covered during games and the percentage of total playing time spent on exercise of different intensities, together with physiological measures such as heart rate, VO_2 and blood lactate have been used by researchers to understand the physiological demands of soccer.

The distance covered by soccer players during a soccer match is one of the measures used to understand the physiological demands of soccer. Even though the distance varies significantly among players even when they play the same position, measures taken from the average distance covered by a player over a couple of games provides a good estimate of how much ground soccer players cover during games. Tumilty (1993) stated that 10km is the average distance covered by division-one players during a game. To support this statement, Tumilty cites studies completed in countries such as England, German, and Japan. In all studies, midfielders covered greater distance than attackers and defenders. Bangsbo, Norregaard, and Torso (1991) reached a similar conclusion when studying the activity profile of 14 Danish soccer players, including 4 defenders, 4 midfielders, and 3 forwards. The Danish soccer players covered an average distance of 10.8km. Also, as in Tumilty's study, the midfielders (11.4km) covered significantly longer distances, followed respectively by the forwards (10.5km) and the defenders (10.1km).

Ekblom (1986) cited other studies in which the total distance covered during a match was a little higher. In Withers et al. study (1982), Australian professional players covered an average of 11.5km, while Agnevik study (1970) found British players covered 13.5km. It is difficulty to assert whether the differences between studies were due to the methodologies used or were true differences related to the quality of competition and style of soccer in the countries where the studies were completed. However, it seems fair to argue that the distance covered by soccer players during a game is approximately 10-12km with midfielders covering more ground than defensive and forward players.

The distance covered by players during a match is a crude measure of the physiological demands of soccer. More detailed information can be attained by analyzing the activities performed by the players over the course of a game. Tumilty (1993) claims that the largest percentage of total game time is spent walking or jogging, although sprint is also used. Bangsbo et al (1994) completed a detailed description of all activities performed by the 14 Danish soccer players. In Bangsbo et al experiment, playing time was also mostly spent walking and jogging. Match-activities described in this study were as follows:

Table 9: Summary of soccer match activity of Danish soccer player (Bangsbo et al, 1994)

Activity	Percentage of total playing time
• Standing	17.1 +/- 1.5%
• Walking: 40.4% of the total playing time;	40.4 +/- 1.6%
• Low intensity running: o 16.7% jogging; o 17.1% low-speed running; o 1.3% backward running	35.1%
• High intensity running: o 5.3% moderate speed running; o 2.1% high speed running; o .7% sprint running;	8.5%
• Headings and tackles	Mean number of 8.9 and 10.9 respectively per game

Gool, Gerven, and Boutmans (1987) reached a similar result after analyzing match activity of seven Belgian college players. Gool et al. categorized match activity in low, medium, and high intensity exercise. Low intensity exercise in their study referred to standing still and walking (0 - 2.04 m s^{-1}). Medium intensity exercise referred to jogging (2.04 - 4.89 m s^{-1}), and finally, high intensity exercise referred to cruising and sprinting (4.89 - 8.15 m s^{-1}). Gool et al. found out that only 7.5% of total game time was played using high intensity exercise, while most of the game was played at low intensity and medium intensity, representing respectively 42.9 and 42.6% of the total playing time.

The percentage of time spent on different activities indicates that physiological demands of soccer are high and constituted predominantly of aerobic with intermittent bouts of anaerobic activity. Measures used to determine the physiological demands of soccer play were heart rate and maximum oxygen uptake. Reilly and Thomas (1979) registered values of an average 157 beats per minutes for outfielders. Ekblom (1986) cited one of his own studies dated from 1981 stating that the heart rate of Swedish players during a game was an average of 80% of the maximum heart rate. Consistent with the mostly aerobic nature of soccer, heart rate is also said to be relatively stable during a match. Rohde and Esperson (1988), researching professional Danish soccer players during the first competitive matches of the season, reported that heart rate was 77% maximum for 66% of the playing time.

Additional evidence links the heart rate of the player to specific levels of VO_2max on the treadmill which is then applied to game performance. Most of the studies attempting to measure aerobic metabolism during a soccer game have monitored heart rate of players during a game, and then compared this heart rate value to the heart rate and VO_2 max relationship obtained through laboratory standardized testing. Using this method, VO_2 max for soccer matches has been suggested (Bangsbo, 1994) to be between 70-75%. In addition, Reilly (1987) and also Gool et al. (1996), studying Belgian college players, reached a similar result. They indicated that the players participating in the experiment worked at around 75% percent of the maximal aerobic capacity during competitive matches.

As previously indicated, a percentage of the game is also played using high intensive anaerobic exercise. The percentage of the game played using anaerobic exercise is much smaller than the percentage of the match in which low and moderate intensity exercise is used. It is generally suggested that the percentage of the game spent on high intensity running is approximately 8 percent (Gool, Gerven, & Boutmans, 1987; Bangsbo et al, 1991). The actual percentage however is likely a little higher than reported in the previous experiments since some high intensity activities such as game skills (i.e. kicking, heading, and tackling) are generally overlooked. Game skills were described by Reilly (1996) to represent 2% of the total game time.

In addition to distance covered by players and analysis of game activities, indication of anaerobic energy expenditure during a game can also be provided based on physiological measures such as heart rate and VO_2. Rohde and Esperson (1988), researching professional Danish soccer players during the first competitive matches of the season, reported that heart rate in the high intensity zone of 91% of the maximum heart rate for an average of 26% percent of the matches analyzed. This suggests that when measured based on heart rate, the percentage of the time spent using the anaerobic metabolism may be a larger than the previous described activity profiles indicate. Most importantly, both measures denote the significance of anaerobic metabolism during a game of soccer.

In addition to heart rate, measures of blood lactate concentration taken during and after games support the role of anaerobic metabolism in soccer. Average blood lactate has been reported to be 3 – 6 mmol/L for Swedish professional players, with individual values frequently above 12 mmol/L (Ekblom, 1986). These values were obtained based on measures taken at the end of each half of the game. Ekblom indicates that even the blood lactate values of recreation players, 9.7 mmol/L, were high. Similar high blood lactate levels have been found when samples of blood were collected during the game. Bangsbo (1994) compiled a group of studies investigating lactate production during match-play in soccer. He stated that in these studies, values higher than 10 mmol/L were frequently reported. These high values indicate that a portion of the game of soccer is spent performing anaerobic exercise.

In summary, soccer is a high intensity exercise that involves predominantly aerobic running with periods of intense anaerobic exercise. This physiological profile of soccer is unaltered even considering the great variability between players and positions.

Up to this point, differences between experts and novices in the components of the information processing theory have been exposed. Among these components, emphasis was placed on decision making, and more specifically decision making in soccer. By showing the differences between experts and novices in soccer, it was demonstrated that decision making is a critical element in soccer performance. Finally, it was also shown that during a game of soccer, players undergo exercise of different intensities. Taken into consideration that decision making is critical in sports and sports are played under conditions of physiological stress, the following sections of this review focus on the effects of exercise on decision making in soccer. First, the theories on the relationship between exercise and cognitive performance are examined. Following, the effects of exercise on cognitive performance are discussed. Finally, the literature on decision making in soccer under conditions of physiological stress is presented.

2.3 EXERCISE INDUCED AROUSAL AND COGNITIVE PERFORMANCE RELATIONSHIP

Arousal refers to the current state of the individual under an intensity continuum that varies from very low to very high excitement. States of arousal, whether low, medium, or high, are generally defined based on physiological manifestations including blood pressure, heart rate, hormonal surge or brain activity (Hanock & Vitouch, 2004). As an example, an individual is considered in a state of high arousal if a situation he was faced with caused any of the above physiological manifestations to increase.

Changes in arousal can be induced by various sources. The most commonly considered source is emotional. Some emotional triggers of arousal are feelings such as fear, anger, happiness, and shame. Arousal state is also influenced by caffeine consumption and physical exercise. Due to the complexity of the topic and its relevance to this dissertation, only exercise induced arousal is discussed.

