



UNIVERSITI PUTRA MALAYSIA

EFFECTS OF NATURE EXPOSURE INTERVENTION ON SELF-REGULATION AND DECISION-MAKING IN MENTALLY-FATIGUED UNIVERSITY SOCCER PLAYERS

SUN HE

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By

SUN HE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

November 2021

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DEDICATION

Dedicated With Love

To

My Beloved Wife, Jia Yanqing

My Cute Son, Sun Woxin



Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

EFFECTS OF NATURE EXPOSURE INTERVENTION ON SELF-REGULATION AND DECISION-MAKING IN MENTALLY-FATIGUED UNIVERSITY SOCCER PLAYERS

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SUN HE

November 2021

Chairman : Professor Soh Kim Geok, PhD
Faculty : Educational Studies

Mental fatigue is a psychobiological state induced by a prolonged duration of demanding cognitive tasks. The effects of mental fatigue on soccer performance have been well investigated in the literature. However, the intervention that can counteract mental fatigue and improve subsequent performance remains unclear, particularly when it comes to decision-making, which is most important skill in soccer. The objective of this study was to examine the impact of nature exposure on self-regulation, and decision-making among mentally fatigue university players. A true experimental design. was utilized in the study. Ninety male university soccer players aged 18-24 years were selected with a simple random sampling technique. And all of them were randomly assigned into six groups (n=15 each group) with comparisons of three different durations of nature exposure intervention (4.170 min, 8.330 min and 12.500 min) in experimental groups and corresponding control groups. All subjects viewed virtual pictures on a computer. Prior to the intervention, a 45 min computer-version Stroop task was used to induce mental fatigue condition.

Results from two-way repeated ANOVA and ANCOVA procedures suggested that nature exposure had significantly improved the players' heart rate variability ($F = 6.284$, $P = 0.014$, $\eta^2 = 0.070$); cognitive and physical anxiety ($F = 4.567$, $P = 0.001$, $\eta^2 = 0.216$) and state confidence ($F = 5.077$, $P < 0.001$, $\eta^2 = 0.232$) of competitive state anxiety; as well as reaction time of decision-making ($F = 4.755$, $P = 0.001$, $\eta^2 = 0.221$). Specifically, Exp 3 not only showed the improvement from pre-test to post-test, but improved significantly in heart rate variability (1.521 ± 0.805 vs. 2.640 ± 0.858), cognitive and physical anxiety (30.267 ± 7.411 vs. 41.200 ± 9.306), state confidence (30.267 ± 3.575 vs. 25.267 ± 4.935), and reaction time of decision-making (5.011 ± 1.457 vs. 7.213 ± 1.652) compared with control group at post-test. Moreover, Exp 2 only showed the significant improvement from pre-test to post-test. To contrast, there was no

significant improvement in Exp 1 ($p>0.050$) in three dependent variables. In line, the mental fatigue condition decreased to the lowest level among six groups in Exp 3, followed by Exp 2. The mental fatigue condition only had a slight decrease in Exp 1. Overall, nature exposure significantly improved self-regulation and decision-making in mentally fatigued university soccer players. However, depending on the duration of the intervention when nature scenes are fixed. The best duration to improve self-regulation and decision-making in this study was 12.50 min. Additionally, the attention can be the third option in the psychobiological model of exercise performance to apply in the sport skilled performance (e.g., decision-making).



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KESAN INTERVENSI PENDEDAHAN ALAM KE ATAS KAWALAN KENDIRI DAN MEMBUAT KEPUTUSAN DALAM KALANGAN PEMAIN BOLA SEPAK UNIVERSITI YANG PENAT MENTAL

Oleh

SUN HE

November 2021

Pengerusi : Profesor Soh Kim Geok, PhD
Fakulti : Pengajian Pendidikan

Keletihan mental adalah status psikobiologi yang disebabkan oleh tugas kognitif yang tinggi dalam jangka panjang. Kesan keletihan mental terhadap prestasi bola sepak telah dikaji dengan baik dalam literatur. Namun, langkah intervensi yang dapat mengatasi keletihan mental dan meningkatkan prestasi seterusnya masih belum jelas, terutama dalam bahagian membuat keputusan, yang merupakan kemahiran terpenting dalam bola sepak. Tujuan kajian ini adalah untuk memeriksa kesan pendedahan semula jadi terhadap peraturan sendiri dan membuat keputusan pemain bola sepak universiti yang keletihan mental. Reka bentuk eksperimen yang benar telah digunakan dalam kajian ini. Sembilan puluh pemain bola sepak universiti lelaki berumur 18-24 tahun telah dipilih dengan teknik persampelan rawak mudah. Dan kesemua mereka dibahagikan secara rawak kepada enam kumpulan ($n = 15$ setiap kumpulan) dengan membandingkan tiga intervensi pendedahan semula jadi yang berbeza jangka masa (4.17 minit, 8.33 minit dan 12.50 minit) antara kumpulan eksperimen dan kumpulan kawalan. Semua subjek melihat gambar maya di komputer. Sebelum intervensi, *Stroop task* selama 45 minit dengan menggunakan perisian komputer digunakan untuk menimbulkan keletihan mental.

