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Where's the Emotion? How Sport Psychology Can Inform Research on Emotion in Human Factors

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Objective: The aim of this study was to demonstrate how research on emotion in sport psychology might inform the field of human factors.

Background: Human factors historically has paid little attention to the role of emotion within the research on human-system relations. The theories, methods, and practices related to research on emotion within sport psychology might be informative for human factors because fundamentally, sport psychology and human factors are applied fields concerned with enhancing performance in complex, real-world domains.

Method: Reviews of three areas of theory and research on emotion in sport psychology are presented, and the relevancy of each area for human factors is proposed: (a) emotional preparation and regulation for performance, (b) an emotional trait explanation for risk taking in sport, and (c) the link between emotion and motor behavior. Finally, there are suggestions for how to continue cross-talk between human factors and sport psychology about research on emotion and related topics in the future.

Results: The relevance of theory and research on emotion in sport psychology for human factors is demonstrated.

Conclusion: The human factors field and, in particular, research on human-system relations may benefit from a consideration of theory and research on emotion in sport psychology.

Application: Theories, methods, and practices from sport psychology might be applied usefully to human factors.

Keywords: motor control, motor planning, risk taking, self-regulation, trait

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INTRODUCTION

The mission of this article is to propose how research on emotion in the field of sport psychology can inform the field of human factors (HF), which historically has paid little attention to the role of emotion within the research on human-system relations. The ISI Web of Science database reveals that this journal has published 2,957 articles since 1958. In searching the titles of these articles, only 3 articles were found containing a derivate of the word stem *emot* or *affect* as their meaning relates to emotion (hereafter the "emotion-and-affect" articles). In addition, only 12 of the article titles contained one or more of the 135 different emotions, such as annoyance, presented by Shaver, Schwartz, Kirson, and O'Conner (1987; hereafter the "Shaver" articles). The 50th anniversary issue of the journal (2008, Volume 50, Number 3) constitutes a recent review of the journal's content to date. Of the 34 articles within the issue, only 5 contain a derivate of the word stem *emot* or *affect* as their meaning relates to emotion within the article text, excluding the references. Derivatives of the word stem *emot* or *affect* do not appear in the titles and descriptions of the 22 technical groups of the Human Factors and Ergonomics Society (HFES; see www.hfes.org) nor in the 18 topic titles proposed to represent "the entire HF/E (HF and ergonomics) domain" and under which an article can appear in this journal (Howell, 2008, p. 357). The topic category within this journal that is most closely aligned with emotion is psychological states. Of the 612 articles published in the journal since 2000, 15 appeared within this topic category. Of these, only 7 contain a derivate of the word stem *emot* or *affect* as their meaning relates to emotion within the article text, excluding the references (hereafter the "psychological-states" articles). (Searches were undertaken February 15, 2010.)

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One potential explanation for the lack of consideration of emotion is that HF researchers do not believe that emotions are an important "human factor" with regard to human-system relations. However, this explanation is undermined by the number of articles in this journal on a closely related concept: stress. The ISI Web of Science database reveals that this journal contains 45 articles with derivates of the word stem *stress* in the title. Of these, 40 relate to psychological stress (hereafter the "stress" articles). A more likely explanation is the field's ancestry in industrial engineering and experimental psychology, which has involved a predominant focus on perceptual and cognitive mechanisms. As Szalma (2009) proposed, the general trend within HF "has been to represent the human as a 'black box' of general cognitive mechanisms, while affective traits and states have been relatively neglected" (p. 382).

In contrast to articles on emotion, this journal contains 121 articles with derivates of the word stems *percept* and/or *cognit* in the title. Of the 34 articles in the 50th anniversary special issue, 30 include derivatives of *percept* and/or *cognit* within the body of the article text, and derivates of *percept* and *cognit* appear in the title of, and/or brief description provided for, 3 of the 23 HFES technical groups. Although derivatives of one of these word stems occurs in only 1 of the 18 journal topic titles (sensory and perceptual processes), at least one of them appears in the body of the text of all of the 14 articles published since 2000 in the psychological states topic category. (All searches were undertaken February 15, 2010.)

The narrow focus on perceptual and cognitive mechanisms within HF means that many important human factors related to emotion have been overlooked. One set of factors relates to *incidental emotions* (cf. Blanchette & Richards, 2010): emotions that are not evoked by the current interaction of the operator with the work system but instead are "carried over" from prior experiences and/or system interactions. Although such emotions are inherently unrelated to the task at hand, they are likely to affect current task performance and work in general. For example, for a financial trader, anxiety experienced during a confrontational team meeting may subsequently affect his or her ability to integrate sources of financial information from multimonitor display systems. A general finding of research on the effects of emotion on cognitive processes is that negative emotions narrow thought-action repertoires and promote referential processing, whereas positive emotions, such as happiness, have the opposite effect (e.g., Clore & Huntsinger, 2007).

These effects create two challenges for HF. First, systems must be designed to accommodate the effects of incidental emotions on operators' attempts to interact with them. For example, Norman (2004) proposed guiding principles for designing systems robust to the effects of operator anxiety, which included ensuring that all task-relevant information is continually at hand and readily visible and providing clear and unambiguous feedback about the system's operations. Second, systems might be designed so they not only accommodate these emotions but proactively address them (Whang, Lim, & Boucsein, 2003). If systems could sense or anticipate emotions, they could respond in ways that limit the detrimental effects of emotions on task performance and promote emotions that facilitate performance. For example, in-vehicle alerting systems that identify visual and cognitive driver distractions (Shinar, 2008) could identify changes in emotions such as anger, which affects driving safety (Matthews et al., 1998), and respond by suggesting cognitive-behavioral strategies known to have countering effects (cf. Whang et al., 2003).

A second set of emotional factors that should be considered by HF researchers relates to *integral emotions* (cf. Blanchette & Richards, 2010): emotions evoked through interaction with the system. Systems should be designed to "evoke target feelings" that facilitate task performance (Kim & Moon, 1998, p. 1). For example, trust is a key barrier in the use of online banking systems, but Kim and Moon (2004) reported that the trust users felt in such a system could be enhanced by changing the system interface from warm primary colors to cool, moderate pastel colors. The unintended negative consequences of poor design on emotions should also be considered. For example, how are emotions affected by system designs that lead to utterances such as

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"How do I stop this machine from doing this?" (Trimmel, Meixner-Pendleton, & Haring, 2003; Woods & Sarter, 2000, p. 239).

