

Review Article

Mindfulness Training Improves Sport Performance via Inhibiting Uncertainty Induced Emotional Arousal and Anger

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Abstract

Mindfulness training has gained popularity in the scientific field, and has been proposed as an efficient psychotherapy for affective disorders. Mindfulness training requires the individual to pay attention to the good things that are happening “right now and here” and neglect the nervous uncertainty. Uncertainty (un-expectancy) plays a critical role in inducing stressful emotions during sport games, and mindfulness training is especially useful in calming the body peacefully for the athletes. In this paper, we will review experimental studies and propose theoretic speculations concerning uncertainty and emotional arousal during sport games. We first analyzed the effects of emotions on sports according to two dimensions (arousal and valence), next we analyzed the effects according to our previous three-primary-color emotional theory, which suggested that there are three prototypical emotions (Joy, Fear and Disgust). In addition, we proposed that anger might be the only basic emotion that can only be evoked by others' behavior responses and directly affect sport performance. Furthermore, we proposed that emotional arousal activates the sympathetic and norepinephrine system, while mindfulness activates the para-sympathetic and dopamine system. Therefore, mindfulness will activate the neural systems that are totally different from or contrary the emotional arousal systems to induce peaceful mind. This review will contribute greatly to theoretical and empirical explorations of emotional regulations with mindfulness during sports.

Keywords: Emotional arousal; Valence; Sport performance; Anger; Basic emotions; Uncertainty; Mindfulness; Sympathetic system; Parasympathetic system

Introduction

It is widely accepted that emotions impact an individual's ability to perform in an athlete performance [1]. In the field of sport psychology, the predominating explanation for the influence of anxiety on sport performance has been the Inverted-U hypothesis, which is originally intended to describe the effects of emotional arousal on sport performance [2]. Even though this theory is essentially true, problems are arising in that it did not pay attention to the individual difference. Thus alternative theory, referred as individual zones of optimal functioning theory, suggested that each athlete has different expectation about the situation, thus possesses different range of emotional anxiety at the same situation [3]. In addition, emotions with different valence might have different effects on sports with different arousals, and it is suggested that positive emotions are largely facilitative to an athlete's performance, while negative emotions can impair performance [4]. Thus a clear understanding of

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the emotions is critically important to understand different emotional stimuli on the sport performance. This study will review recent advances about prevalent theories about emotions in last decades, and propose a possible systematic analysis of emotions on sport performance.

Recently, mindfulness training has gained popularity in the scientific field, and has been proposed as a common factor across all schools of psychotherapy. Mindfulness, which is the heart of Buddhist meditation, have given rise to many different mindfulness training programs, but all have the same way of focusing to present situations with an accepting attitude [5]. Mindfulness is characterized by sustained moment-to-moment attention to the present situation, including continuous immediate attention to physical sensations and affective states, with dispassionate non-evaluative and perceptible mental states [6]. Over the past 20 years, majority of studies have focused on clinical intervention to evaluate the efficacy of mindfulness-based interventions, such as the mindfulness based stress reduction program. Recently, mindfulness has been widely accepted and employed in different fields to cope with normal or significant stresses of daily life as well as sport games [7]. The more popular the mindfulness training in our lives, the more curious we are thinking about the underlying physiological and psychological mechanisms of mindfulness training. However, studies about the underlying neural and emotional

mechanisms during sports are lacking. Mindfulness training is sure to affect the nervous system and physiological processes, and these studies can develop into a new field-mindfulness neuroscience to probe into the neural networks and neurotransmitters/ hormones involved in mindfulness training [8]. Some studies found that mindfulness training can activate autonomous emotional regulation, inhibit the sympathetic system, and activate the parasympathetic system [5], in contrast, emotional arousal has been proved to activate the sympathetic system [9]. Thus, this paper will specially analyze the effects of mindfulness on emotional arousal during sport.

Basic Emotional Theory and Dimensional Theory

Emotions are internal states evoked by external stimulations, and characterized by induced physiological changes (mostly neuromodulator release), and response behaviors. Emotional studies in the last decades are prevalent with two contradict theories: dimensional theory and basic emotional theory. The dimensional theory suggests that emotions are continuously distributed in a quadrant which is composed of two dimensions (arousal and valence). And the basic emotional theory suggests that emotions are composed of a limited number of independent basic emotions. Some psychologists suggested it is a long-time war between the dimensional approach and basic emotions.