Hasil ujian ANOVA dan ANCOVA berulang dua arah menunjukkan bahawa pendedahan semula jadi meningkatkan kebolehubahan degupan jantung pemain bola sepak dengan signifikan ($F = 6.284$, $P = 0.014$, $\eta^2 = 0.070$); kecemasan kognitif dan fizikal kecemasan keadaan kompetitif ($F = 4.567$, $P = 0.001$, $\eta^2 = 0.216$) dan keyakinan status ($F = 5.077$, $P < 0.001$, $\eta^2 = 0.232$); dan masa reaksi membuat keputusan ($F = 4.755$, $P = 0.001$, $\eta^2 = 0.221$). Secara khusus, Exp 3 tidak hanya menunjukkan peningkatan dari ujian pra hingga ujian pasca, tetapi juga signifikan dari segi kebolehubahan degupan jantung (1.521 ± 0.805 vs 2.640 ± 0.858), kecemasan kognitif dan fizikal (30.267 ± 7.411 vs 41.200 ± 9.306) juga meningkatkan, status keyakinan diri (30.267 ± 3.575 vs 25.267 ± 4.935) dan masa membuat keputusan (5.011 ± 1.457 vs 7.213 ± 1.652)

dibandingkan dengan kumpulan kawalan dalam ujian pasca. Selain itu, Exp 2 hanya menunjukkan peningkatan yang signifikan dari ujian pra hingga ujian pasca. Sebaliknya, Exp 1 ($p > 0.05$) tidak meningkat dengan signifikan dalam ketiga pemboleh ubah bersandar. Sejajar dengan itu, status keletihan mental dikurangkan ke tahap terendah di antara enam kumpulan dalam Exp 3, seterusnya ialah Exp 2. Status keletihan mental hanya sedikit menurun dalam Exp 1. Secara keseluruhan, pendedahan semula jadi secara signifikan meningkatkan peraturan sendiri dan membuat keputusan pemain bola sepak universiti yang keletihan mental. Namun, apabila pemandangan semula jadi ditetapkan, ia bergantung pada jangka masa intervensi. Masa terbaik untuk memperbaiki peraturan sendiri dan membuat keputusan dalam kajian ini adalah 12.50 minit. Di samping itu, perhatian boleh menjadi faktor ketiga dalam model psikobiologi prestasi sukan, yang dapat digunakan pada prestasi kemahiran sukan (membuat keputusan).



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Soh Kim Geok, PhD

Professor
Faculty of Educational Studies
Universiti Putra Malaysia
(Chairman)

Mohd Rozilee Wazir bin Norjali Wazir, PhD

Senior Lecturer
Faculty of Educational Studies
Universiti Putra Malaysia
(Member)

Samsilah binti Roslan, PhD

Professor
Faculty of Educational Studies
Universiti Putra Malaysia
(Member)

ZALILAH MOHD SHARIFF, PhD

Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date: 09 March 2022

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LIST OF ABBREVIATIONS

HRV	Heart Rate Variability
ART	Attention Restoration Theory
ACC	Anterior Cingulate Cortex
RPE	Rating Perception of Effort
VAS	Visual Analogue Scale
AX-CPT	AX-version Continuous Performance Task
SART	Sustained Attention to Response Task
BRUMS	Brunel Mood Scale
LF	Low Frequency
HF	High Frequency
TSC	Trait Self-control
BSCS	Brief Self-control Scale
CUSL	China University Soccer League
ZZU	Zhengzhou University
ZUT	Zhongyuan University of Technology.
IT	Immersive Tendency
ITQ	Immersive Tendencies Questionnaire
PR	Perception of Restorativeness
PRS	Perception of Restorativeness Scale
CSA	Competitive State Anxiety
CSAI-2	Competitive State Anxiety Inventory-2
CVI	Content Validity Index
EFA	Exploratory Factor Analysis

KMO	Kaiser-Meyer-Olkin
MO1	Pre-test Motivation
CPA	Cognitive and Physical Anxiety
SC	State Confidence



CHAPTER 1

INTRODUCTION

The sport of soccer has been getting more and more attention in China. With the so-called “football revolution on campus”, which has been ongoing since 2014, the development of soccer has become a national program in China (China's football revolution kicks into overdrive, 2016). Eighty-eight universities, including several that are top-class (e.g., Tsinghua University, Perking University) have set a special admission for students who have soccer talent. Moreover, China has opened 27,059 “soccer-specialized schools” to provide professional soccer training (The Overall Plan of Chinese Football Reform and Development Program, 2015). After the launch of the project of “football revolution on campus”, nearly 30 million elementary and secondary school pupils receive one soccer lesson per week. More than 149,000 soccer pitches are further set to be built by the end of 2020 (The Overall Plan of Chinese Football Reform and Development Program, 2015).