In summary, research on emotional factors affecting human-system relations might make designers of work systems, tools, and devices reconsider current design principles and practices. For example, researchers have argued that too much adherence to the abstraction of screen-based interfaces has reduced physical interaction with systems, exemplified by "knobs for turning . . . [and] levers for . . . switching" (Norman, 2004, p. 80). This reduction in physical interaction can negatively affect "emotional experience" and within it a sense of control, leading to irritation and anger (Carayon, 1993; Carayon, Smith, & Haims, 1999; Norman, 2004, p. 80). At this time, however, the field remains largely "affect blind," and the development of interfaces that can detect and respond to human emotions "is still at an embryonic stage" (Whang et al., 2003, pp. 623-624). Nonetheless, there is some recognition that the predominant perceptual-cognitive focus within HF is limiting understanding of human-system relations and, furthermore, that emotion is a critical HF absent within the field (Hancock, Pepe, & Murphy, 2005; Szalma, 2008; Whang et al., 2003, p. 624).

We argue that HF would benefit from a consideration of research on emotion within sport psychology for several reasons. One reason is that sport psychology shares important ground with HF. To elaborate, both fields are (a) concerned fundamentally with performance enhancement, and emotions have been demonstrated to affect performance in important ways, and (b) inherently applied fields, involved with phenomena in the complex environments characterizing real-world domains. Second, compared with HF, sport psychology has an established history of a more even-handed treatment of cognition and emotion and thus has the potential to inform HF about existing research on emotion and about how such research would add value to the field. Finally, a given scientific field tends to benefit from contributions from outside of that field (Andrews, 1979; Simonton, 2003). In line with this characteristic, Moray (2008) recently noted that an interdisciplinary synthesis has been "not merely good but essential" to the development of HF (p. 415).

Next, we describe three areas of research on emotion within sport psychology and then discuss how this research can stimulate and inform research on similar topics within HF. The first area concerns emotional preparation and regulation for performance; the second, how emotional traits can affect athlete behavior; and the third, the link between emotion and motor behavior. The rationale for presenting these three areas is twofold. This sample of areas represents and illustrates the diversity of research on emotion within sport psychology. In addition, each area has clear implications for research in the field of HF. The article concludes with suggestions for how to continue cross-talk in the future between HF and sport psychology about research on emotion and related topics.

EMOTIONAL PREPARATION AND REGULATION FOR PERFORMANCE

A key area of research within sport psychology concerns how skilled athletes regulate themselves psychologically and, in particular, emotionally in preparation for and during practice and competition (Hardy, Jones, & Gould, 1996). In this section, we first present the background to this area. We then set out the theoretical framework dominant within the area and describe the empirical evidence underpinning it. Finally, we propose implications of this research for HF.

Background

In the 1950s, recognition grew that psychological factors could affect the performance of physically fit and highly skilled athletes, prompting research into the relationship between emotions and sport performance (Regnier & Salmela, 1987). Initially, attempts were made to identify the personality profiles as well as self-regulatory and coping skills (hereafter *psychological skills*) of elite versus less skilled athletes. In the 1970s, research began to indicate that psychological skills use predicted performance better than personality traits (Horn, 2008). Subsequent research focused on these skills, resulting in more than 100 studies of psychological skills use by athletes since 1970. These studies led to the development of a theoretical framework of the role of psychological skills

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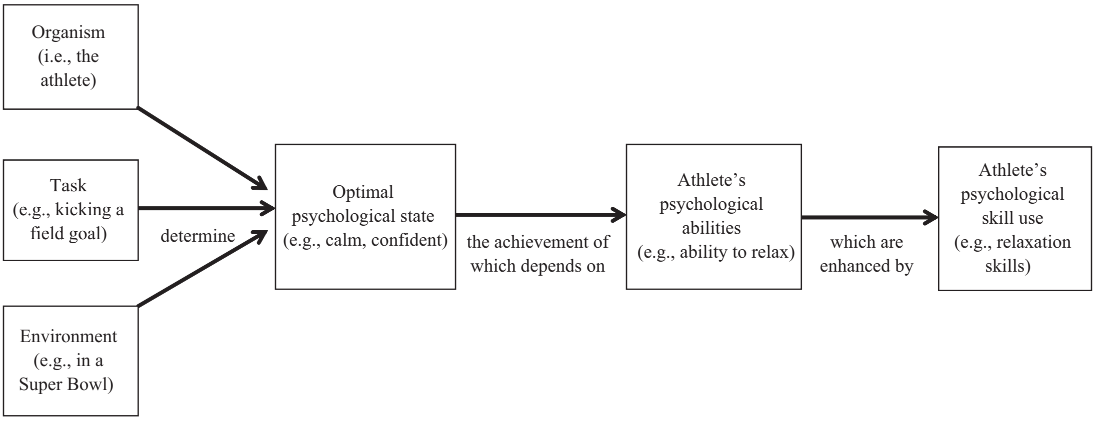

Figure 1. Theoretical framework for the self-regulation of emotional state in athletes.

in emotional preparation and regulation for athletic performance, which is described next.

Theoretical Framework

The theoretical framework comprises three aspects (Hardy et al., 1996; see Figure 1). First, an individual's *psychological state* is considered to affect performance during practice and competition. Furthermore, there is a psychological state optimal for performance. An individual who achieves this state is considered psychologically prepared. The state is considered to comprise emotions and cognitions relating to self-confidence, motivation, anxiety, and attention. Optimal psychological states are dependent on three sets of constraints: those related to the organism (i.e., athlete), the task, and the environment (cf. Newell, 1986). An optimal psychological state for a field goal kicker in football might be different, for instance, depending on the kicker's personality (an organismic constraint), whether the distance to the goal is 30 yards or 60 (a task constraint), and whether the kick is undertaken during practice or in a Super Bowl (an environmental constraint). Thus, an individual athlete must attempt to attain and maintain the optimal state, comprising the right "recipe" of emotions and cognitions appropriate for him or her given the situation.

Second, the ability to obtain an optimal psychological state depends on *psychological abilities*, including the ability to regulate (a) self-confidence, (b) motivation, (c) anxiety, and (d) attention. Third, athletes use psychological skills to enhance these psychological abilities. These skills are cognitive-behavioral in nature and include (a) goal-setting, (b) mental imagery, (c) relaxation and activation, and (d) self-talk skills. Goal setting involves establishing an end toward which behavior is directed. Mental imagery describes mental activity that resembles perceptual experience but occurs in the absence of the appropriate external stimuli. Relaxation and activation skills involve thoughts and actions that alter levels of cognitive anxiety and physiological arousal. Self-talk involves talking to oneself internally or externally (Hardy et al., 1996).

Sport psychologists have also developed theories of how each psychological skill enhances different psychological abilities. For example, studies of athletes' imagery use were initially framed by Paivio's (1985) analytic framework of imagery effects, within which imagery can have cognitive and motivational functions that operate at specific or general levels. Cognitive functions relate to effects of the mental rehearsal of motor skills on their acquisition. Consider how a kicker in football might image taking field goals to attempt to enhance his actual kicking ability. Cognitive imagery functions have received research attention within HF (e.g., Driskell, Cooper, & Moran, 1994), so the focus here will be on imagery's motivational functions. Motivational general imagery involves imaging situations that evoke positive, motivating

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emotions, such as entering a packed stadium to play a big game. Motivational specific imagery involves imaging the achievement of specific goals, such as winning an important game, to evoke positive, motivating emotions.