Dimensional emotional theory originated from Wundt [10], who proposed that emotions can be defined by three-independent dimensions: unpleasant-pleasant, calm-excitation, relaxation-tension [11]. Later, many psychologists found that two-dimensions (unpleasant-pleasant and tension-calm) are sufficient to define the difference among emotions. For example, Russell [12] proposed that all emotions can be arranged in a circumplex, which is anchored on a quadrant defined by two independent dimensions: hedonic (unpleasant-pleasant) and arousal (calm-tension) (Figure 1) [13]. The two dimensions are refixed on two features of stimulations: 1) whether they fit into our physiological needs (liked-disgust); 2) whether they happen as expected (Figure 1). In face of the external stimulation, we will get the sensational emotions: if it fits into our physiological needs, we will have the happy feeling; if not, we will have the disgustful feeling; this is reflected on the horizontal dimension (hedonic valence). If the stimulations happen as expected, we are clam; if the stimulations happen as un-expected, we will be aroused; this is reflected on the vertical dimension (emotional arousal) [14]. The vertical dimension can be named arousal and energy; while the horizontal dimension can be named valence or hedonic dimension [15]. Hedonic value and arousal are two core features of human emotions, and constitute the two dimensions of emotional quadrants (Figure 1). The different location of emotions in the quadrant represents different

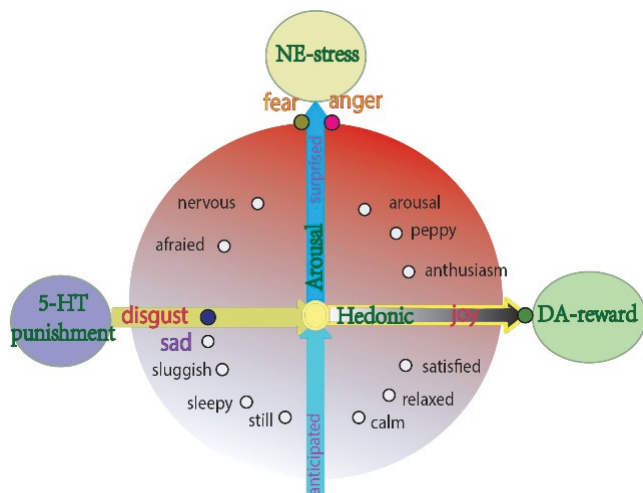


Figure 1: Circumplex model of emotion. Circumplex model proposes that all emotions can find their locations on a circle which are defined by two dimensions. The two dimensions represent two features of stimulus: whether it is our liked or disgusted; whether it happens expected or unexpected. These two features can also be named as: the safety value of the stimulus and the hedonic value of the stimulus. Different locations of emotions on the circumplex mean that different emotions have different amounts of arousal or hedonic parameters. On the dimensions, we also located the basic emotions: the three basic emotions that located on the poles of the dimensions represent three most prototypical emotions: joy, disgust and fear.

amounts of arousal and hedonic properties, which are named arousal dimension and hedonic dimensions [16,17].

Basic emotion theory proposes that there are a limited number of basic emotions (e.g. fear, anger, joy, sadness) [18], which are proposed to be biologically and psychologically “basic”, and each emotion has its own distinct neural circuitry [19]. However, even though most psychologists agree upon the idea of basic emotions, they cannot agree upon the number of basic emotions.

Three primary color model of basic emotion: We proposed an integrative model of basic emotion and dimensional theory. We hypothesized that basic emotions should also be able to find their locations on the quadrant if all emotions can find their locations on the dimensional quadrant (Figure 1) [20]. The specialty of basic emotion is that they locate on special locations on the quadrant (the pole of the dimensions): joy represents the positive hedonic valence, disgust (sadness) represents the negative valence, and fear represents the highest arousal. So there might be only three basic emotions: joy, disgust and fear, which might be called three primary color model of basic emotions. The three dimension poles can also be called three core affects (reward, punishment and stress), which are subsided by three monoamines [21].