However, the results of this program and the development of soccer are disappointing. China fails to enter the World Cup yet again for both 2018 and 2022. It can be said that soccer is the most popular sport in China, but its current Federation International Football Association (FIFA) world ranking is only No. 76 (FIFA: Men’s ranking, 2020). On the other hand, China obtained 88 medals in the Tokyo Olympic and ranked at the second position (Shivaram & Barco, 2021). Why is China so dominant in other Olympic sports and so awful at soccer? Why, with full support from various policies and vast expenditures, are Chinese soccer players still unable to perform well?

One of the most repeated phrases players hear coaches use on the sideline or during practice is decision-making (Kaya, 2014). On the field, players are taught to think one step ahead, and trained to know what to do with the ball, long before they receive it. Decision-making, a fundamental element of soccer, plays an unparalleled role for players to perform accurately and fast (Kaya, 2014; Rulence-Pâques et al., 2005). However, recent investigations found that decision-making is impaired by mental fatigue (Fortes et al., 2020; Gantois et al., 2019).

1.1 Background of the Study

Mental fatigue is generally a psychobiological condition that is caused by increased demand cognitive actions (Hancock & Desmond, 2001), which is characteristically found among the team players of soccer games. For a long time, adverse effects of mental fatigue on soccer performance only existed as an anecdote. For instance, Manchester team manager Roberto Mancini, in an interview with Eurosport TV channel, talked about his worries that his side could fail to obtain silverware due to mental fatigue (Marcora, 2014). On another occasion, one of Germany’s football coaches, Jurgen Klopp,

announced to the media that scrutiny and constant stress were taking their toll on players' performance, but that they do not know the specific method to assess mental fatigue rather than physical tiredness (Marcora, 2014). This was the case until Marcora (2014) found that mental fatigue decreased 15% of running distance in a Yo-Yo soccer specific endurance test. The negative evidence came out strongly among soccer players. The results were further proven by Smith et al. (2015), and later on it was found that the reductions did not only occur in specific endurance performances, but also in technique and decision-making (Badin et al., 2016; Gantois et al., 2019; Smith et al., 2017). Since sports players are bound to being exposed to mental fatigue during games (Russell et al., 2020; Smith et al., 2018), these investigations about mental fatigue and soccer players' performance are important. However, the reasons underlying these reductions are also crucial.

1.1.1 Mental Fatigue, Self-regulation and Athletic Performance

Given the cognitive demand in sport activities, reducing the cognitive load of athletes is of great importance to avoid declines in overall efficiency (van Cutsem et al., 2017; Smith et al., 2018). Many of an individual's "self" activities depend on the same resource pool, just as strength or energy. The executive function of the "self" for example, is responsible to make decisions, initiate and maintain action, and adjust by maneuvering internal states (Vohs et al., 2008). The strength model of self-regulation considers every act of self-regulation, voluntary attention, as well as decision share one resource pool, and that prolonged actions thus leads to a state of fatigue called ego-depletion (Inzlicht & Berkman, 2015). Several works have proven this theory by demonstrating that an act of self-regulation can hinder performance another, but unrelated task (Baumeister, 2002; Baumeister & Vohs, 2016). Muraven et al. (1998) initiated the study and found that after exertion of effort to regulate emotional responses in response to a movie that is upsetting, the performance in another action or task of squeezing a handgrip was measured to take longer, and maximal strength was impaired. Muraven and his colleagues concluded that both physical and cognitive demands require self-regulation. In another experiment, people who ate radishes and resisted delicious chocolates showed shorter persistence time (Baumeister et al., 1998). Thus, this existence of the same resource pool was proved through two irrelevant tasks that required cognitive or/and physical demands (Baumeister, 2014; Schücker & MacMahon, 2016).

One "self" function related to the cognitive activity of directed attention seems to be inevitably needed to maintain performances in soccer (Smith et al., 2018): to be able to ignore irrelevant stimuli (e.g., worrisome thoughts, state anxiety, or clutter) as well as to instead concentrate on the task or action-relevant details of the situation itself (the position of teammates or ball location). Importantly, the implementation of directed attention requires self-regulation (Englert, 2017; Schmeichel & Baumeister, 2010), because it is voluntary and effortful (Yantis, 2009). When resources of self-regulation are depleted (leading to mental fatigue), the players' attention becomes automatically occupied any threatening stimulus that can either be from an external source (e.g., clutter) or from an internal source (e.g., worrisome thoughts or competitive anxiety), which result in less available attention for the actual task, and a decrease in decision-making ability (Fortes et al., 2020; Gantois et al., 2019; Smith, Zeuwts, et al., 2016).