Following research on imagery within sport psychology, Hall, Mack, Paivio, and Hausenblas (1998) expanded Paivio's (1985) framework by delineating motivational general imagery into subfunctions: motivational general-arousal (MG-A) imagery and motivational general-mastery (MG-M) imagery. MG-A imagery relates to arousal regulation, such as imaging "handling the stress and excitement" during competition (Hall et al., 1998, p. 81). MG-M relates to perceptions of self-confidence and mental toughness. Tiger Woods has been reported to image the ball dropping into the hole to make him feel confident prior to attempting difficult shots, which is an example of MG-M imagery (Loehr & Schwartz, 2001). Next, we describe, among other things, studies of motivational imagery use by skilled performers and the effects of motivational imagery training.

Evidence of Psychological Skill Use by Skilled Athletes

Empirical studies underpinning the theoretical framework presented in the previous section involve self-report, psychophysiological, behavioral, and neurophysiological methods. A sample of studies is described next for each of these methods.

Early studies attempted to identify psychological skills that reliably differentiated skilled and less skilled athletes with the use of self-report methods, such as interviews. For example, Orlick and Partington (1988) interviewed or surveyed 235 athletes from the 1984 Olympic Games about factors perceived as affecting their psychological readiness to compete, finding that Olympic medalists reported using *preperformance routines* prior to competition, involving the use of relaxation techniques and positive self-talk, to prepare themselves emotionally. These early studies prompted the development of theoretically driven self-report instruments assessing psychological skill use. For example, the Test of Performance Strategies questionnaire (Thomas, Murphy, & Hardy, 1999) measures athletes' use of goal setting, imagery, relaxation, and self-talk skills. An example item assessing self-talk is "I keep my thoughts positive during competitions." Thomas et al. (1999) employed the instrument to examine psychological skill use by athletes competing at five performance levels and showed that in general, higher performance levels were associated with increased psychological skill use.

Studies involving psychophysiological measures, such as galvanic skin response, have provided indirect evidence of skilled athletes' psychological skill use. For example, sports requiring fine postural control, such as rifle shooting, can be affected negatively by increased physiological arousal. Helin, Sihvonen, and Hänninen (1987) indicated that the systolic phase of the heart causes a jerk to the shooter's arms, and thus, shots taken during systole are significantly poorer than those taken during diastole. However, there is evidence that skilled athletes develop relaxation skills to ameliorate these problems. Boutcher and Zinsser (1990) studied elite and novice golfers as they attempted short (4-ft) and longer (12-ft) putts. Both groups of golfers showed cardiac deceleration before short putts, but elite golfers showed significantly greater deceleration before longer putts, which suggests they have the ability to more completely relax the cardiovascular system when required.

Behavioral studies of skilled athletes' preparation for sport have also provided indirect support for psychological skill use. For example, in the putting study described already (Boutcher & Zinsser, 1990), behavioral elements (e.g., practice swings, glances at the hole) of the golfers' preputt routines were also examined. The elite golfers' routines were significantly longer and more complex than those of the novices, and there was more consistency in the way they were executed. These findings have been interpreted as behavioral evidence of acquired preperformance routines comprising psychological skills that function to psychologically prepare athletes for performance.

There is also neurophysiological evidence of skilled athletes' use of psychological skills. Neurophysiological studies have revealed that brain activity is different for skilled and less skilled athletes during preperformance routines and

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TABLE 1: Examples of Evidence Obtained via Different Methods of Skilled Athletes' Use of Psychological Skills

Method	Example Study	Example Measure/Task	Example Finding: How Did Skilled Athletes Differ From Less Skilled Athletes?
Self-report	Thomas, Murphy, & Hardy (1999)	Questionnaire about psychological skill use	Made greater use of goal setting
Psychophysiological	Boutcher & Zinsser (1990)	Heart rate during preputt routine in golf	Exhibited greater cardiac deceleration prior to longer putts
Behavioral	Boutcher & Zinsser (1990)	Nature and latencies of behavioral elements of preputt routine in golf	Routines were longer and more complex but more consistently executed
Neurophysiological	Milton, Solodkin, Hluštík, & Small (2007)	Functional MRI during imagined preputt routine in golf	Exhibited less neural activity in emotional centers preceding task execution

actual performance. The skilled athlete's brain is generally "quiet" at these times, with activity concentrated to areas related to motor control (e.g., premotor areas), but the less skilled athlete's brain is "noisy," with greater activation of emotional centers (e.g., limbic structures). These findings have been interpreted as evidence of the skilled athlete's ability to obtain an enhanced state of concentration and to ignore distracting information.

For example, Milton, Solodkin, Hluštík, and Small (2007) used functional magnetic resonance imaging (fMRI) to assess brain activity in 7 novice and 6 professional golfers. Participants viewed photographs of a golf pin and green (active condition) or of a flagpole (control). In the active condition, they were asked to undertake their normal preshot routine to prepare for a shot to the pin before indicating their readiness to take the shot. Milton et al. collected fMRI data across the preparation phase. Results indicated that the neural activity of the professional golfers during the phase was reduced and concentrated to the superior parietal lobule and dorsal lateral premotor and occipital areas compared with novices. However, all but one of the novices showed increased activity in the basal ganglia and limbic structures. The researchers concluded that relative to novices, the minds of the professionals were "cool and focused" (Milton et al., 2007, p. 804). Taken together, findings from this research area have been interpreted as evidence of the neural consequences of the use of preperformance routines comprising psychological skills.

Research showing differences in psychological skill use between skilled and less skilled athletes have led to more than 100 studies on the trainability of these skills since 1960. For example, Martin and Hall (1995) tested the effectiveness for learning to putt of using an MG-M imagery strategy similar to that reportedly used by Tiger Woods (described earlier). Novice golfers assigned to a treatment group mentally "image[d] themselves performing 'a perfect stroke' and . . . 'the golf ball rolling across the green and into the hole'" before each putt in a series of practice sessions to boost feelings of confidence (Martin & Hall, 1995, p. 59). Control group participants were trained in golf-specific stretching and stretched before each putt. In a posttest, participants in the treatment compared with control group holed significantly more balls. A self-report manipulation check revealed three significant group differences: Treatment group participants used more performance-related imagery, formed more complete images, and set more challenging learning goals.

In summary, and as Table 1 illustrates, the available empirical evidence obtained by a variety of methods suggests that skilled athletes develop psychological skills for use in enhancing their

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ability to achieve psychological states optimal for performance. In addition, training studies have provided some evidence of the trainability of psychological skills in less skilled athletes, with beneficial effects for performance.