Uncertainty Induces Emotional Arousal

There is an increasing interest in uncertainty and its role in affective disorders, which broadly refers to response to uncertainty at cognitive, emotional, and behavioral levels [22]. Existing literature surrounding uncertainty confirms that uncertainty is a critical feature of stimulation that induces emotional arousal; however, little is known about its exact nature. At an uncertain situation, we humans usually have a safety check with the situation, similar to Lazarus’s primary appraisal [23], the individual will consciously compare the situation with his own ability to see if he can cope with the situation. Uncertainty (un-expectancy) can induce fear and anger emotions, or initiate fight or flight behaviors [24]. As we suggested before, the arousal is reflected on the vertical dimension that is due to the unexpected way something happened, and is related to the arousal state of the body, so it is called arousal dimension. Consistently, it is proposed that the function of arousal is to detect potential threats [25].

Many previous studies showed that uncertainty is highly associated with emotional arousal [21], the vertical dimension of the emotional quadrant. According to the integrative definition of emotions, uncertainty can induce emotional arousal, fear and anger emotion as well and anxiety that is about uncertain future events [26]. Definitions of uncertainty and anxiety showed that they both share many common features regarding future uncertainty and uncertainty-induced maladaptive responses. Researchers have investigated the

relationship between uncertainty and emotional arousal, and found that uncertainty was highly related to panic sensations and anxiety [27].

Uncertainty Emotions in Sport Games

Emotion arousal in sport games

Uncertainty induced emotional arousal plays a pivot role in athlete performance. For example, uncertainty impairs our ability to prepare for the game, thus contributing to fear, anxiety and worry. The uncertainty about what event will occur before its final onset contributes to feelings of distress and worry. Uncertainty is threatening and dangerous; therefore, we have to be alert. However, the literature review provides theoretical explanations for the popular, common-sense belief that a little stress improves performance, whereas when severe stress impairs performance. Many studies suggested that increases in adrenaline and noradrenaline accompany a variety of emotional arousal, and induce “fight or flight” response [9]. Thus emotional arousal or fear and anger emotions can increase sport performance merely by “getting the adrenaline flowing”. However, the accompanying physiological and metabolic responses facilitate performance to a point [28], and extremely high levels of arousal may adversely affect the athlete’s proficiency, this is especially true for the sports that requires skills in steadiness, precision, and concentration [29]. In addition, it is found that the effects of catecholamine depend on the skills: if the entire ability range is high, adrenaline and arousal can increase the performance in sport. This is consistent with the proposal by Lazarus, that the individuals will show angry response with sufficient resources, but show fear response at insufficient RESOURCES [23].

Emotion valence in sport games

Recent theories about the relation between emotion and sport performance showed that sport performance is not only affected by emotional arousal, but also affected by emotional valence. People tend to be more affected by negative stimulation, and try to ignore loss, which is called loss aversion in the economic behaviors. An extensive review by Baumeister [30] suggested that negatively valence emotions occupy more mental resources, and thus might increase the reaction times in sports. Social behaviors during sport are influenced not only by the emotional experience, but also by the anticipation [31]. The valence of future-oriented emotions or anticipatory positive emotions, such as enjoyment, pride, and satisfaction, may help exercise behavior. While negative valence emotions, such as fear, disappointment can impair sport performance [32].

Basic emotions in sport games

Even though most psychologists agree upon the idea of basic emotions, which suggested that there are a limited

number of basic emotion. However, few people agree upon the number of basic emotions, for example, Ekman suggested that there are 7 basic emotions (joy, anger, sadness, fear, surprise, contempt and disgust). Jack et al. [33] suggested that there may be 4 basic emotions (joy, anger, sadness and fear). Like the primary colors, Newton first proposed 7 basic colors, and finally it comes to three primary color, because physiological studies found that there are only three kinds of conic visual cells in the eyes. We also proposed three prototypical emotions: joy, disgust and fear (Figure 2) [34,35]. Indeed, at the sensation level, there are really only three basic emotions, which might be called prototypical emotions for they are the emotions at the sensation level, like the sense for cognition. They are due to the sense of physical properties of stimulation; instead anger cannot be evoked by physical properties of stimulation, and it is evoked by somebody's behavior. We tried to use pictures from the International Affective Picture System to evoke anger, but failed; for most the pictures cannot evoke anger emotion except a few pictures with somebody's behavior. We found that anger is the only one emotion among Jack's 4 basic emotions that is related to behaviors [36]. People never feel angry at seeing an object, instead people can only feel anger at somebody's intentional blocking of an effortful behavior. Thus anger might be the only emotion that can affect sport performance.