In fact, players in invasion sports (e.g., soccer) should perform in a reciprocal and sequential manner (e.g., controlling the ball following a pass from a teammate), meaning that a phase of play can involve frequent decision-making moments (Araújo et al., 2006; Bennett et al., 2019; Royal et al., 2006). Thus, the capacity to react fast (e.g., defending in a split-second) and accurately (e.g., passing the ball to targeted teammate) is crucial among players. It requires players continually maintain concentration to perceive relevant information in the complex and rapidly changing environment (Afonso et al., 2012). However, as the self-regulatory resource is depleted, mentally fatigued players cannot fully maintain directed attention to ignore irrelevant and distracting stimuli (Giboin & Wolff, 2019; Hagger et al., 2010b). Subsequently, players cannot think one step ahead and find the targeted teammate accurately.

Self-regulation takes place through the interaction of specific structures of the brain, including parts of the frontal cortex, interacting with the central autonomic network in the brain (Julian et al., 2000). Cortical awareness (as a response to information), cortical control of brainstem autonomic centers, and vagal outflow to the heart all contribute to the self-regulation process (Porges, 2001). Heart rate variability (HRV), the difference in heart rate between beats, is one sign of vagal parasympathetic activity (Montaquila et al., 2015). Self-regulation brain structures also govern the nervous system, heart rate variability (or HRV) has been recognized in physiology as a measure of self-regulation ability (Segerstrom & Nes, 2007). Segerstrom and Nes (2007) observed, for example, that state anxiety elicits a sympathetic response, which increases energy consumption, whereas self-regulatory effort elicits restraint, which reduces energy consumption to conserve glucose and other brain resources. In summary, state anxiety decreased HRV, but self-regulation increased it.

1.1.2 Nature Exposure as a Recovery Intervention

Individuals can benefit in various ways from being exposed to nature (Keniger et al., 2013), such as an enhancement in the capability of directed attention (Rogerson & Barton, 2015; Berman et al., 2008), release of pressure (Pilotti et al., 2015), and an improvement of emotion (Kim et al., 2014).

The Attention Restoration Theory (or ART) suggests that directed attention is recharged by interacting with nature (Kaplan & Berman, 2010). This theory separates attention into two primary classes: voluntary and involuntary. The latter is caught by intrinsically intriguing stimuli. Voluntary attention, or better referred to as directed attention, is generally directed by the cognitive control process (Kaplan & Berman, 2010). It comprises conflict resolutions as an individual has to suppress distracting stimuli (see Berman et al., 2008). Indeed, many studies showed that fatigue of directed attention leads to negative effects, decreasing the accuracy and speed of performance (Berto, 2005; Berto, 2014; Ohly et al., 2016; Stevenson et al., 2018), which is in accordance with soccer decision-making. Since mental fatigue is bound to soccer players during games (Russell et al., 2019; Smith et al., 2018), restoring mental resources (e.g., attention and self-regulation) is obviously important.

Notably, when environments that are abundant in fascinating stimuli (e.g., forest, mountain, lake, etc.) stimulate involuntary attention, the executive process regulating directed attention has a chance to rest, and this gives directed attention process replenishment (Berto, 2014; Berman et al., 2008). Therefore, post- interaction with restorative environments (Berto, 2014), an individual can be more able to carry out actions rely on capacities of directed attention (Berman et al., 2008). Moreover, the exposure to nature scenes allows for renewal physiologically, for example, the inducement of the parasympathetic system reactions, which lead to more self-regulation (Berto, 2014). The effects of visual environments during exercise have been found to significantly increase cognitive test scores (see Rogerson & Barton, 2015).

The ART portrays that directed attention and self-regulation shares common resources (Kaplan & Berman, 2010), suggesting that nature can increase self-regulation effectiveness, which in turn suggests that the nature exposure intervention restores the self-regulation resource. Therefore, nature exposure may increase the capacity of self-regulation among mentally fatigued players, and let them better regulate physiological (HRV) and psychological state (competitive state anxiety).

1.2 Problem Statement

While China has displayed significant success at the Olympics, soccer has remained its Achilles Heel (Cui et al., 2021; Kolonko, 2020). When China's national soccer team lost 1-2 to Syria in November 2019, many fans bemoaned the "loss of face" and "shame" that the team brought to China (Cortese, 2019). On the other hand, Japan as the arch-rival of Chinese soccer has enjoyed far greater success.