Implications for HF

Although HF researchers have proposed that a consideration of the topic of emotion would enhance the current understanding of human-system relations, there has been little concern for the topic of emotional regulation within this journal. A search for article titles in the journal containing derivates of the word stem *regulat* (as in *regulation*) revealed no such articles. Subsequently, a review was undertaken of the 3 emotion-and-affect, the 7 psychological-states, and the 12 Shaver articles published in the journal. None involved an empirical study concerned with emotional self-regulation. Finally, a review was made of the 40 stress articles. Of these, 2 articles contained an empirical study concerned with this topic (Driskell, Johnston, & Salas, 2001; Murphy, 1983).

Murphy (1983) studied the efficacy of a stress reduction intervention for nurses involving teaching relaxation skills. Groups undertook electromyography-based biofeedback, guided progressive muscular relaxation, or self-relaxation sessions for 1 hr daily for 2 weeks. All groups reported lower trait anxiety after the intervention. At a 3-month follow-up, the biofeedback group reported increased work energy and perceived effectiveness of workplace coping skills. Thus, in terms of the emotional regulation framework described previously, the intervention involved teaching a psychological skill, relaxation, to improve a psychological ability, the self-regulation of anxiety.

Driskell et al. (2001) investigated whether the effects of stress training aimed at addressing one type of stressor and task would remain when participants performed with a novel stressor or performed a novel task. The stress training intervention involved three stages: (a) describing stressors that would be experienced and their effects on the individual, (b) attention skills training, and (c) applying the learned attention skills during the performance of a task and in the presence of a stressor.

The training was based on a broader attention training program developed by sport psychologists Singer, Cauraugh, Murphy, Chen, and Lidor (1991) and extensively studied by researchers in the sport psychology community. Training focused on three points: "(a) stress training can be distracting; (b) to counter the distraction, individuals should selectively attend to task-relevant stimuli; and (c) the key to effective performance is to ignore distracting stimuli and maintain focus on the task" (Singer et al., 1991, pp. 103-104). The results indicated that stress training benefited performance and that these beneficial effects were retained when participants performed with a novel stressor and task. In terms of the emotional regulation framework described earlier, the intervention involved attempts to enhance a psychological ability, the self-regulation of attention. Furthermore, enhancing this ability effectively resulted in the enhancement of another psychological ability, which was the self-regulation of anxiety.

Although only two studies within this journal concern self-regulation of emotion, it was clear from the reviews generally, and of the stress articles particularly, that HF professionals recognize the important role that emotional self-regulation is likely to play within work environments. For example, in a study by Klein et al. (2008), participants received 12 min practice on a peg transfer task designed to mimic endoscopic surgery and observed changes across practice in self-reported task-irrelevant interference and self-focused attention. Klein et al. interpreted these changes as increases in coping in relation to task-related stress and concluded that surgery training is limited by its focus on developing clinical and technical skills at the expense of critical "nontechnical cognitive skills," such as stress-coping skills (Klein et al., 2008, p. 298). These authors also proposed that the identification of such skills may lead to more effective instruction and training for surgery.

In addition, Szalma et al. (2004) showed that self-reported frustration and stress increased as time spent monitoring displays increased. They proposed that some stress effects observed may be explained by the use of ineffective coping skills, concluding that training in coping skills may help task performance. Furthermore,

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Matthews et al. (1998) studied how self-reported driver stress predicted performance on a driving simulator, finding that self-reported high driving aggression was associated with frequent and error-prone overtaking. They attributed these overtaking behaviors to the use of confrontive coping strategies in interaction with other vehicles and proposed that interventions aimed at reducing stress-related driving accidents should be based on a "fine-grained understanding of how drivers' coping strategies and appraisals of the traffic environment vary across individuals and situations" (Matthews et al., 1998, p. 146).

However, despite this recognition, there were few calls for studies of self-regulatory skills in the future. The interest generally within the research reviewed here has concerned environmental stressors and/or task constraints. Although some researchers have emphasized organismic constraints related to emotional regulation (e.g., throughput and output stressors; Hancock & Warm, 1989), few have examined these directly.

For example, in a study by Szalma et al. (2004) of stress in vigilance tasks (described earlier), the authors considered sensory modality (an environmental constraint) as a moderator variable for the stress arising from monitoring and found that auditory monitoring was less stressful than visual monitoring. They also considered operators' time on task (a task constraint) as a moderator variable and found that stress increased with length of time on task. Although Szalma et al. proposed that their findings may be explained by the use of coping skills and that training in coping skills may enhance performance on vigilance task, no effort was made in their study to identify operators' attempts to cope with the task-based stress, and no calls were made for such research in the future. This leads us, as well as others (including Szalma, 2008, p. 382), to pose the question, Where's the human in "human factors"?

As HF professionals believe that operators are likely to develop emotional self-regulatory skills following practice on their tasks (e.g., Szalma et al., 2004), future research could follow the lead set by sport psychology (cf. Hardy et al., 1996) by focusing on comparing psychological skills use between proficient and less proficient operators. HF researchers might also consider employing the methods used by sport psychologists to this end, some of which were described earlier (see also Eccles, in press). For example, Hanton and Jones (1999a) used interview methods (not dissimilar from the critical incident technique) to study how elite swimmers maintained facilitative interpretations of anxiety prior to important swim meets. The swimmers reported developing "cognitive skills and strategies" that were used to this end, such as developing a routine of "channeling anxiety" by telling oneself immediately prior to important meets to use the anxiety to help focus on preparing systematically for the meet (Hanton & Jones, 1999a, p. 1).

Furthermore, if psychological skill use is identified in proficient operators, the next step from a sport psychology perspective would be to study how the skills might have been developed. Hanton and Jones (1999a) investigated this with regard to the swimmers in their study and found that they had acquired psychological skills not only through natural learning experiences, such as having to compete at a high level at a young age, but also via various educational methods.

The results of such research can then inform the design of programs that train the use of the skills in novice operators. Subsequently, the efficacy of such programs for enhancing task performance can be tested. For example, Hanton and Jones (1999b) integrated the cognitive skills and strategies identified in their earlier study (Hanton & Jones, 1999a) into a training program to help less skilled swimmers interpret feelings of anxiety in a facilitative way and with beneficial results in terms of reported feelings of anxiety and actual swim performance.

The results of such research could also be used to inform the design of systems prompts and directions that support the operator's use of psychological skills so that the operator can more easily achieve and maintain psychological states most conducive to performance. Simple versions of such self-regulatory prompts can be seen in the form of signs strategically placed in the wings of a stage that remind the actor to breathe before entering onto the stage before a large crowd. Furthermore, if systems can be designed to sense changes in emotion that are not conducive to the task, they may be able to

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automatically prompt the operator to use a specific psychological skill.