Anger is an emotion when one's goals are perceived to be intentionally blocked, and try to fight against these unexpected bad things, which is a common phenomenon during sport games [37]. It is found that anger can induce stronger gross muscular peak force performance, while happiness did not influence sport performance [38]. However, hope or motivation does yield faster soccer-related reaction times in soccer players. As shown in Figure 2, we propose that anger is due to a combination of fear and disgust, while hope/motivation is due to a combination of fear and likeness (joy), which suggested that anger is often evoked by unexpected disliked (negative) stimulation, while motivation is due to unexpected liked (positive) goals. However, there are other reports that anger can impair performance [39], thus the effects of anger on performance might be a U-shape. Alternatively, it is related to the skills or strengths, for example, anger really improve exercise performance, particularly for the slower runners [40].

Monoamines and sport performance

If it was not for the physiological finding that there are only three kinds of conic visual cells in the eyes, we would never find that there are only three kinds of basic emotions. Similarly, people are trying to find the neural proof for basic emotions. Many studies tried to find the neural basis for basic emotions with neuroimaging, however the results are quite controversial, which leads some psychologists suspect the theory of basic emotions [41]. However, we proposed that the

neural basis for emotions might not be the specific domain in the brain, instead it might be the neurotransmitters [20,21]. The neural basis of monoamine transmitters for emotion has been a long time since the 50s in last century [42], and the first-line antidepressants are still focusing on enhancing monoamine neurotransmitters. Our 'Three Primary Color Model of Basic Emotions' fully supports the theory of monoamine transmitters, and here we try to see the altered monoamine neurotransmitters during emotional arousal at sport games.

Norepinephrine, serotonin and anxiety

The function of Norepinephrine (NE) and sympathetic system has long been suggested to be involved in "fight-or-flight" behavior, and we have also suggested that they are the neural basis for fear and anger [9,43]. In the field of sport psychology, the predominating explanation for the influence of emotional arousal (fear and anger or anxiety) on sport performance has been the Inverted-U hypothesis, which means low or too high emotional arousal can induce poor performance. However, anger is the only basic emotion among the four basic emotions (fear, joy, sad and anger), that is specially evoked by others' behavior, and it might be the major emotion that can affect behaviors during sports (Figure 3). Anger might be the only way for the individual to fight against the environment, or anger might be the only emotion that can induce behavior for the individual to cope with the situation. Anger is often evoked by unexpected negative stimulation (disgust), or angry behavior is induced by a

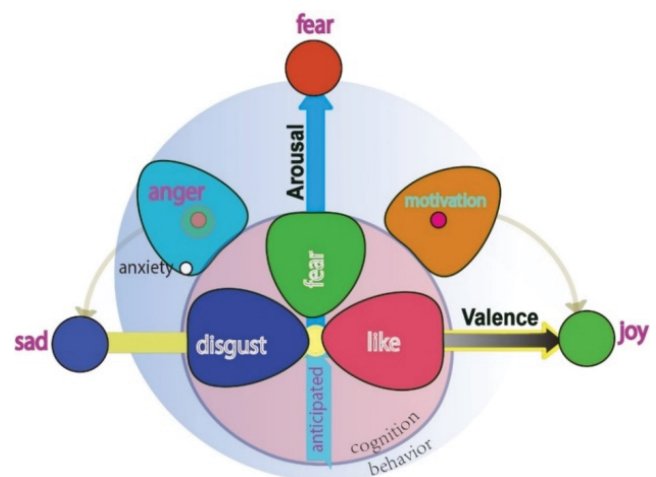


Figure 2: Three primary color model of basic emotion in cognition and behaviors. A schema shows different levels of emotions: at the sensation level, there are only three primary color model of basic emotion and their locations on the dimensions. They are the most primary emotions, like the senses for the cognition level, so there can be called three prototypical emotions. At the higher behavior level, there are only one basic emotion anger. At even higher subjective feeling level, reappraisal can induce three basic emotions: joy, sadness and fear [36].