Surprisingly, Chinese soccer players can compete with other countries' players in terms of anthropometric and physical ability (Tsukoshi & Asai, 2015; Wong & Wong, 2009). On the other hand, mounting evidence shows Chinese soccer players lack the skill and brain ability (Li, 2010; Meng et al., 2015). This is concerning, because skillful performance in soccer requires quick and accurate decision-making, which is the most crucial ability for soccer players (McGuckian et al., 2018; O'Connor et al., 2018; Romeas et al., 2016). Previous studies have used various comprehensive training methods, such as web-based training (Put et al., 2013), small-sided games (Davids et al., 2013), as well as specific activity (Roca et al., 2012), and even the physical status (e.g., hydration, Fortes et al., 2018) to improve decision-making. Specifically, besides traditional training methods, China uses modern technology, such as a video-game-like training program (Thomas et al., 2011). However, Chinese soccer players still cannot perform well in decision-making (Jian, 2010; Yin, 1999).

Importantly, decision-making relies highly on the ability to perceive useful clues from the complex surrounding while blocking out irrelevant distractions in soccer (Baker et al., 2003a; Gantois et al., 2019). For instance, soccer players may need to make a passing or penalty shoot-out decision while under competitive state anxiety and increased heart rate. This process is controlled by directed attention and draws on the limited pool of

self-regulation resources (Furley et al., 2013; Vohs et al., 2008). In short, when self-regulation resources are sufficient, players can better regulate physiological (e.g., heart rate) and psychological state (e.g., competitive state anxiety) while searching for relevant information for making a good decision. However, subjects who are mentally fatigued usually have an insufficient capacity of self-regulation (Hagger et al., 2010; Pageaux et al., 2015). And, recent research has shown that decision-making is significantly impaired by mental fatigue (Fortes et al., 2020; Gantois et al., 2019; Smith, Zeuwts, et al., 2016). Specifically, players constantly exert mental resources (e.g., directed attention) to process a large array of continually changing information: ball location, the position of teammates and opponents (Trecroci et al., 2020; Beavan et al., 2020). This cognitive demand is extremely challenging in a 90 min soccer competition to make accurate decisions under strict time constraints (Thompson et al., 2018; Clemente et al., 2021). Therefore, many studies showed that players likely experience mental fatigue during competition, which contributes to the performance reductions observed in a match (Russell et al., 2019; Smith et al., 2018). Moreover, mental fatigue is also attributed to some pre-game activities, such as education, travel, and pressure (Thompson et al., 2020). Thus, it is important to know how to minimize mental fatigue and improve soccer performance.

Marcora et al. (2009) proposed a psychobiological model to illustrate the adverse effect of mental fatigue on physical performance. It proposes that when the maximal perception of effort meets motivation, performance reductions appear. This was further proved in the sport of soccer (Coutinho et al., 2018; Smith, Coutts, et al., 2016). Therefore, supplements (e.g., caffeine, creatine) that increase mental energy (Kumar et al., 2015; van Cutsem et al., 2020), and extra incentives to increase motivation can effectively attenuate mental fatigue (Brown & Bray, 2017). However, intake of supplements might be less desirable in some specific situations (e.g., stomach upset, Ramadan), and extrinsic rewards can undermine intrinsic motivation (Deci et al., 1999). So, there is a demand to investigate more methods that can attenuate the negative effect of mental fatigue.

Interestingly, nature exposure enhances dopamine transportation (Darna et al., 2015), which leads to improved directed attention and self-regulation resources (Kaplan & Berman, 2010). Consequently, mentally fatigued players may better maintain concentration on retrieving information and block irrelevant stimuli (e.g., competitive state anxiety), and improve their decision-making. As mental fatigue is prevented or minimized, nature exposure is thus a third option that may lead to declines in reduced decision-making. Therefore, this study may use this to expand the psychobiological model, which provides theoretical reasoning to conduct this research.

Furthermore, it seems that nature exposure can be implemented effectively in a short period of time (e.g., 6 minutes) (Chow & Lau, 2015), doesn't demand subjects to have any skilled preparation (e.g., meditation), does not require pricy equipment (e.g., biofeedback), and has been demonstrated to increase self-regulatory capacity and minimize mental fatigue (Birrer et al., 2012; Brown & Bray, 2019). Hence, nature exposure may be commonly used in soccer teams. However, the duration to use to get

the most benefit from nature exposure is still unclear, and warrants more investigations to be determined.

Previous researches have mainly focused on the level of elite players (e.g., Fortes et al., 2020; Gantois et al., 2019; Smith et al., 2017), as they experience extreme pressure coupled with high training and competition demands, and a large potential for mental fatigue exists. Consequently, above 75% performance of decision-making reaction time was influenced by the condition (Smith, Zeuwts, et al., 2016). In addition, the effect of mental fatigue on passing decision-making showed a medium effect size ($d = 0.6$) (Fortes et al., 2019). Nevertheless, compared to elite players, university players not only face pressure from routine training, but also face extra-occupational cognitive load, which is related to school-related stress characterized by exhaustion for schoolwork (Seibert et al., 2016). Consequently, mental fatigue is easily bound to university players, and impair soccer decision-making. Moreover, to cultivate reserved players, Chinese campus soccer has risen to be included in the national strategy (Yang, 2019). So, the investigation of mental fatigue among the category of university players is necessary. Therefore, this study, which aimed to evaluate the effects of nature exposure intervention on the capacity of self-regulation, as measured by the physiological and psychological state among mentally fatigued university players, and to consequently influence their performance in decision-making, needed to be conducted.