Assumptions that physical exercise can induce changes in the arousal levels derives from the fact that physiological responses common in emotionally induced arousal such as increased heart rate, respiratory rate, sweating and blood pressure are observed when one is exposed to physical activity (McMorris & Graydon, 1997a). Chmura et al. (1994) also claimed that exercise causes adrenaline and noradrenaline to be released from the adrenal medulla which results in their increased concentration in the central nervous system. Increased concentration of adrenaline and noradrenaline in the central nervous system in turn affects cognitive processing. Exact mechanisms of how arousal influences performance are unknown.

Even though the biological link between arousal and brain functioning has not been fully determined, it has long been accepted that changes in the arousal state impacts cognitive performance. The literature dealing with the effects of arousal on cognitive performance has greatly emphasized Yerkes-Dodson law and Easterbrook cue-utilization hypothesis. Yerkes-Dodson was first conceptualized in 1908, and today is commonly referred as the inverted-U theory. The inverted-U theory argues that cognitive performance shows an inverted-U shape parallel to arousal increases. The inverted-U theory expects cognitive performance to improve up to a point with increased levels of arousal. Yet with further increase in arousal level, deterioration in performance is expected.

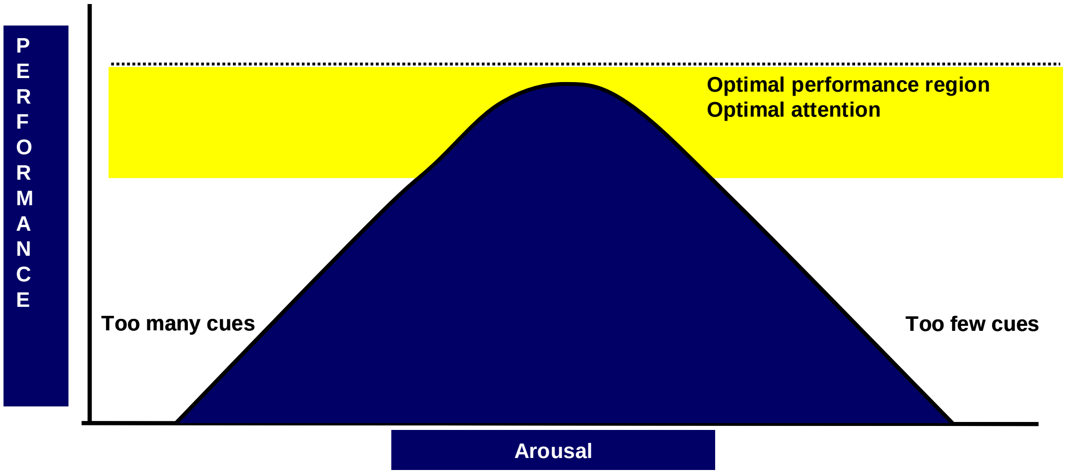


Figure 5: representation of the interaction between the inverted-U theory and the cue-utilization hypothesis (Easterbrook, 1959)

Although the inverted-U theory predicts the relationship between arousal and cognitive performance, it does not explain how cognitive performance acquires an inverted-U shape as an effect of different levels of arousal. In 1959, Easterbrook attempted to explain this relationship by suggesting the cue utilization hypothesis. This hypothesis states that attention mediates the effect of arousal on cognitive performance. Based on the hypothesis, the attention capacity of an individual is affected by the arousal state. At low levels of arousal, individuals attend to too many cues present in the environment, some of which are irrelevant and impair cognitive performance. As the level of arousal increases, individuals are able to narrow their attention to only the relevant cues present in the environment. At this point, attention reaches an optimal level and so does cognitive performance. However, if arousal continues to rise, individuals narrow their attention too much and important cues in the environment are missed.

In addition to providing the link between arousal and performance, Easterbrook's hypothesis also connects the inverted-U theory to the information processing demands of the behavior in question. For tasks that have low processing demands (few relevant cues), high levels of arousal might be beneficial. However, for tasks that have many relevant cues and so have high processing demands, high levels of arousal are likely detrimental. This relationship between task demands and levels of arousal is important because it indicates that other factors, in addition to arousal, influence cognitive performance.

The inverted-U theory and the cue-utilization hypothesis have been the most extensively used theories to explain the relationship between arousal and cognitive performance. Experiments using tasks ranging from simple reaction time, to choice reaction time, decision making in sports have been used to test their assumptions. In the following sections, these experiments are described. The results of experiments using laboratory tasks such as simple and choice reaction time are presented. Finally, in greater detail, experiments dealing with the effects of arousal on decision making in sports are also discussed.

2.3.1 Effects of exercise induced arousal on reaction time

The great majority of research studies on the effects of exercise induced arousal on cognitive performance were designed to test the inverted-U theory. The inverted-U theory states that increased levels of arousal improves cognitive performance up to a point after which cognitive performance deteriorates. One of the first efforts to systematize the literature on the effects of exercise on cognitive performance was done by Tomporowski and Ellis (1986). Tomporowski and Ellis reviewed exercise of varying intensities and duration including short-duration/high-intensity exercise, short-duration/moderate-intensity exercise, and long-duration/aerobic exercise. This review of literature indicated that results from some studies support while others contradict the inverted-U theory. In some studies, exercise facilitated cognitive performance, in others it deteriorated, and still in others it had no effect on cognitive performance.

The lack of consistency in the results of their review led Tomporowski and Ellis to formulate possible reasons of the various results. The authors suggested four possible reasons for the inconsistencies among results of different studies: a) the nature of physiological tasks; b) the time at which the cognitive test is administered; c) the physical fitness of subjects and; d) the intensity and duration of exercise intensity. Following, each reason is explained in more detail.

First, a great number of tasks have been used to measure cognitive performance. Indeed, tasks measuring cognitive skills ranging from intelligence coefficients, memory, attention, decision making, to perceptual skills have been used. Some of these skills are more demanding than others. They are also processed in different parts of the brain. It is unlikely that exercise has the same effect on different mental functions. In this section, only experiments measuring simple and choice reaction time tasks are discussed. Reaction time tasks seem appropriate considering that game situations require players to make fast and accurate decisions.

Second, experiments have not been consistent in terms of the time at which the reaction time task is administered to subjects. Some experiments have measured cognitive performance during a period of exercise recovery while in others cognitive performance was measured during exercise. Measuring cognitive performance during exercise recovery does not provide much information on the impact of exercise on cognitive tasks, such as decision making, used during match play. Consequently, in addition to restricting information to reaction time tasks, this review focuses almost exclusively on studies that measured cognitive performance during exercise.

Third, the physical fitness of subjects was a problem for many studies because they tested individuals of different fitness levels without equating exercise intensity. Many studies conducted used a percentage of heart rate calculated based on the age of subjects as the only criteria for controlling exercise intensity. However, 60% of maximum heart rate has very different meanings in terms of exercise intensity for fit and unfit subjects. A more appropriate strategy used in the literature is to pre-test the aerobic capacity of the subjects to then set the exercise intensity requirements as a percentage of their aerobic capacity.

When subjects exercise at the same percentage of their VO_2max, the effect of exercise on cognitive performance is generally the same for individual of high and low fitness levels. Travlos and Marisi (1995), for example, tested the attention of the subjects, using a random number generation task, during increased exercise conditions: rest, 40%, 50%, 60%, 70%, 80%. Travlos and Marisi concluded that the effect of increased exercise intensity on cognitive performance of novices is not different between high and low fit individuals. In congruence with the generally reported results showing similar effects of exercise on cognitive performance for subjects equated on fitness level, this research will restrict information to studies that attempted to control for differences in the fitness level of the subjects by requiring subjects to exercise at the same percentage of their VO_2max.

Finally, studies measuring the effects of exercise on cognitive performance have made use of exercise that varies greatly in intensity and duration. Some authors only used exercise below the anaerobic threshold while others used exercise that was anaerobic in nature. Also, some authors used exercise of short duration usually lasting 3 minutes while others used exercise of long duration lasting up to 1 hour. It is possible that exercise of different intensity and duration have different effects on cognition. In sports, players perform exercise that varies in intensity. For this reason, studies using increased exercise protocols are reviewed first. It is important to point out that, in sports, exercise intensity does not increase linearly, but studies manipulating exercise intensities randomly were not located. Finally, exercise of long duration will also be reviewed due to the fact that most team sports require players to exercise during relatively long periods of time.