For example, Whang et al. (2003) considered that a system that was able to detect an emotional state known to be detrimental to task performance could automatically suggest a remediating intervention, such as playing the operator's "favorite multimedia content," which had been previously selected by the user and stored in a system database (p. 633). By contrast, the proposal here is that the intervention suggested by the system is evidence based; that is, it should be based on psychological skills shown empirically to facilitate the attainment of a psychological state conducive to task performance.

In summary, sport psychologists have an established history of research into how performers in sport prepare themselves emotionally for, and regulate themselves emotionally during, sport practice and competition. By contrast, although HF researchers have proposed that a consideration of the topic of emotion would enhance the current understanding of human-system relations, they have seldom attempted to study how operators might learn or have learned to regulate their emotions during task performance or how systems might be designed to support useful regulation attempts. Provided here were insights into how HF researchers could attempt research of this kind.

EMOTIONAL TRAITS AND ATHLETE BEHAVIOR

Recent work in sport psychology has concerned how emotional traits might underlie motivations and behaviors of athletes in sports settings. In this section, we describe how sport psychologists have provided new insights into the motivation and behavior of athletes involved in risky sports through a consideration of research on emotional traits. The section begins with a definition of, and the traditional explanation for, risk-taking behavior. Following this definition, a contemporary emotional trait–based theory of risk taking is presented, and recent research supporting this theory described. The implications for HF of this research, and of research on emotional traits more generally, are then proposed.

Background

Mainstream psychology is replete with studies on risk-taking activities, such as smoking, substance abuse, and dangerous driving. These activities are widely accepted as antisocial behavior and have been extensively investigated (e.g., Gomà-i-Freixanet, 1995). Of course, risk taking is not limited to antisocial behavior, and various socially accepted risk-taking activities exist, including risk-taking professions (e.g., armed forces) and risk-taking sports (e.g., mountaineering).

However, risk-taking professions and risk-taking sports are not the same. What differentiates them is the perceived necessity to engage with risk. Risk is perceived as the military person's necessary evil to serve the greater good. As such, these risk-taking activities are deemed prosocial (Gomà-i-Freixanet, 1995); that is, in taking a risk, the person serves society. In contrast, the risk-taking sportsperson's (e.g., mountaineer) relationship with risk is neither antisocial nor prosocial. That is, despite the possibility of avoiding risk, high-risk sportspeople seek out dangerous environments with no apparent need to do so. It is this paradox that typically fascinates the layperson. Why do individuals engage in such high-risk activities when there is no objective and urgent need to do so?

Sensation Seeking

Zuckerman's (1983) sensation seeking framework states that people with a habitually low level of catecholamine (e.g., adrenaline) will engage in excitement-inducing activities to raise this level. In other words, the person engages in the high-risk activity for the thrill and adrenaline release that it procures. This view has become the sine qua non of risk-taking literature. Although research suggests that this view has some validity, it is deterministic, limiting, and inaccurate. As we will see, there are other, more psychological, reasons that people engage in these activities. Furthermore, thrill and high-risk activities (e.g., armed forces) are rarely associated. For example, although a fighter pilot is engaged in a high-risk activity, to label such a person a "thrill seeker" is inaccurate and unhelpful for understanding motives for risk engagement (e.g., Cazenave, Le Scanff, &

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Woodman, 2007; Shapiro, Siegel, Scovill, & Hays, 1998). We aim here to elaborate on research that might inform the study of risk taking in different domains.

Risk Taking as Emotion Regulation

A theoretical framework helpful for examining motives for engagement in high-risk activity is that of emotion regulation. This theory is based on a multifaceted theoretical framework, including Fenichel's (1939) counterphobic model and Taylor and Hamilton's (1997) compensation-escape model, which itself is based on the work of Carver and Scheier (1981) and Duval and Wicklund (1972).

According to Carver and Scheier's (1981) self-regulation theory, if people feel a discrepancy between the self and the ideal self, they will engage in activities that help them approach their ideal self. In accordance with Duval and Wicklund (1972), when attempts to reduce such discrepancies fail, negative affect ensues. There are two ways that one can deal with such negative affect. First, one can turn attention away from the self by seeking to escape from self-awareness. Second, one can disengage from the task at hand and shift attention to an alternative task in which one has more chance of success (i.e., more chance of reducing the actual-ideal discrepancy).

Engaging in a risk-taking activity per se does not discriminate between these two self-regulation processes; it can be used as a way to *escape* from self-awareness (to lose oneself in the activity) or as a means of *compensation* by shifting one's efforts to a risk-taking task more likely to meet with a favorable outcome. However, although compensation is not significantly correlated to any indicators of psychological distress, escape is significantly correlated with depression, negative affect, pessimism, and anxiety. In other words, although risk-taking behavior may sometimes represent psychologically healthy and fulfilling goal-directed behavior, it can reflect a form of ineffective emotion regulation (Cazenave et al., 2007; Michel, 2001; Taylor & Hamilton, 1997).

According to Fenichel (1939), the principal emotion regulation benefit of high-risk sport is the experience and subsequent control of anxiety. That is, the risk-taking individual suffers from generalized and internalized anxiety but is unable to identify its origin, express it, or control it effectively; the source of the anxiety is subconscious. In experiencing externally derived emotions in a fear-inducing domain (e.g., the base jumper jumping off a cliff), risk takers are able to gain control of the source of the emotion and experience subsequent well-being (e.g., the fear has been overcome). The risk-taking domain is attractive to such individuals, as it affords opportunities to experience emotion in the form of anxiety, to control its source by successfully completing the task, and then to experience associated relative well-being (absence of anxiety).

Furthermore, when an individual's difficulties with emotions are too great, there is a tendency to replace emotions with physical sensations, which are more readily accessible and less threatening in the quest to experience something intense (cf. Cohen, Auld, & Brooker, 1994). When used this way, physical sensations allow one not to think of oneself and one's emotions. In other words, the physical sensation serves as an escape from self-consciousness.

When emotions are a threat to the self or are less accessible, one often finds an underlying emotional trait: alexithymia. This trait is characterized by the absence of words to express one's emotions and difficulty recognizing one's own emotions and feelings along with the inability to express them to others (Sifneos, 1972; Taylor, Bagby, & Parker, 2003). Alexithymic individuals tend to describe events without integrating any affective connotation, become bored, live a monotonous everyday life, and express little or no emotion (Corcos & Speranza, 2003; Taylor et al., 2003). They are predisposed to develop disorders related to poor emotion regulation, including depression, trait and state anxiety, and low self-esteem (cf. Corcos & Speranza, 2003; Lumley, Stettner, & Wehmer, 1996). As alexithymic individuals have difficulty identifying and expressing their emotions, the risk-taking domain and its concomitant emotion regulation function are attractive. For example, recreational risk-taking sportswomen are more alexithymic than their nonrisk-sport counterparts (e.g., swimmers; Cazenave et al., 2007).