1.3 The objective of the study

The research objectives posed in this study all sought to investigate the impact of nature exposure on self-regulation and decision-making among mentally fatigued university players. Specifically, the aims of this research are as follows:

- (i) To evaluate the effects of nature exposure on self-regulation among mentally fatigued players.
- (ii) To evaluate the effects of nature exposure on decision-making among mentally fatigued players.
- (iii) To analyze the effects of different durations of nature exposure on the capacity of self-regulation in experimental groups.
- (iv) To analyze the effects of different durations of nature exposure on decision-making in experimental groups.

1.4 Research Hypothesis

The general hypothesis of the study is:

There is no significant difference on the effect of nature exposure intervention on self-regulation and decision-making in mentally fatigued university soccer players.

The specific null hypotheses associated with the first objective included:

- H01:** There are no significant differences on the value of HRV (physiological self-regulation) between each experimental and control group.
- H02:** There are no significant differences on the score of competitive state anxiety (psychological self-regulation) between each experimental and control group.

The specific null hypotheses associated with the second objective included:

- H03:** There are no significant differences on the score of decision-making accuracy between each experimental and control group.
- H04:** There are no significant differences on the score of decision-making reaction time between each experimental and control group.

The specific null hypotheses associated with the third objective included:

- H05:** There are no significant differences on the value of HRV at post-test between the three experimental groups.
- H06:** There are no significant differences on the score of competitive state anxiety at post-test between the three experimental groups.

The specific null hypotheses associated with the fourth objective included:

- H07:** There are no significant differences on the score of decision-making accuracy at post-test between the three experimental groups.
- H08:** There are no significant differences on the score of decision-making reaction time at post-test between the three experimental groups.

1.5 Significance of Study

The study has some significance in terms of:

(i) Theoretical Contribution

The psychobiological model of exercise performance indicates that the influence of mental fatigue comes from the perception of effort, rather than other psychological and physiological parameters (Marcora et al., 2009). However, perception of effort cannot be the reason to explain the impairment in skilled performance (technical and decision-making skill), for only one study reported that mental fatigue has elevated it to be at a higher level (Badin et al., 2016). On the other hand, mental fatigue activates the brain's anterior cingulate cortex (ACC) and increases the concentration of adenosine. Meanwhile, there is a corresponding decline of dopamine. Moreover, ACC plays a key role in executive functions, especially in enabling focus of attention (Boksem et al., 2005). Importantly, a recent study argued that nature exposure enhances dopamine transportation, restoring directed attention (Darna et al., 2015). Therefore, as the negative influence of mental fatigue is counteracted, nature exposure may lead to a reduction in performance declines. This study tests this unique conjecture that arises in this area. The findings may contribute to this model to explain the influence of mental fatigue on decision-making skill.

Attention Restoration Theory is another theory used in the current study. The theory mainly indicates that attention can be divided into two types: involuntary and directed (voluntary) attention. Natural environments, replete with soft fascination, can attract involuntary attention, simultaneously allowing resources of directed attention to rest and become restored (Berto, 2005; Kaplan & Berman, 2010). Although attention is crucial for sport performance (Mellalieu & Hanton, 2009), ART has not been tested in sports. ART needs to be taken into consideration to increase sport performance by improving decision-making.

(ii) Practical Contribution

The overarching practical contribution of this study is to the soccer team and the coach. The study provides effective methods to minimize the influence of mental fatigue, restore capacity for self-regulation, and improve decision-making among soccer players. Moreover, the current study tested different intervention durations, providing better suggestions and displaying the optimal method to coach or manage a university soccer team.

Another significance of this study is that it fills a practical gap in sports psychology, especially concerning the intervention of mental fatigue on soccer performance. Other studies have thoroughly investigated the effect of mental fatigue on soccer, including physical, technical, and decision-making effects, but without consideration of an intervention to overcome mental fatigue (Badin et al., 2016; Fortes et al., 2019, 2020; Smith, Coutts, et al., 2016; Smith, Zeuwts, et al., 2016). The current study developed

natural photos to enhance the ability of self-regulation (Beute & de Kort, 2014), and suggests the best duration for nature exposure to obtain maximum decision-making among mentally fatigued soccer players.

Therefore, this study provides a unique contribution to the growing body of knowledge and literature on mental fatigue for sports performance. The outcome of this study can also be used practically in soccer teams.