2.3.1.1 Short duration exercise

Restricting the literature to studies using reaction time tasks measured during exercise, the effect of short duration exercise, performed under increased exercised intensity, generally supports the inverted-U theory. Indeed, Chmura, Nazar, and Kaciuba-Uscilko (1994) indicated that choice reaction time improved with increased exercise intensity up to 75% VO_2max after which performance rapidly and severely deteriorated. In this study, the cognitive task was a choice reaction time task, and the exercise test was a multistage incremental exercise starting at work load of 50W which were incremented of 50W every 3 minutes until volitional exhaustion. Reaction time task was used before and during the last two minutes of each three-minute cycle.

Kruk, Chmura, Krzeminski, Ziemba, Nazar, Pekkarinen, and Kaciuba-Uscilko (2001) had similar results. The design of the experiment was slightly more complex, including caffeine, temperature, and exercise. This experiment was set to test whether caffeine and room temperature attenuate the effects of exercise on choice reaction time. The authors concluded that independent of room temperature (22^oC or 4^oC) or whether subjects ingested caffeine prior to exercise, choice reaction time improved up to a certain exercise intensity point, 64% VO_2max for the placebo and 70% VO_2max for the caffeine group. Choice reaction time deteriorated with further increases in exercise intensity. The only exception was for subjects tested under the placebo condition with the temperature set at 4^oC. For these subjects, choice reaction time performance leveled-off when they reached the intensity corresponding to approximately 64.4% of the VO2max. However, in general, results of this experiment suggest that the effects of exercise are robust to temperature or when subjects have ingested caffeine.

Contradicting the findings of the previously presented studies, the results of Ando, Kimura, Hamada, Kokubu, Moritani, and Oda (2005) do not support the inverted-U theory. The authors measured simple reaction time, using an increased intensity exercise protocol, at rest, 40W below, at, and 40W above anaerobic threshold. The only significant finding was an increase in reaction time during exercise above anaerobic threshold. Consequently, in this study, although reaction was affected by high intensity exercise as predicted, exercise of moderate intensity did not affect reaction time.

In summary, the results of experiments testing the effects of short term exercise on simple and choice reaction time generally support the inverted-U theory. That seems to be case at least when restricting the literature to studies using reaction time tasks measured during exercise performed under increased exercised intensity conditions. There is some conflicting evidence point to detrimental or no effect of exercise on cognitive performance. Consequently, although strong, support for the inverted-U theory from short duration exercise is not unanimous.

2.3.1.2 Prolonged exercise

In sports, exercise is not only performed at different intensities, but it is also generally performed for a relatively long period of time. Professional soccer matches, for example, are played in two halves of 45 minutes each. For this reason, several experiments have been conducted to measure the effects of prolonged exercise on simple and choice reaction time.

Chmura, Krysztofiak, Ziemba, Nazar, and Uscilko (1998), developed an experiment to determine whether changes in choice reaction time performance would be maintained during prolonged exercise. Two exercise conditions were studied. A 60-minute exercise condition at an intensity of 70% of the lactate threshold and a 20-minute exercise condition at an intensity of 10% above the lactate threshold. Percentages of lactate threshold were chosen to represent exercise performed under predominantly aerobic and anaerobic conditions respectively. For the 60-minute condition, reaction time improved during the first 40 minutes of exercise and stabilized thereafter. This was an expected result. Based on the inverted-U theory, cognitive performance is supposed to improve with moderate exercise. However, different from his previous findings using short duration exercise, in the 20-minute condition, high intensity exercise did not cause choice reaction time to decay. In fact, the results indicated that there was a steady improvement in choice reaction time from the fifth all the way to the last minute of exercising.

The effect of moderate aerobic exercise on choice reaction time was also measured by Arcerlin, Brisswalter, and Delignieres (1997), although they did not test strenuous exercise. The exercise consisted of pedaling on a cycle ergometer at an intensity equivalent to 60% VO2max during 10 minutes. Choice reaction time was measured during the beginning of the exercise (3-5 minutes) and at the last two minutes (8 – 10 minutes). The authors found improvement in reaction time during both exercise periods compared to rest. Results point toward a positive effect of moderate exercise on reaction time.

Improvements in reaction time during prolonged moderate exercise are fairly consistent in the literature. Several other studies also indicate that moderate exercise positively impact reaction time. Davranche, Burle, Audiffren, and Hasbroucq (2006) demonstrated that simple reaction time decreased due to moderate exercise performed at 50%VO_2max for 20 minutes. In a similar experiment, Davranche, Audifren, and Denjean (2006), also reached the same results, decreased choice reaction time as a result of moderate exercise. Finally, Davranche and Audifren (2004) showed that exercise performed at 50%VO_2max improved choice reaction time while at 20%VO_2max the difference in reaction time compared to rest was not significant. These experiments show the positive impact of moderated exercise on reaction time, providing support to the inverted-U theory.

An exception to the results for prolonged exercise performed at moderate intensity presented so far is provided by Collardeau, Brisswalter, Vercruyssen, Audiffren, and Goubault (2001). Exercise consisted of a 100-min run (treadmill for 15 minutes, overground for 70 minutes, and treadmill for 15 minutes). Visual simple reaction time was measured during the treadmill runs. Moderate exercise performed during the first 15-minute treadmill run caused simple reaction time to increase compared to rest values. No significant differences were found between rest and the second treadmill run. Reaction time results during the first treadmill run certainly contradict the inverted-U hypothesis of moderate exercise improving cognitive performance.

Although there is no consensus in the literature in terms of the effects of prolonged exercise on reaction time, the vast majority of studies favor improvement on simple or choice reaction time during exercise of moderate intensity. The body of literature for prolonged exercise performed at high intensity is not substantial at the moment probably because it is difficult to design studies in which subjects can sustain high intensity exercise for 10 minutes or longer. Consequently, more studies need to be conducted to determine the effects of high intensity prolonged exercise on reaction time.

Puling together the effects of short and prolonged exercise on simple and choice reaction time, the results are conflicting but generally support the inverted-U theory. That is especially true for studies using moderate prolonged exercise. However, neither type of exercise simulated the conditions present in a sport setting. Sports are generally practiced for relatively long periods of time, but they are hardly performed at a constant moderate speed as manipulated in the prolonged exercise studies. Studies using short exercise did test exercise under different exercise intensities. However, the intensities were increased linearly, where in sport performance exercise intensity changes in a much more random fashion. Compared to the design of the studies reviewed so far, this experiment will be make improvements in the design by counterbalancing the exercise intensities.

Finally, simple and choice reaction time tasks simulate the cognitive demands of sports, but they possess very low ecological validity. Consequently, in order to provide better answer to the problem "effects of exercise on sport related cognitive performance", it is necessary to use tasks that better mimic the mental functions used in sports. The next section deals with the effects of exercise on decision making using sport specific tasks.

2.3.2 Decision making under conditions of physiological stress (different exercise intensities)

Expanding the literature to how decision making is impacted by exercise intensity is crucial for a better understanding of decision making in sports. As previously stated, sports are generally played under conditions of physiological stress. For example, Bangsbo et al (1991) found that 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.

Decision making has also been previously argued to be fundamental for optimal performance in soccer. Several experiments were described in which experienced players possessed more effective decision making skills than novices (Campos, 1993; McMorris & Beazeley, 1997; McPherson, 1999).

On the other hand, although sports are 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 1996 (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.

To elucidate the problem, McMorris and Graydon (1996a, 1996b, 1997a, 1999) 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, the other experiments used only experts. 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) cue utilization hypothesis. This hypothesis attempts to explain the inverted-U effect of arousal on cognitive performance. It 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), 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 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 of 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 scores on the complex task were significantly lower than scores on the simple 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. Therefore, 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, using a complex decision making task, were not captured even when players were told that speed of decision was not a factor or was not being tested. 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, 1997a) 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 perception 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.