More direct support for this position comes from recent studies in which parachutists' anxiety

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was measured at different times before, during, and after a jump (Woodman, Cazenave, & Le Scanff, 2008; Woodman, Huggins, Le Scanff, & Cazenave, 2009). Alexithymic parachutists experienced elevated anxiety before the jump and a significant decrease afterward, whereas more emotionally aware individuals experienced no such fluctuations; they were not doing it to overcome fear. These results could not be explained by sensation seeking. The implications from such findings are that some people engage in high-risk activities to experience, and subsequently control, their emotions. They use the risk domain to regulate their emotions, probably subconsciously.

Because the (internalized) source of the emotional difficulty is not addressed by engaging in high-risk activities, alexithymic individuals who engage in high-risk activities will likely feel the need to repeat the activity, as it provides a continued sense of renewed emotional control. They come to rely on risk taking to experience emotion, as they experience little in other life domains (e.g., personal relationships). In one of the parachutist studies, within 90 min of the completion of the jump, alexithymic individuals' anxiety began to rise again, suggesting that the anxiety was not addressed by succeeding at the jump. The danger is that the person will feel the need to increase the risk by exposing himself or herself and others to increased danger to experience emotion. Conversely, individuals with a balanced emotional life outside of the high-risk domain will likely seek to minimize risk within the high-risk domain (i.e., be meticulous about reducing danger) and be less accident prone.

This research challenges 40 years of explanations for participation in high-risk activities based on Zuckerman's (1983) sensation-seeking framework. Furthermore, it provides a framework for understanding the psychological motives to engage in high-risk activities and to risk one's own and others' lives within those activities.

What Next?

Some risk-taking individuals appear to derive self-construct benefit from engaging in high-risk activities: Individuals engaged in such activities can construct a positive identity (Michel, 2001) and have a balanced emotional life (cf. Cazenave et al., 2007). The other end of this spectrum is less positive. Some people appear to use the high-risk domain to escape from a lack of identity and from emotional difficulties (cf. Cazenave et al., 2007; Woodman et al., 2008; Woodman, Huggins, et al., 2009). One obvious question is, Can a person shift from an escape-type motive for risk taking to a more compensatory and constructive motive? If so, such a model might be applied to a variety of risk-taking activities (e.g., drug taking, dangerous driving), which would benefit both the individual and society.

Another avenue for future research is to understand more fully the origins of the emotional difficulties experienced by those who engage in risk-taking activities to escape from self-awareness. Obtaining this understanding will not be easy, particularly as the theoretical framework outlined here suggests that any difficulties are trait oriented and deep-seated (e.g., alexithymia). Nevertheless, it seems worthy to try to understand the mechanisms via which people might come to regard risk-associated danger as simultaneously destructive and attractive. Early signs are that this tendency is increased in individuals who had childhood relations with parents that were insecure (e.g., Le Scanff, 2000).

A promising avenue for future research is to identify individuals who adopt a risky attitude within the risk-taking domain and then to provide a forum via which the person can develop his or her emotional expression and regulation (e.g., stress management) more positively in the original and other environments. This approach would likely involve interventions that underscore the importance of choice within high-risk domains; in other words, interventions that foster an understanding that one does not need to take risks to derive self-worth. One key aspect of the escape motive is that it is thought to result from a perceived lack of alternative avenues for self-worth. As long as the person perceives the risk-associated potential gain to outweigh the potential harm, then he or she will likely take the risk. When risk taking leads to harm to oneself and others, such a perception seems misguided and these mechanisms need to be unearthed.

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Implications for HF

HF professionals have an established interest in understanding risk taking in risky environments, such as vehicle driving and aircraft piloting, evidenced by published research on this topic within this journal (e.g., Deery & Fildes, 1999; Evans, Wasielewski, & von Buseck, 1982; Molesworth & Chang, 2009). However, although the research in sport psychology described previously suggests that certain emotional traits might be important predictors of risk-taking behavior, only one study of risk taking in the field of HF has involved a consideration of emotional traits (Deery & Fildes, 1999). Deery and Fildes (1999) showed that young car drivers low in emotional adjustment and high in sensation seeking reported high levels of driving aggression and speeding in competition with other drivers and performed poorly in a simulated driving task.

It is also of note that the only study of risk taking within this journal that has involved a consideration of emotional traits (i.e., Deery & Fildes, 1999) made no use of emotion-related theory. Unlike in the research in sport psychology described previously, no psychological explanations were offered by Deery and Fildes (1999) about why the emotional traits studied might predispose an individual to take risks. An understanding of the psychological mechanisms mediating the trait-behavior relationship is a prerequisite to the design of interventions effective at countering unwanted risk taking. In summary, the theoretical framework adopted within the research on risk taking in sport psychology described earlier provides new ideas for understanding and conceptualizing the problem of risk taking, ideas that may suggest potentially fruitful new avenues of research on risk taking in HF and new ways of dealing with this problem through interventions and training.

The research in sport psychology described earlier might not only inform current considerations of risk taking in HF; there may be potential benefits for the field of research on individual differences in emotional traits more generally. There has been some interest in the topic of individual differences within this journal. The ISI Web of Science database reveals that the journal contains 17 articles featuring an empirical study and including the term *individual differences* or *personality* in the title.(A search for articles featuring an empirical study with titles containing the term *trait* was conducted but with no result.) Furthermore, the HFES has a technical group called Individual Differences. However, there has been little consideration of individual differences in relation to emotion.

A review was undertaken of the 17 articles described to identify those concerned with individual differences in relation to emotion. Only 5 such articles were identified (Glasscock, Turville, Joines, & Mirka, 1999; Lester & Bombaci, 1984; Loo, 1978; Morgan, Winne, & Dugan, 1980; Vicente, Hayes, & Williges, 1987). By contrast, the remaining 12 were primarily focused on individual differences in perceptual-cognitive constructs, such as working memory (e.g., Baldwin & Reagan, 2009).

A review was also undertaken of the 3 emotion-and-affect articles published in this journal to identify empirical studies of individual differences in relation to emotion, with one result (Roring, Hines, & Charness, 2006). A similar review was then made of the 7 psychological-states articles, but no relevant studies were identified. The 12 Shaver articles were also reviewed, revealing six such studies (Arthur, Young, Jordan, & Shebilske, 1996; Ellis & Allaire, 1999; Frank, Casali, & Wierwille, 1988; Keuning, Monné, Ijsselsteijn, & Houtsma, 2005; Pauley, O'Hare, Mullin, & Wiggins, 2008; Ray & Minch, 1990). Finally, five such studies were revealed following a review of the 40 stress articles (Berkun, 1964; Coermann, Magid, & Lange, 1962; Galinsky, Rosa, Warm, & Dember, 1993; Matthews et al., 1998; Trimmel et al., 2003).