1.6 Delimitation

The study has some delimitations in terms of:

(i) Subject Delimitation

The study recruited male players and excluded female players due to gender differences in responses to cognitive demand (Pereira et al., 2015; Yoon et al., 2009). It's also because campaigns for female university soccer competitions are inadequate compared to those for males in China.

Moreover, the elite level players are also not included —the study only focuses on university soccer players. There are three main reasons: (a) in order to reserve elite players, the program of campus soccer has been raised to a national level status (Xu et al., 2016); (b) university players not only face stress from training and competition, but extra stress from studying (Seibert et al., 2016), which make it easier for them to be mentally fatigued; and (c) previous studies mainly focused on the level of elite players (Fortes et al., 2020; Gantois et al., 2019; Smith et al., 2017). Furthermore, the study also excludes goal keepers. The main reason is because compared to the other players, the goalkeepers have different cognitive activities in soccer games (Schumacher et al., 2018). The same exclusion criteria about goalkeepers were also found in many similar studies (Fortes et al., 2019; Smith, Coutts, et al., 2016).

(ii) Measurement Delimitation

The measurement delimitations are related to physiological self-regulation, and the inducement of a mental fatigue condition. Regarding physiological self-regulation, it was only measured by HRV. There are also other physiology indicators that can be measured, such as skin conductance and respiration rate. However, it is widely accepted by many studies that self-regulation is highly associated with physiological changes in the parasympathetic nervous system activity and that vagally facilitated HRV serves well to index the brain structures' functional capacity that are supporting the efficiency of cognitive actions (Brown et al., 2012; Evans & Segerstrom, 2017; Reynard et al., 2011; Segerstrom & Nes, 2007). Therefore, the HRV is used in the current study.

In addition, the successful inducement of mental fatigue is only measured subjectively. Indeed, there are also cognitive and objective indicators for mental fatigue. However, three different measures (subjective, cognitive and physiological indicators) do not have to be presented simultaneously (van Cutsem et al., 2017). Also, subjective measurement is the most reliable indicator, for it comes before any decrease in performance (Kanfer, 2011, as cite in Smith et al., 2019). Particularly, the subjective indicator of mental fatigue appears to be an effective instrument and has been widely implemented (Badin et al., 2016; Smith, Coutts, et al., 2016; Smith et al., 2017), for its minimum time requirements and easy interpretation (Christodoulou, 2005). Therefore, the current study employed a subjective indicator to measure mental fatigue.

(iii) Intervention Delimitation

The nature exposure is an intervention for recovering and enhancing the strength of self-regulation. However, there are some other methods which can improve the ability of self-regulation. The current study discussed all methods according to the components of self-regulation. Compared to other methods, nature exposure needs less expenditure and time, and it is more suitable to implement in the soccer context, which involves an open-skill sport (see details in the section of chapter 2: 2.5.1 Overcoming Mental Fatigue with Self-regulation). Therefore, the current study used nature exposure intervention to increase self-regulation.

1.7 Limitation

Limitations are potential influences that are not controlled or can also be the outcome of the restrictions enforced by an investigator (see Thomas et al., 2011). Although this study has carefully considered details put into its design and execution, as with all studies, it is still imperative to highlight potential limitations.

Firstly, there are limitations related to the instrument employed to induce the condition of mental fatigue, which is a prolonged computerized Stroop task (45 min). Several studies have employed this Stroop task to induce mental fatigue (e.g., Badin et al., 2015; Smith et al., 2016; Smith et al., 2017; Gantois et al., 2019). However, players are usually not involved in this task before training or competitions. Overall, there are three reasons to recruit Stroop task to induce mental fatigue for soccer players.

- (i) A systematic review (the effect of mental fatigue on skilled performance in all sports) is included in the current study (see the section 2.2.4). It shows that Stroop task is the most common and reliable method to induce mental fatigue for players in sports (see Appendix A: Table 2).
- (ii) Players should exert cognitive demands (inhibition and sustained attention) in Stroop task. These demands are also similarly present in soccer players during their games (Smith et al., 2018). For example, players should exert inhibition frequently to suppress an ongoing action since they perform in a rapidly-occurring changing environment. Moreover, players must maintain

attention on relevant information in a long period (90 min). Thus, Stroop task is quite similar as the actual scenario among soccer players.

- (iii) Martin (2016) argued that in order to investigate effects of mental fatigue on a subsequent performance, the condition of fatigue must be experimentally-induced. The current study examines the potential intervention to counteract mental fatigue. Thus, in order to induce mental fatigue, Stroop task is recruited, which is the most reliable method and can facilitate the purpose completed in the current study.