Even with their initial argument weakened, a second experiment was set to further explore the assumption that visual search was facilitating speed of decision making performance during exercise conditions. 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. As with some of their earlier experiments, forms of the test were equal with the exception to the location each situation was positioned in the field. Each form of the test 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 for the 10 situations in which the ball was present to decide 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. The results for the 10 situations in which the ball was present indicated that accuracy of decision was once again not a factor and speed of decision improved from rest to moderate exercise but did not deteriorate with maximal exercise. Since the same results were achieved for speed and accuracy of decision making, but no improvement was seen in visual search, the authors' argument that visual search was responsible for improved speed of decision performance was weakened even further.

In their most recent experiment, McMorris et al. (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 et al. 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 et al. 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 et al. 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, 1997a, 1999) never fully supported their hypothesis. If the results had been supported 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 the decrease in speed of decision from rest to moderate exercise. The authors also claimed that there was no change in speed of decision as exercise intensity progressed from moderate to maximal exercise even when complex tasks were used. Finally, accuracy of decision making was not affected by exercise in McMorris and Graydon experiments.

The results reached in the experiments by McMorris and Graydon could be the true effects of exercise on decision making in soccer. However, it is also possible methodological limitations in McMorris and Graydon’s experiments might have obscured the true effects of exercise on decision making in soccer. Lack of ecological validity and use of the same questions across forms of the tests are just some of the limitations that might have interfered with the findings.

In the next section, the methods used by McMorris and Graydon to test decision making in soccer are discussed in depth. First, the data collection instrument will be critiqued, followed by the critique of his exercise protocol. Finally, improvements made to experiment are presented. This study largely justifies itself by its refined methodological procedures.

2.4 METHODOLOGICAL LIMITATIONS OF STUDIES MEASURING DECISION MAKING UNDER CONDITIONS OF PHYSIOLOGICAL STRESS

The methodological limitations of studies measuring decision making under conditions of physiological stress might have greatly impaired the results. The main limitations in these studies, all conducted by McMorris and Graydon, are related to the data collection instrument used to measure decision making. However, inconsistencies in the exercise protocol used to manipulate exercise intensity are also present. With more appropriate control, the results depicting the effects of exercise on decision making in soccer might have been different. Consequently, the following sections criticize data collection instruments measuring decision making and exercise intensity. Improvements made to the instruments chosen for the current experiment are also indicated.

2.4.1 Decision making measurement

The validity of the decision making instrument used by McMorris and Graydon (1996a, 1996b, 1997a, 1999) is questionable. The majority of the limitations are related to the reliability evidence provided, and the content of the instrument and its ecological validity. A critic of the lack of validity evidence is conveyed in the following sections.

2.4.1.1 Reliability

McMorris and Graydon (1996a, 1996b, 1997a, 1999), investigating the influence of exercise on decision making, used an instrument consisting of multiple forms. Three forms were required due to the instrument being used to measured decision making under three different exercise conditions. Reliability among forms was determined based on intraclass correlations for accuracy and speed of decision making (.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. Use of forms with the same questions also affected the content validity of the instrument as described in the next section.

2.4.1.2 Content validity

Content validity evidence of the instrument used by McMorris and Graydon (1996a, 1996b, 1997a, 1999) to collect decision making information was provided by a group of eight experienced soccer coaches. Only plays which coaches agreed to being typical situations of soccer matches were selected. However, as with reliability, content validity evidence might be biased by identical plays with the exception of field location. In fact, they seem to explain the results in accuracy and speed of decision making reached by McMorris and Gradyon.

Findings from McMorris and Graydon experiments indicated that exercise had no effect on accuracy of decision making. It is possible that differences were not found because subjects were merely repeating the answers from one form to another because they realized the forms of the test were the identical.

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 were 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 from one exercise condition to the next. This pattern of results is exactly what was found for speed of decision in McMorris and Graydon experiments.

The instrument used in this experiment, in addition to being assessed by a panel of three experienced soccer players, also possesses forms that are equivalent but have different decision making plays. The refinements in the content of the instrument chosen for this experiment will better enlighten whether the inverted-U theory is appropriate to explain the effects of exercise on decision making in soccer. It is possible that even with improvements in the methodology of this study, the inverted-U theory will not be useful to explain the effects of exercise in decision making in soccer.

2.4.1.3 Ecological validity

Ecological validity is defined as the degree of generalization of score interpretations. The more similar the test is to the actual situation, 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.

The instrument used in the experiments of McMorris and Graydon (1996a, 1996b, 1997a, 1999) shows very poor ecological validity. First, only situations in which one optimal answer was present were included. This helps increase the objectivity of the instrument. On the other hand, it reduces its ecological validity. In sports, more than one decision can turn out to be a good play. Ranking of the decisions seems more appropriate. In the instrument chosen for this experiment, ranking of decisions was conducted by three experienced soccer players.

A second problem of the decision making instrument used by McMorris and Graydon relates to its inability to capture the dynamics of an open sport such as soccer. The environment in soccer is constantly changing requiring players to be continually adapting to the environment. On the other hand, the decision making tests used by McMorris and Graydon consisted of static presentations 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. Slides do not capture the dynamics involved in soccer. Clearly, these tests do not simulate the relation among perception, decision making, and the action present in the game of soccer.

An improvement from 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). The instrument used in this experiment makes use of videotape segments of real soccer matches.

Although improvements to the decision making instrument have been proposed, the exercise protocol used by McMorris and Graydon also needs to be refined. Limitations of this protocol are presented in the following section.

2.4.2 Exercise protocol

McMorris and Graydon examined decision making performance of experienced soccer players at three different exercise intensities: rest, 70% maximal power output (moderate exercise), and 100% maximal power output (maximum exercise). Two limitations of this protocol can be readily pointed out: same pattern of increments of exercise intensity and lack of control over potential extraneous variables.

Same pattern of increments of exercise intensity is a problem because it does not simulate well the type of exercise present in real soccer matches. Although, in soccer matches, exercise intensity varies greatly, changes in exercise intensity are random. There are points in the game in which players are exercising at high intensities, followed by moderate intensity exercise, followed by high intensity again. Increasing exercise intensity using the same pattern from rest to maximum intensity only answers the question of whether increased exercise intensity affects decision making in soccer. This is certainly not as appealing as asking whether exercise of different intensities affects decision making in soccer.

It is also interesting to notice that McMorris and Graydon did not attempt to control whether power outputs chosen were evoking intended exercise intensities. It is likely that the chosen maximal power outputs, 70% and 100% of the subjects' maximal, represent exercise performed at moderate and maximal intensity. However, that is not possible to determine with certainty since exercise intensity was not measured. Physiological responses, such as heart rate, could have been used to improve the control over exercise intensity.

2.4.3 Methodological improvements

The purpose of this experiment is to investigate the effects of exercise on decision making in soccer of experienced and inexperienced soccer players. Other experiments with the same rationale have already been conducted (McMorris & Graydon, 1996a, 1997b, 1997a, 1999). Consequently, methodological improvements should help clarify whether or not the inverted-U theory can be used to explain the effects of exercise on decision making performance**.** If the inverted-U theory is not supported, even with a more rigorously controlled experiment, one could assert with more certainty that the inverted-U theory is not a viable explanation of the effects of exercise induced arousal on decision making in soccer.

Two data collection instruments were used in the research by McMorris and Graydon (1996a, 1997b, 1997a, 1999). One instrument was used to collect decision making information while a second to manipulate exercise intensity. The discussion of the improvements present in the decision making instrument used in the current experiment precedes the discussion about the improvements made to the exercise protocol.

2.4.3.1 Decision making instrument

Several improvements were made to the decision making instrument chosen for the current experiment. First, the instrument contains four different forms compared to the three forms of the instrument used by McMorris and Graydon. The presence 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.

Second, the test forms of the instrument to be used here will have different items (plays). Reliability of these test forms has been extensively studied indicating equivalence of the forms (Fontana, 2004).