A notable point about the 17 studies identified from these reviews is that personality is the primary interest in 3 studies. Emotional traits were involved in these studies only because such traits are a facet of an omnibus personality inventory examined in the studies. For example, the effects of Type A and Type B personality on neuromuscular control strategies and biomechanical loading were the foci of the study by Glasscock et al. (1999). Consequently, irritability featured in the study because it is a factor within Type A and Type B personality types.

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A second point of note is that for studies in which emotion has been the construct of primary interest (i.e., vs. personality), the majority (11 out of 14) have been concerned chiefly with stress or anxiety. In only 3 studies has the primary focus been on individual differences in emotions other than stress and anxiety: Frank et al. (1988) studied individual differences in the uneasiness experienced by users of a driving simulator, individual differences in satisfaction experienced by users of computer-pointing devices were the foci of the study by Keuning et al. (2005), and Roring et al. (2006) examined how age affects the ability to identify emotions in small image sizes typical within electronic media.

A final observation about the 17 studies identified in the reviews is that of the 3 studies concerned with emotions other than stress and anxiety (i.e., Frank et al., 1988; Keuning et al., 2005; Roring et al., 2006), only the study by Roring et al. (2006) is framed by a theory of individual differences in an emotional trait. The study featured younger (M_{age} = 23 years), middle-aged (M_{age} = 49 years), and older (M_{age} = 77 years) participant groups. Participants viewed computer-displayed pictures, in two different sizes, of actors portraying one of six emotions: happiness, sadness, fear, anger, surprise, and disgust. The name of an emotion, such as *HAPPY*, was displayed immediately prior to the presentation of a picture in the range, and participants responded by indicating whether the name matched the emotion displayed in the picture. When compared with the other age groups, older participants responded more slowly to the smaller pictures and less accurately in relation to fearful, sad, and surprised emotions.

These findings are consistent with socioemotional selectivity theory (Carstensen, Isaacowitz, & Charles, 1999), which proposes that older adults' perception of time as limited increases their prioritization of emotional regulation, promoting a focus on emotionally meaningful goals and gratifying experiences. Roring et al. (2006) proposed that the theory, which states that older adults pay less attention to negative information, explained the poorer perception of emotionally negative stimuli by the older adults in their study.

In summary, there has been little empirical interest in this journal in individual differences in relation to emotional traits. By contrast, the research on individual differences reflects the research interests of the journal more broadly: The predominant focus is on perceptual-cognitive constructs and, when there has been interest in the area of emotion, for the most part, it has been with the constructs of stress and anxiety. We propose that the current understanding of individual differences in relation to human-system relations will be advanced markedly by a consideration of emotional traits, in line with recent arguments within the field by Szalma (2008):

> If the individual differences in affective and cognitive traits and states are not incorporated into theories of human performance and principles of interface design, we are in essence neglecting half of the question central to human factors and ergonomics, and conducting a very curious kind of "human-centered" design that neglects human personality, emotion, and motivation. (pp. 325–326)

We recommend that HF researchers consider three key ways in which research on emotional traits will contribute to their field. First, HF researchers should consider how research on emotional traits will improve personnel selection (cf. Matthews et al., 1998). For example, as the research in sport psychology described earlier demonstrated, candidates who present as highly motivated to take on dangerous work or appear fearless in the face of potentially dangerous environments might seem ideal selections (e.g., Scales, 2008). However, they might actually be highly inappropriate selections, as they may lack emotional stability and, consequently, seek to regulate their emotions through engagement in these professions, which may affect their ability to make reasoned decisions under stress. Furthermore, to meet their self-regulatory needs, they may increase rather than manage and reduce risks within the workplace, thereby increasing risks to others. Consequently, assessments of emotional traits, such as alexithymia, might inform personnel selection in these domains.

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Second, HF researchers should consider how research on emotional traits will help enhance training by allowing it to be better tailored to an individual's needs (Deery & Fildes, 1999; Gildea, Schneider, & Shebilske, 2007; Molesworth & Chang, 2009). For example, Gildea et al. (2007) demonstrated Space Fortress, an aviation-like video game, to participants before assessing their stress appraisals in relation to the task using self-report items, such as "How threatening do you expect the upcoming task to be?" (p. 749). During subsequent training on the task, participants whose appraisals denoted challenge outperformed those whose appraisals denoted threat. Gildea et al. proposed that stress appraisals could be used to identify threatened trainees prior to training so that they could be provided with additional training aimed at countering the perceived threats.

Third, to ensure that systems are used effectively and efficiently, HF researchers should consider whether it is necessary to tailor system interfaces and other parameters according to the individual differences in emotional traits that characterize the diversity of the operators (cf. Vicente et al., 1987). For example, operators often experience frustration when interacting with systems that are unpredictable, because such systems undermine one's sense of control (e.g., Carayon, 1993; Carayon et al., 1999; Trimmel et al., 2003). What is not known, however, is how emotional traits, such as trait anger, might exacerbate these responses. Laboratory studies have shown that emotional traits exacerbate concurrent states interactively (e.g., Farin, Hull, Unwin, Wykes, & David, 2003; Rusting, 1999). Thus, those with high trait anger may be more pronounced in their responses to system glitches.

As demonstrated already, there has been a historic interest in this journal in the perceptual and cognitive processes underpinning tasks involved in a variety of HF domains. Research in the affective sciences and sport psychology has indicated that emotions can have profound effects on such processes (Blanchette & Richards, 2010; Clore & Huntsinger, 2007; Woodman, Davis, et al., 2009). However, no studies in the journal have been concerned with how emotional states and traits, and their interaction, affect the perceptual and cognitive processes involved in tasks of interest to HF researchers and, in turn, the performance of these tasks. As these effects will need to be accommodated within the design of system interfaces, there is a clear rationale for future research on this topic in HF.

In summary, HF researchers have largely ignored emotional traits as an important human factor. It is hoped that the implications of the research from sport psychology described here will inform and stimulate research into this topic within HF, which in turn will enhance the current understanding and practice of selection, training, and the design of man-machine systems.

EMOTION AND MOTOR FUNCTION: AN INTEGRATED APPROACH

Sport psychologists have a vested interest in determining the effects of emotions on the specific motor parameters underlying sports behaviors. This section begins with background information about research on the relationship between emotion and motor functioning within sport psychology. Research on the effects of emotion on movement planning and control is briefly reviewed. Implications of this work for HF are then proposed.