combination of disgust and fear. So the monoamines involved in anger might be serotonin (5-HT) and NE. The function of 5-HT is related with sedation or behavioral inhibition, which is similar to prolonged helpless state during depression. Anger is evoked by somebody’s intentional blocking of an effortful behavior. Physiological arousal is an important feature of anger, which can be assessed with autonomic nervous system activity. Heart rate and respiratory rhythm are positively related with angry levels (e.g., Luecken and Appelhans [44]). As Lazarus [23] suggested, the resources is important in choosing fear or anger, indeed self-concept was negatively correlated with fear and positively with angry emotions [45].

Dopamine, Norepinephrine and motivation

Unexpected positive stimulation can induce motivation to strive with efforts to gain a goal, which is a combination of prototypical emotions (fear and joy), requires the underlying substrates are Dopamine (DA) and NE. Many studies have found that NE inputs from Locus Coeruleus (LC) into VTA have been shown to modulate VTA neuronal activity, and are implicated in motivation. Indeed, phasic LC activity are involved in decision making, motivation and attention, in contrast, pharmacological inhibition of NE signaling in VTA specifically attenuates goal-seeking behavior. In all, the Catecholamines (CAs) including Dopamine (DA), Norepinephrine (NE), and Epinephrine (E), are the principal neurotransmitters that mediate a variety of motivational functions (Figure 3) [46].

In a multivariate model, the statistically significant variables were the presence of one or more previous injuries (OR 2.30; 95% CI 1.56-3.39) and the presence of a current injury (2.09; 1.24-3.51). BMI, weight, height, as well as years of experience were not associated with a significantly increased risk of sustaining an injury in our cohort.

Mindfulness and Sport Performance

Increasing the mental aspects of athlete health and athlete well-being is attracting more attention than the traditional physical interventions to promote athlete health and performance. Recently, mindfulness meditation has been shown to enhance athletic performance, improve athlete mental health and reduce injury risk [47]. Mindfulness training has garnered much support in enhancing sport performance via paying attention to breath and focusing attention to the present with non-judgmental thoughts [48-50]; and mindfulness-based training programs have been highly established for competitive and recreational sports [51]. Mindfulness might increase athletes' attention, and improving working memory [47]. In addition, mindfulness levels have been suggested to mediate anger and anxiety [37].

Mindfulness reduces emotional arousal

As the sport medicine moves towards the mental health with mindfulness, it is critical to understand the respective and interactive contributions of autonomic arousal and cognitive bias to anxiety [52]. It is really the case that we are specifically interested in probing in the relationships between mindfulness in inhibiting sympathetic, rather than parasympathetic system. Mindfulness induced sport-confidence and attention by positive reappraisal has been proved to be useful, and might be a potential tool to improve sport-confidence or develop a positive orientation to arouse excitement [54]. In addition, mindful reappraisal after coping has been shown to be an effective strategy during stress to reduce anxiety. Anxiety is a kind of distressing, disabling mental health problem for athletes (up to 25%; [54]), which is characterized as hyper-reactivity to environmental stimuli (e.g., Daleiden and Vasey [55]; Field and Lester [56]). Mindfulness is effective in reducing anxiety, and diminishing sympathetic activity, improving parasympathetic functions.