A third improvement from previous research is that answers (options in each play) were ranked by level of correctness by three expert soccer players, each with more than 20 years of soccer experience. Ranking answers by level of correctness resembles more closely what happens during actual matches. In soccer, there is not a decision dichotomy, more than one decision can result in a good play.

Finally, the instrument (Fontana, 2004) chosen for the current experiment shows ecologically valid improvements compared to the static instruments previously used. It simulates the complex and dynamic situations involved in soccer by using videotape segments taken from real soccer matches. The advantage of video clips over slides is that it allows subjects to follow developing plays, and therefore provides a greater number of cues for subjects to determine the most appropriate action. Validity of research instruments, consisting of videotape segments taken from real soccer games, has been used in previous experiments (Campos, 1993). The ideal scenario is to use an instrument in which decision making is measured during game play. In sports, however, the number of extraneous variables is so large and the ability to control the situation across trials so difficult that such instrument has yet to be developed.

2.4.3.2 Exercise protocol

In addition to the improvements made to the decision making instrument, improvements to the exercise protocol used in previous studies are also necessary. It is possible that the methodological limitations of the exercise protocol used in previous studies might have masked the decision making results. The improvements made to the exercise protocol chosen for this experiment include counterbalancing exercise intensities and using heart rate to control exercise intensity.

Determining the effects of exercise on decision making, without counterbalancing exercise intensities, only allow results to be generalized to situations in which exercise intensity increases linearly. In soccer, however, variations in exercise intensity are random. In this experiment, exercise intensity will be counterbalanced. By counterbalancing exercise intensity, conclusions about the effect of exercise on decision making can be drawn irrespective to the order the exercise is presented.

Finally, in the current experiment, heart rate will be used to control for subjects exercising at target intensities. McMorris and Graydon determined maximal power output based on the subjects' aerobic capacity pretest results. Similarly, an aerobic capacity pre-test will be used to determine the speed and grade the treadmill is set. However, the pretest results will also be used to determine a target heart rate for each subject and exercise intensity.

In summary, all refinements present in the decision making instrument and exercise protocol chosen for this experiment are likely to provide better control over the dependent variables in this experiment. These refinements will help clarify whether or not the inverted-U theory can be used to explain the effects of exercise on decision making performance. Even with a more rigorously controlled experiment, it is possible that the inverted-U theory does not provide a plausible explanation to the effects of exercise on decision making in soccer.

APPENDIX B

In appendix B, recruitment and screening procedures are described.

Recruitment/Screening Script

Hi, thanks for calling to find out more information about our research. My name is Fabio Fontana (Oldemar Mazzardo) and I am a doctoral student in the Health and Physical Activity Department. The purpose of our research is to determine whether physical exercise affects decision making in soccer. If you decide to participate in the study, you will need to come to the Human Energy lab in Trees Hall twice, 3 to 8 days apart. In the first session, we will determine your aerobic capacity – you will walk/run on a treadmill until you are tired and unable to continue. In the second session, as you are walking/running on the treadmill you will watch clips of a soccer match and when the clip freezes make decisions about what the player in control of the ball should do. You will do this while exercising at four different exercise intensities (rest, low, moderate, and high intensity).

Are you are interested in participating in this study?

{If no}: thanks very much for your call

{If yes}: before I enroll you in the study, I need to ask you some questions about your soccer experience and about your health status to determine if you are eligible to participate in this research. You do not have to answer any of the questions, and your answers, including your name and any other identifying information, will be confidential and kept under lock and key. You do not have to answer any of the following questions, however if you do not answer the questions you will be excluded from the study.

Do you I have your permission to ask you these questions?

I will start by asking about your soccer experience and if you qualify I will then ask you about your health status.

Soccer Experience Questionnaire

Name: ________________________________

Birth Date: ____________________________

1. Do you play competitive soccer for your college team?

( ) Yes, how many years? _________ ( ) No

If YES to question 1

2. When did you start playing competitive soccer? __________

If NO to question 1

2. Have you ever played soccer?

( ) Yes ( ) No

If NO to the question above then the subject is NOT eligible to participate in the study.

3. How many years of soccer did you play? _______
4. When was the last time you played soccer? __________

5. Did you play competitive soccer for your high school team?

( ) Yes, how many years? _________ ( ) No

6. Did you play on a traveling soccer team during high school?

( ) Yes, how many years? _________ ( ) No

7. Did you play on an intramural soccer team during college?

( ) Yes, how many years? _________ ( ) No

____

If based on soccer experience, subject is NOT eligible to participate in the study:

- I am sorry but your experience does not qualify for this experiment. We are looking for college soccer players with 8 years of experience or novice soccer players with 1-4 years of soccer experience and no competitive experience since leaving high school. I am sorry again, and thanks very much for your call.

If based on soccer experience, subject is eligible to participate in the study:

8. Based on your soccer experience, you are eligible to participate in this study. Now I am going to ask you a few questions to determine if you are eligible to complete the treadmill exercise…

Physical Activity Readiness Questionnaire (PAR-Q)

1. Has your doctor ever said that you have a heart condition and that you should only do physical activity recommended by a doctor?

No _____ Yes _____ If yes, specify: ______________________________

2. Do you feel pain in your chest when you do physical activity?

No _____ Yes _____ If yes, specify: ______________________________

3. In the past month, have you had chest pain when you were not doing physical activity?

No _____ Yes _____ If yes, specify: ______________________________

4. Do you lose your balance because of dizziness or do you ever lose consciousness?

No _____ Yes _____ If yes, specify: ______________________________

5. Do you have a bone or joint problem that could be made worse by a change in your physical activity?

No _____ Yes _____ If yes, specify: ______________________________

6. Is your doctor currently prescribing drugs (for example, water pills) for a blood pressure or heart condition?

No _____ Yes _____ If yes, specify: ______________________________

7. Do you now of any other reason why you should not do physical activity?

No _____ Yes _____ If yes, specify: ______________________________

APPENDIX C

In appendix C, several procedures followed during the fitness session are described including: Session 1 – Script, Exercise Performance Data Sheet, instructions for Bruce protocol test, and instructions for decision making test.

Script: Session 1

Person A

1. Set-up VO2 cart
2. "Set-up computer to record VO2 max every 15 seconds under options"

Person B:

3. Set up equipment to show demonstration of decision making test

Person A

4. Get Informed consent

Person B:

5. Record subjects height (cm), weight (pounds) and age on the "Exercise Performance Data Sheet".

Person A

6. Explain VO2 test (VO2 TEST EXPLANATION SHEET: SESSION 1)
7. Remember to set up the 1 minute warm-up (Under Bruce protocol, click in warm up and set to 60 seconds)
8. Run cart

Person B:

9. During the test, record HR and RPE at the beginning of the last minute of each stage (Recording should be made on the "Exercise Performance Data Sheet"). Write down the HR first, and then ask RPE question (1. how does your breathing feel, how do your legs feel, and how do they feel overall?)

Person A

10. Explain the demonstration of the decision making test at the end of the VO2 test (use explanation sheet First Session: Decision Making Test).

Person A

11. Schedule session 2 (Ask subjects to write their information including phone number, e-mail address, and name into the Second Session Schedule Sheet)
12. Send subjects e-mail to remind them of their appointment.

1. **Exercise Performance Data Sheet**

Date: ____

Name: ____

Age: _______________

Weight: ______________lbs or kg

Height: ______________ ins or cm

				Rate of Perceived exertion			
	Speed (mph)	Grade %	HR	Chest	Leg	Overall	MIN
Stage 1	1.7	10					3
Stage 2	2.5	12					6
Stage 3	3.4	14					9
Stage 4	4.2	16					12
Stage 5	5	18					15
							18

Don’t forget to get last RPE and HR

Comments: ____
____
____
____.

Explanation of Bruce protocol

You can start by putting the polar monitor on.