Secondly, there is a limitation regarding the stimuli materials of intervention. Considering the age of the stimuli material and to maintain the efficiency of the nature exposure intervention. The current study recruited restorative environment, which is developed in recent years (from an outdoor photography course in Zhongyuan University of Technology). However, due to the Covid-19 situation, the researcher could not get photos from an urban environment for the control groups. Therefore, the researcher employed the urban photos from Berto (2005) to compare to nature stimuli in the current study. The urban photos are old. There are three reasons to use these stimuli material from Berto's (2005) publication:

- (i) Berto's (2005) publication is based on a well-done and well-recognized study with the highest citation (e.g., Google scholar: 1015, October 2020) in terms of viewing virtual nature photos. This study is the first to prove that restoration of directed attention can be done by virtual pictures of nature, thus demonstrating the ART from a special perspective. Steven Kaplan, the father of the ART, was enthusiastic about this achievement. He wrote to Berto about her 2005 article: *Dear Rita, [...] Congratulations! It is a solid and important contribution to the literature on restoration. [...] as you can see, it has already made a difference here at the University of Michigan, and I suspect it will continue to make difference for a long time to come (personal communication, email from Steven Kaplan, received on January 26, 2006)* (Berto, 2020, p. 1). These confirmations provided assurance to select Berto's method for this study.
- (ii) The stimuli material still works according to a suggestion from Berto: *"sorry if picture quality is sometimes low, originally a few of them were images from magazine then turn into slides to be projected and finally into jpg files. Long story. Anyway, they still work"* (personal communication, email from Rita Berto, received on October 8, 2020).
- (iii) The most recent study in this field also recruited these stimuli materials (see: Hicks et al., 2020).

1.8 Definition of Terms

The research variables are defined in terms of conceptual and operational aspects. Listed below are the terms and their definitions:

1.8.1 Nature Exposure

Conceptual Definition: Nature exposure is a “direct physical or sensory contact with the natural environment” (Kamitsis & Francis, 2013).

Operational Definition: A series of methods that let subjects immerse in the nature scenes of photography that have fulfilled some specific criteria to benefit the psychological state.

The methods include the environment to use during viewing virtual nature pictures (e.g., dimming the light and avoid noise, making subjects fully focus on nature scenes). Moreover, the duration of viewing virtual nature pictures is extremely important, as the time attained to rest the capacity for directed attention during viewing of nature pictures determine the efficacy of the intervention. The specific criteria of the nature photos are determined by the definition of nature scenes (for details see 3.3.4 Development of Stimuli Material).

1.8.2 Mental Fatigue

Conceptual Definition: Mental fatigue as a fatigue condition, generally induced by increased demand of cognitive actions, which usually recognized as a complex phenomenon of psychophysiology (Desmond & Hancock, 2001).

Operational Definition: A state of acute rising in subjective rating of fatigue, induced by a 45 min computerized Stroop task, and measured by a 100 mm visual analogue scale. The Stroop task require subjects to perform sustained attention and inhibition control (Rauch & Schmitt, 2009), which should also be utilized in a soccer competition. However, sustained attention and inhibition control can be exhausted by prolonged performance. This exhausted condition is mental fatigue, impairing subsequent soccer performance (e.g., decision-making).

1.8.3 Decision-making

Conceptual Definition: The ability of the human brain to identify useful clue from the surrounding, precisely interpret the clue, then choose proper motor responses (Baker et

al., 2003b).

Operational Definition: The cognitive operation of selecting the most appropriate reaction from a range of available responses in sport circumstances, when an action is needed (Araújo et al., 2006), especially within the constraints of a certain response time limit. The performance is measured by an online system (TacticUP). The accuracy and reaction time is recorded.

1.8.4 Self-regulation

Conceptual Definition: Self-regulation is recognized as an ability to modulate an individual's behavior, emotion and thought voluntarily or involuntarily (Karoly, 1993), e.g., inhibition (Ridderinkhof et al., 2004).

Operational Definition: Self-regulation is a widely applicable idea that was proposed early on during the progression of sport psychology to be a vital element in sport performance (see Englert, 2016). Particularly, when considering athletic outcomes, self-regulation is the ability to adjust physiological and psychological state adaptively to the specific context (e.g., soccer) (Baumeister & Vohs, 2016; Nigg, 2017).

In the current study, HRV and competitive state anxiety (CSA) are indicators of this physiological and psychological state, respectively. When players have sufficient ability for self-regulation, they can modulate their attention better. Also, they can manage their condition better (e.g., lower stress) to adapt to a soccer competition.

1.8.5 Soccer Player

Conceptual Definition: A soccer player is a person who plays soccer, especially as a profession ("Football Player", 2021). Usually, eleven players are organized to be a team that aim to move the ball up the pitch and beyond the goal line of the opponent's goalpost.

Operational Definition: A soccer player who has more than 3 years training experience in a university and played at least once for the university in a season at province level. Concurrently, they are also students that take normal courses in the university. Moreover, in the current study, it only indicates players who can play as defender, midfielder and forward. It does not refer to the goalkeeper.

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