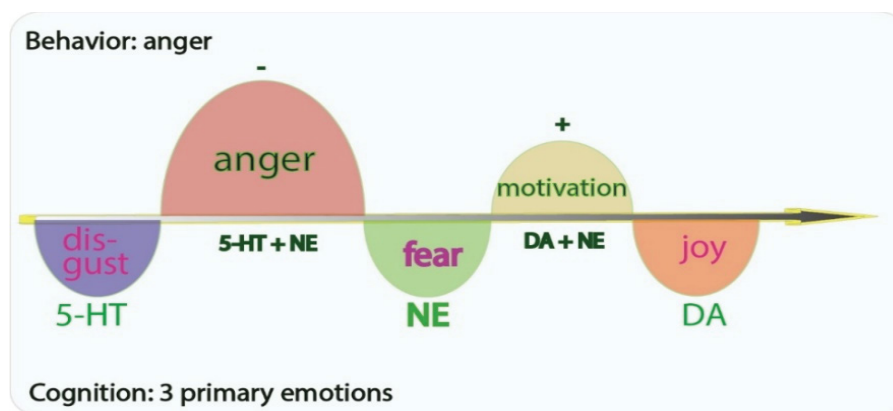


Figure 3: Linear model shows three primary color model of basic emotions. The model shows that there are three prototypical emotions, like the primary colors, which are subsided monoamine neuromodulators (DA-joy, 5-HT-disgust, NE-fear). At the behavior level (sport), anger is the only basic emotion, which is induced by disgust and fear. Anger might be the major impacting emotion for sport games. Motivation is a kind of behavior that is due to positive stimulations.

It has been reported that anxiety can induce autonomic nervous system hyper-arousal, including elevated resting heart rate, increased sympathetic activity during stress, and impaired autonomic recovery following stress [57-61]. Other investigations have found that targeting thoughts and feelings in mindfulness training clearly specify blocks the development and maintenance of anxiety over time.

Mindfulness enhances parasympathetic activity

Mindfulness has been proved to be a widely accepted stress-reduction intervention due to its ability to promote Parasympathetic Nervous System (PSNS) dominance [62]. Mindfulness is associated with reduction in emotion arousal and improvements in attitude, health-related behavior and coping skills [63]. Several studies have evaluated the role of mindfulness-based stress reduction, and found that it increased parasympathetic activity with reduction in sympathetic vascular tone, enhancing blood flow and breathing depth. In addition, mindfulness can induce DA in the striatum has been proved to be the major substrates for motivation [49]. Indeed, mindfulness can activate the central nervous system, such as the anterior cingulate, striatum, and acumen nucleus, especially the rewarding dopaminergic center [64]. In addition, it is reported that arousal reappraisal can induce more positive interpretations of physiological arousal and anxiety, which can break the connection between physiological arousal intensity and physiological arousal interpretation [65].

Mind the breath and mind the steps: Thus mindfulness training should be an important aspect of training for athletes, not only training the attention to be focused on the present, but also training the body. We suggested that every movement can be divided into two steps: 1) taking in breath and preparing for the movement; 2) the movement itself. The eastern culture has been using meditation or Taichi to train the first step, and has got very good results in many aspects of lives, including sports. But there is almost nothing for this kind of training in the western culture. Recently, many people have adopted some ways of Chinese traditional medicine, such as acupuncture or “Baguan” to train athletes, we hope that the mindfulness training with “minding the breath” should be used in training athletes.

Conclusion

Many recent studies have probed into the effects of a mindfulness-based intervention on athletic performance, and have provided preliminary evidence to support the idea that mindfulness could serve as a promising form of training for fine motor sport performance [66]. In this paper, we reviewed recent studies concerning the effects of mindfulness on cognitive uncertainty and emotional arousal during sport games. We analyzed the relation between emotions and sports according to recent emotional theories, including

dimensional theory and three-primary-color emotional theory. We proposed that there might be three basic emotions, which include joy, disgust and fear. Anger is not a prototypical emotion for it is the major emotion that depends on behavioral responses. Furthermore, we proposed that emotional arousal activates the sympathetic and norepinephrine system, while mindfulness activates the para-sympathetic and dopamine system. Though most of these studies used short duration, mindfulness training strategies can be useful techniques to modify lifestyle and help improve sport performance, we hope this review will shed light on the theoretical and empirical explorations of emotional regulations with mindfulness during sports [67-69].

Innovative preventive and educational strategies are required in this growing population. Multidisciplinary programs including nutritionists, physiotherapists, sports psychologists, and coaching staff support (i.e. modified or adapted training programs, development of injury surveillance systems) should be developed. Specific attention to head injuries prevention through modified teaching techniques is mandatory. New studies are required to measure the impact of these programs.

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