The purpose of the session today is to determine how much oxygen you are using during exercise

Explain the test:
We are using the Bruce protocol. For this protocol, you exercise for 3 minutes in each stage. Every three minutes the treadmill gets steeper and faster. At the last minute of each stage, I will ask you how your chest feels (breathing), legs, and overall. You can just point to each number corresponds to how you are feeling. The numbers go from 0 to 10, 0 being the easiest and 10 the hardest.

You are going to exercise until you can not go anymore. When you really can not go any further just step on the side and hold the hand bars. And the treadmill will slow down.

There is one stage that is a little awkward to walk or job. Try to walk as much as you can, once you can not walk anymore, then you can start jogging.

During the entire test, you have to wear this mouth piece and a nose clip. That is important because that is what determines your aerobic capacity.

You also need to stay close to the front of the treadmill. If I notice that you are sliding back, I will gently tap your back.

Finally, just remember that you are in control of the test. If you are not feeling well, just step on the side and hold the hand bars.

Do you have any questions?

Decision Making Test

I will show you for tests. As you saw last week, each test consists of seven clips taken from soccer games of the 1986 and 1990 World Cup games. Each lasts 12 seconds. When each clip is finished, the videotape will freeze. Four possible decision sentences containing two words will be projected onto the screen such as…

The sentence:

- “Shoot goal”: The player in possession of the ball will shoot the ball to the goal
- “Pass direction: means that the player in possession of the ball will pass to a teammate that is on the “that” side of the field;
- “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, because there is a space for the to advance, he will just dribble the ball forward, without dribbling an opponent
- “Kick forward”: because of offensive pressure, the player in possession of the ball would clear the ball away from defense

“Cross direction”; longer pass, direction (right...)

As you noticed, teams are always attacking to this side of the screen
Between videos, there the one second warning video
Between videos 3-4 and 5-6 there is a six second video warning. During that period, we might increase or decrease a little video the speed of the treadmill.

APPENDIX D

Exercise Intensity Data Sheet: Session 2

Break: 10min + HR<100bpm

Break: 10min + HR<100bpm

ID		Condition 1			Condition 2			Condition 3		
1	Rest	80%			60%			40%		
EX	HR=	VO2= Speed= Slope= HR=			VO2= Speed= Slope= HR=			VO2= Speed= Slope= HR=		
	1	1			1			1		
	2	2			2			2		
	3	3	🟨		3	🟨		3	🟨	
	4	4		1st	4		1st	4		1st
	5	5	🟩	2nd	5	🟩	2nd	5	🟩	2nd
	6	6			6			6		
	7	7			7			7		

REST HR=

REST HR=

HR: 5<->7= .2
HR: +7=.3

Time Break 1: _______

Time Break 2: _______

Script: Session 2

Person A

1. Set up VO2 test equipment (Don't forget to use two HR monitors)
    - Make sure computer is set up for 15 seconds
    - Have two Polar watches ready

Person B:

2. Set up Decision making test
    - Bring computer, microphone, lamp (positioned behind treadmill), LCD projector, and board
3. Open up the Final Cut express
    - always leave first form ready
    - the order of forms is specified on the cover of the subject's folder (it is also specified inside the subjects' folder)
4. Video screen should be on the left, Voice Over screen should be on the right, Timeline screen should be on the bottom.
5. Voice Over: to visualize the voice over screen you have to click on voice over under tools.
6. *Making sure to set Video at ZERO (press the back bottom until yellow arrow is at the beginning, check yellow arrow before testing)*
7. *Enter the ID of subjects into the Voice over screen, this is very important or we loose data.* Id should correspond to what is on the folder (first= #; second= exp or inex; third= percentage of VO2)
8. Make sure the sound is off for previous recording (click bottom window "timeline" and click sound icon to fade it off)
9. Check if Input volume is 100% everytime you open a new form (go to system preferences, sound, input volume)

Person A

10. Ask Subject to put hear rate monitor on
11. Explain test (use Session 2: Decision Making Test)
12. Ask subject to practice taking Mouth piece and nose clip off
13. Tell subject he will start answering the first decision making test. Say: "we will play the first test and you will answer as you stand on the treadmill are you ready".

Person B

14. Press record to start Decision making videos
15. Make sure to "SAVE PROJECT" before closing each session

Person A

16. Make sure computer is set up to 15 sec. (utilities, VO2 metab. Test display, display averaging 15s)
17. Open VO2 Metabolic test

18. Do Patient Look-up (last name, search) (Don’t forget to enter the % of VO2 on Rec)
19. Test degree (other, treadmill, inactive)
20. Ask subject to “put the mouth piece on, and hold on to the nose clip”
21. Choose “manual computer control” (that is only going to work if subject is wearing the mouth piece)
22. Set up speed and slope of the treadmill on the screen. Look at number present at session 2 recording sheet
23. Two seconds before the first minute, ask subject to “start walking”
24. have to put nose clip on right away, explain that “once he does, he should not be able to breath through his nose”)
25. If you need the extra minute, warn the subject: “one minute left”
26. Mark down the baseline HR on the “Session two record sheet”
27. Press stop on manual control to stop the test, after subject is done answering the questions
28. Mark down the time the subject finishes each condition on the “Session two record sheet”
29. Print the results

<u>Person B</u>

- Save the project before closing (click on “save project” under file)
- Set up the next session: the order of the forms is on the cover of each test.

Decision Making Test

Purpose: today, the purpose of the test is measure whether exercise intensity affects your ability to make decisions

I will show you for tests. The first test, you will answer as you stand on the treadmill, the other tests you will answer while exercise at ___%, ___%, and ___% of your aerobic capacity measured in session one. Between exercise conditions, there is a 10-minute rest period. At the beginning of each exercise condition, there is a habituation period which is used to get you at the target intensity. The habituation period will take 2 or 3 minutes depending on how long it takes you to reach target. At the end of the habituation period, I will ask to give me the mouth piece and the nose clip (Demonstrate and practice once). After hand the mouth piece to me, you will start answering the question as you walk on the treadmill.

As you saw last week, each test consists of seven clips taken from soccer games of the 1986 and 1990 World Cup games. Each lasts 12 seconds. When each clip is finished, the videotape will freeze. Four possible decision sentences containing two words will be projected onto the screen such as…

- "Shoot goal": The player in possession of the ball will shoot the ball to the goal
- "Pass direction: means that the player in possession of the ball will pass to a teammate that is on the "that" side of the field;
- "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, because there is a space for the to advance, he will just dribble the ball forward, without dribbling an opponent
- "Kick forward": because of offensive pressure, the player in possession of the ball would clear the ball away from defense
- "Cross direction"; longer pass, direction (right...)

Your are asked to select as **quickly** and as **accurately** as possible the <u>most appropriate action </u>for the player in possession in possession of the ball. In other words, once the video freezes you are asked to select as quickly and as accurately as possible what the player in possession of the ball should do next.

Remember that all players in the video are very experienced and skilled.

Do you have any questions?
As you will notice, teams are always attacking to this side of the screen
Between videos, there the one second warning video
Between videos 3-4 and 5-6 there is a six second video warning. During that period, we might increase or decrease a little video the speed of the treadmill

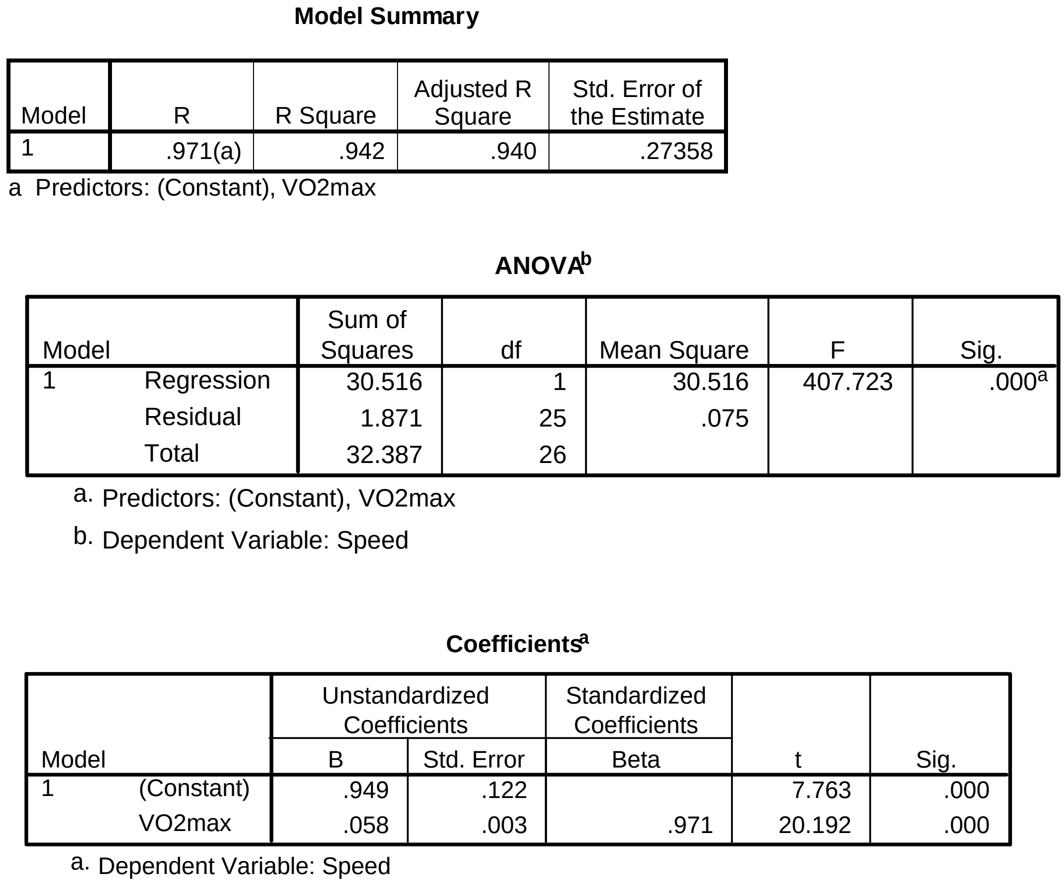
<u>Finally, just remember that you are in control of the test. If you are not feeling well, just step on the side and hold the hand bars.</u>

APPENDIX E

In appendix E, an example of how predicted speed, grade and VO_{2max} were computed is provided.

VO2max	Speed	Grade
13.8	1.7	10
13.3	1.7	10
17.9	1.7	10
18.9	1.7	10
16.4	1.7	10
19.7	1.7	10
19.3	2.5	12
22.8	2.5	12
25.8	2.5	12
24	2.5	12
25.7	2.5	12
26	2.5	12
32.9	3.4	14
34.5	3.4	14
33.9	3.4	14
39.7	3.4	14
36.2	3.4	14
41.1	3.4	14
44.4	4.2	16
50.2	4.2	16
52.2	4.2	16
55.2	4.2	16
55.5	4.2	16
57.2	4.2	16
61.1	5	18
64.3	5	18
69.7	5	18
73.5	5	18

Figure 6: Data derived from results of VO2max test of Subject 1



Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.971(a)	.942	.940	.27358

a Predictors: (Constant), VO2max

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	30.516	1	30.516	407.723	.000[a]
	Residual	1.871	25	.075		
	Total	32.387	26			

a. Predictors: (Constant), VO2max

b. Dependent Variable: Speed

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.949	.122		7.763	.000
	VO2max	.058	.003	.971	20.192	.000

a. Dependent Variable: Speed

Figure 7: The results of a simple linear regression with VO2max as predictor and Speed as criterion

On the coefficient table, constant represent the intercept of the line and VO2max represent the slope of the line. These values are used on the regression equation to calculate the predicted speed.

Equations

$Y= b+bi(X)$
$G= 8.197+.139(X)$
$S= .949+.058(X)$

$S= .949+.058(29.4)$
$S= .949+.058(44.1)$
$S= .949+.058(58.8)$

Adam	VO2max	%	% VO2max	Grade	Speed
	73.5	0.4	29.4	12.28	2.65
		0.6	44.1	14.33	3.51
		0.8	58.8	16.3702	4.36

Figure 8: Regression equations for speed and grade are presented. The % VO2max column represents the predicted percentage of exercise intensity (40%, 60%, and 80%). Speed and grade are derived by substituting X in the equation by % VO2max values.

APPENDIX F

ID		Form	Condition 1	Form	Condition 2	Form	Condition 3	Form
1	Rest	4	80%	1	60%	3	40%	2
2	Rest	2	40%	3	80%	1	60%	4
3	Rest	3	40%	4	60%	2	80%	1
4	Rest	2	40%	3	60%	1	80%	4
5	Rest	3	40%	4	80%	2	60%	1
6	Rest	1	80%	2	40%	4	60%	3
7	Rest	1	80%	2	60%	4	40%	3
8	Rest	2	60%	3	40%	1	80%	4
9	Rest	4	60%	1	80%	3	40%	2
10	Rest	4	80%	1	40%	3	60%	2
11	Rest	4	40%	1	80%	3	60%	2
12	Rest	1	60%	2	40%	4	80%	3
13	Rest	2	80%	4	60%	3	40%	1
14	Rest	1	40%	2	60%	4	80%	3
15	Rest	3	60%	4	80%	2	40%	1
16	Rest	3	80%	4	40%	2	60%	1

Figure 9: Exercise conditions and test forms were counterbalanced and randomly assigned to subjects

APPENDIX G

Table 10: ANOVA summary table for fitness level

ANOVA

Aerobic_Capacity

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	453.005	1	453.005	3.932	.057
Within Groups	3456.050	30	115.202		
Total	3909.055	31			

Table 11: ANOVA summary tables for within exercise intensity analysis

Multivariate Tests[b]

Effect		Value	F	Hypothesis df	Error df	Sig.
intensity	Pillai's Trace	.983	249.448[a]	3.000	13.000	.000
	Wilks' Lambda	.017	249.448[a]	3.000	13.000	.000
	Hotelling's Trace	57.565	249.448[a]	3.000	13.000	.000
	Roy's Largest Root	57.565	249.448[a]	3.000	13.000	.000
intensity * Level_of_Experience	Pillai's Trace	.000	.[a]	.000	.000	.
	Wilks' Lambda	1.000	.[a]	.000	14.000	.
	Hotelling's Trace	.000	.[a]	.000	2.000	.
	Roy's Largest Root	.000	.000[a]	3.000	12.000	1.000

a. Exact statistic

b.

Design: Intercept+Level_of_Experience
Within Subjects Design: intensity

Pairwise Comparisons

Measure: MEASURE_1

(I) intensity	(J) intensity	Mean Difference (I-J)	Std. Error	Sig.[a]	95% Confidence Interval for Difference[a]	
					Lower Bound	Upper Bound
1	2	-44.275*	3.391	.000	-51.503	-37.047
	3	-69.525*	3.965	.000	-77.976	-61.074
	4	-94.450*	3.409	.000	-101.717	-87.183
2	1	44.275*	3.391	.000	37.047	51.503
	3	-25.250*	3.282	.000	-32.245	-18.255
	4	-50.175*	2.797	.000	-56.136	-44.214
3	1	69.525*	3.965	.000	61.074	77.976
	2	25.250*	3.282	.000	18.255	32.245
	4	-24.925*	2.369	.000	-29.974	-19.876
4	1	94.450*	3.409	.000	87.183	101.717
	2	50.175*	2.797	.000	44.214	56.136
	3	24.925*	2.369	.000	19.876	29.974

Based on estimated marginal means

*. The mean difference is significant at the .05 level.

a. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments).

Table 12: ANOVA tables for the carry-over effect

Multivariate Tests[b]

Effect			Value	F	Hypothesis df	Error df	Sig.
Between Subjects	Intercept	Pillai's Trace	.997	5594.324[a]	2.000	29.000	.000
		Wilks' Lambda	.003	5594.324[a]	2.000	29.000	.000
		Hotelling's Trace	385.815	5594.324[a]	2.000	29.000	.000
		Roy's Largest Root	385.815	5594.324[a]	2.000	29.000	.000
	Level_of_Experience	Pillai's Trace	.560	18.423[a]	2.000	29.000	.000
		Wilks' Lambda	.440	18.423[a]	2.000	29.000	.000
		Hotelling's Trace	1.271	18.423[a]	2.000	29.000	.000
		Roy's Largest Root	1.271	18.423[a]	2.000	29.000	.000
Within Subjects	order	Pillai's Trace	.159	1.279[a]	4.000	27.000	.303
		Wilks' Lambda	.841	1.279[a]	4.000	27.000	.303
		Hotelling's Trace	.189	1.279[a]	4.000	27.000	.303
		Roy's Largest Root	.189	1.279[a]	4.000	27.000	.303
	order * Level_of_ Experience	Pillai's Trace	.223	1.943[a]	4.000	27.000	.132
		Wilks' Lambda	.777	1.943[a]	4.000	27.000	.132
		Hotelling's Trace	.288	1.943[a]	4.000	27.000	.132
		Roy's Largest Root	.288	1.943[a]	4.000	27.000	.132

a. Exact statistic

b.

Design: Intercept+Level_of_Experience
Within Subjects Design: order

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
order	accuracy	Sphericity Assumed	11.438	2	5.719	1.545	.222
		Greenhouse-Geisser	11.438	1.865	6.134	1.545	.223
		Huynh-Feldt	11.438	2.000	5.719	1.545	.222
		Lower-bound	11.438	1.000	11.438	1.545	.223
	speed	Sphericity Assumed	67584.695	2	33792.348	.456	.636
		Greenhouse-Geisser	67584.695	1.624	41610.995	.456	.596
		Huynh-Feldt	67584.695	1.761	38374.971	.456	.612
		Lower-bound	67584.695	1.000	67584.695	.456	.505
order * Level_ of_Experience	accuracy	Sphericity Assumed	12.521	2	6.260	1.692	.193
		Greenhouse-Geisser	12.521	1.865	6.715	1.692	.195
		Huynh-Feldt	12.521	2.000	6.260	1.692	.193
		Lower-bound	12.521	1.000	12.521	1.692	.203
	speed	Sphericity Assumed	80871.157	2	40435.579	.546	.582
		Greenhouse-Geisser	80871.157	1.624	49791.293	.546	.547
		Huynh-Feldt	80871.157	1.761	45919.099	.546	.561
		Lower-bound	80871.157	1.000	80871.157	.546	.466
Error(order)	accuracy	Sphericity Assumed	222.042	60	3.701		
		Greenhouse-Geisser	222.042	55.936	3.970		
		Huynh-Feldt	222.042	60.000	3.701		
		Lower-bound	222.042	30.000	7.401		
	speed	Sphericity Assumed	4446752.494	60	74112.542		
		Greenhouse-Geisser	4446752.494	48.726	91260.206		
		Huynh-Feldt	4446752.494	52.835	84163.038		
		Lower-bound	4446752.494	30.000	148225.083		

Table 13: MANOVA tables depicting the effects of exercise intensity on decision making

Multivariate Tests[b]

Effect			Value	F	Hypothesis df	Error df	Sig.
Between Subjects	Intercept	Pillai's Trace	.992	1762.856[a]	2.000	29.000	.000
		Wilks' Lambda	.008	1762.856[a]	2.000	29.000	.000
		Hotelling's Trace	121.576	1762.856[a]	2.000	29.000	.000
		Roy's Largest Root	121.576	1762.856[a]	2.000	29.000	.000
	Level_of_Experience	Pillai's Trace	.503	14.690[a]	2.000	29.000	.000
		Wilks' Lambda	.497	14.690[a]	2.000	29.000	.000
		Hotelling's Trace	1.013	14.690[a]	2.000	29.000	.000
		Roy's Largest Root	1.013	14.690[a]	2.000	29.000	.000
Within Subjects	intensit	Pillai's Trace	.471	3.715[a]	6.000	25.000	.009
		Wilks' Lambda	.529	3.715[a]	6.000	25.000	.009
		Hotelling's Trace	.892	3.715[a]	6.000	25.000	.009
		Roy's Largest Root	.892	3.715[a]	6.000	25.000	.009
	intensit * Level_of_Experience	Pillai's Trace	.094	.433[a]	6.000	25.000	.850
		Wilks' Lambda	.906	.433[a]	6.000	25.000	.850
		Hotelling's Trace	.104	.433[a]	6.000	25.000	.850
		Roy's Largest Root	.104	.433[a]	6.000	25.000	.850

[a] Exact statistic

[b] Design: Intercept+Level_of_Experience
Within Subjects Design: intensit

Tests of Between-Subjects Effects

Transformed Variable: Average

Source	Measure	Type III Sum of Squares	df	Mean Square	F	Sig.
Intercept	accuracy	344.606	1	344.606	2564.852	.000
	speed	289075160.134	1	289075160.134	354.757	.000
Level_of_Experience	accuracy	2.224	1	2.224	16.551	.000
	speed	5318299.170	1	5318299.170	6.527	.016
Error	accuracy	4.031	30	.134		
	speed	24445636.153	30	814854.538		

Univariate Tests

Source	Measure		Type III Sum of Squares	df	Mean Square	F	Sig.
intensit	accuracy	Sphericity Assumed	.382	3	.127	1.320	.273
		Greenhouse-Geisser	.382	2.865	.133	1.320	.274
		Huynh-Feldt	.382	3.000	.127	1.320	.273
		Lower-bound	.382	1.000	.382	1.320	.260
	speed	Sphericity Assumed	1860227.710	3	620075.903	7.119	.000
		Greenhouse-Geisser	1860227.710	2.451	758883.903	7.119	.001
		Huynh-Feldt	1860227.710	2.775	670415.124	7.119	.000
		Lower-bound	1860227.710	1.000	1860227.710	7.119	.012
intensit * Level_ of_Experience	accuracy	Sphericity Assumed	.141	3	.047	.488	.692
		Greenhouse-Geisser	.141	2.865	.049	.488	.683
		Huynh-Feldt	.141	3.000	.047	.488	.692
		Lower-bound	.141	1.000	.141	.488	.490
	speed	Sphericity Assumed	163796.012	3	54598.671	.627	.600
		Greenhouse-Geisser	163796.012	2.451	66820.936	.627	.569
		Huynh-Feldt	163796.012	2.775	59031.119	.627	.588
		Lower-bound	163796.012	1.000	163796.012	.627	.435
Error(intensit)	accuracy	Sphericity Assumed	8.693	90	.097		
		Greenhouse-Geisser	8.693	85.947	.101		
		Huynh-Feldt	8.693	90.000	.097		
		Lower-bound	8.693	30.000	.290		
	speed	Sphericity Assumed	7839163.168	90	87101.813		
		Greenhouse-Geisser	7839163.168	73.538	106600.117		
		Huynh-Feldt	7839163.168	83.242	94172.943		
		Lower-bound	7839163.168	30.000	261305.439		

3. 1=INEX; 2=EX * intensit

Measure	1=INEX; 2=EX	intensit	Mean	Std. Error	95% Confidence Interval	
					Lower Bound	Upper Bound
accuracy	1	1	1.821	.095	1.628	2.015
		2	1.777	.077	1.620	1.934
		3	1.833	.074	1.682	1.984
		4	1.659	.079	1.498	1.820
	2	1	1.598	.095	1.405	1.792
		2	1.438	.077	1.281	1.594
		3	1.518	.074	1.367	1.668
		4	1.483	.079	1.322	1.643
speed	1	1	1949.706	148.269	1646.900	2252.511
		2	1726.174	150.995	1417.801	2034.548
		3	1612.254	105.177	1397.453	1827.055
		4	1538.400	106.839	1320.206	1756.594
	2	1	1429.750	148.269	1126.945	1732.556
		2	1306.576	150.995	998.203	1614.949
		3	1269.027	105.177	1054.226	1483.828
		4	1190.491	106.839	972.297	1408.685