Background

Advances in measurement, engineering technology, and statistics have accelerated the study of stress and performance within sport psychology, cognitive psychology, and HF. However, understanding the behavioral sequelae of stress has been limited by neglect of the ubiquitous construct of emotion. Although influential hypotheses, models, and theories have been forwarded to capture the relationships among stress (e.g., Hancock & Warm, 1989), arousal (e.g., Yerkes & Dodson, 1908), anxiety (e.g., Eysenck & Calvo, 1992), and performance (for a review, see Woodman & Hardy, 2001), emotion has largely been neglected. Likewise, theorists have postulated explanations of how motor actions learned implicitly or explicitly might predispose individuals to being more or less susceptible to stress (e.g., Masters, 1992). The vast literature emerging from this work has been foundational to sport psychology and HF, but these conceptual approaches have ignored mainstream affective science, prompting Lazarus

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(2000) to note, “Stress is important in its own right, but emotion encompasses all of the important phenomena of stress.” (p. 231).

Signs of remedying past neglect are evident, however. Processing efficiency theory, for example, has been overhauled to consider the role of emotion in determining attentional allocation and performance (Eysenck, Darakshan, Santos, & Calvo, 2007). Within sport psychology, Hanin (2007) continues to evolve his theory of individual zones of optimal functioning (IZOF) to be more “emotion friendly.” Finally, sport psychologists have begun exploring the effects of emotional traits on motor performance (Woodman, Davis, et al., 2009). These conceptual approaches and others have advanced through theoretical induction and consideration of predominant orientations in the affective sciences.

Herein, we highlight efforts by sport psychologists to wed mainstream affective science with questions confronted by performance psychologists. These novel perspectives can help inform unanswered questions concerning how behaviors, in particular, the fundamental movement parameters that are necessary for completion of functional voluntary activities, are altered in different affective contexts. Our intent is not to undermine contributions made by researchers using traditional approaches to understanding stress and performance. Rather, we provide considerations for alternative approaches and design options that will advance understanding of human performance in inherently fluctuating emotional conditions.

A growing literature supports the notion that human emotion and motor action are intertwined and interrelated. Affective theorists generally agree that the evolutionary importance of emotion lies in priming behavioral responses to approach pleasant and avoid unpleasant stimuli. Empirical support for such assertions has relied on inferences made from protocols in which emotional state is manipulated and then movements toward and away from the body are analyzed. A key issue within the emotion and movement literature concerns the interaction between motivational priming and the direction of an intended movement.

Generally, unpleasant emotions (excluding anger; cf. Gable & Harmon Jones, 2008) activate defensive circuitry, which prime avoidance behaviors and facilitates movements away (e.g., lever pushing) from the body. Pleasant emotions, in contrast, activate appetitive circuits that prime approach behaviors and facilitate movements toward (e.g., lever pulling) the body (e.g., Cacioppo, Priester, & Berntson, 1993; Centerbar & Clore, 2006; Chen & Bargh, 1999). Researchers have also manipulated movement and examined the influence of motor perturbations on emotional experience, yielding evidence that preferences and attitudes are modulated by inhibition, alteration, and exaggeration of motor action (Niedenthal, 2007).

Although such efforts have enhanced understanding of the interdependence of emotion and motor function, theoretical advancement has been limited by failures to consider the specific aspects of motor execution modulated by emotions. Different tasks, varying from button pressing to more complex motor actions, have been investigated and have yielded an equivocal database that is paradoxically replete with significant findings. Among existing accounts, recent variations of embodiment, such as the evaluative coding view of approach and avoidance reactions (Eder & Rothermund, 2008), can accommodate such disparate findings and attributes affective modulation to response selection influences. However, precisely which parameters of response planning are affected by emotion remain unspecified. Moreover, no existing theoretical framework can account for the influence of emotion on the control of motor execution when initiated.

Emotional Influences on Motor Planning and Control

Although theorists differ in specifics regarding human action production, there is general agreement that emergent motor behavior is derived from interacting planning and control processes (Glover, 2004). Research has demonstrated that activation of appetitive and defensive brain circuitry modulates movement speed (Coombes, Janelle, & Duley, 2005), accuracy (Coombes, Gamble, Cauraugh, & Janelle, 2008), and direction (Coombes, Cauraugh, & Janelle, 2007a, 2007b). There is also evidence (Hajcak et al., 2007) that engagement of the neural structures and pathways involved in processing emotion alters the cognitive operations underlying

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motor planning and the systems involved in controlling action execution. A few examples of this work are highlighted next.

Emotion and movement planning. The planning system is responsible for selecting the target, macroscopic aspects of the movement and initial conscious parameterization of motor kinematics. Motor planning is subject to interference from competing cognitive processes, as it is consciously regulated. Movements shorter in duration than the typical reach-to-grasp movement (i.e., ballistic movements) rely primarily on the planning system for execution (Glover, 2004).

Evidence suggests that emotional states alter how short duration movements are executed. For instance, Coombes and colleagues (2008) implemented a protocol in which participants were presented with emotional images and were required to execute a rapid movement. More specifically, image onset cued participants to plan a ballistic movement of the wrist and finger extensors, which they then executed as quickly as possible after the onset of an auditory stimulus delivered during picture presentation. The presentation of unpleasant stimuli led to a greater rate of change of force production and faster premotor response times. The congruence between the extension movement and the unpleasant emotional state apparently primed the motor system such that movement onset was more rapid and the rate of force exertion was accelerated.

This protocol was modified to demonstrate how specific emotional reactions (rather than the broad pleasant-unpleasant affect dimension) influence movement quality (Coombes et al., 2007a). Responses during the presentation of threatening and disgusting images were analyzed as separate subcategories of unpleasant affect, the hypothesis being that threat-inducing images would prime extension movements more so than disgust-inducing images. The hypothesis was supported. Threat images led to speeded premotor reaction time (PRT). Importantly, no differences in motor time (MRT) were evidenced between emotional conditions. Hence, although threat and disgust images each elicited unpleasant emotional states, only threat images expedited extension movements in such conditions. Second, modulation was found in PRT but not in MRT, replicating earlier findings that central rather than peripheral processes expedite extension movements. Thus, perceived threat enhances the rapidity by which extension movements are executed when speed is the primary movement goal, suggesting that motivational direction and affective valence differentially modulate movement.

Recent work has advanced these findings by requiring participants to execute a force pulse (using a pinch grip) at a specified target force level and also by considering individual differences in dispositional anxiety (Coombes, Higgins, Gamble, Cauraugh, & Janelle, 2009). High anxiety was associated with slower response times, and threat cues led to faster response times irrespective of trait anxiety. These findings indicated that motor efficiency (speed), but not effectiveness (accuracy), is compromised in high- relative to low-anxious individuals, suggesting that increased stimulus-driven attentional control interferes with movements requiring greater attentional resources.

Emotion and movement control. As movement progresses over time, its execution is increasingly regulated by the control system. Movement corrections regulated by this system rely heavily on the spatial characteristics of the actor and target and proceed uninhibited by cognitive processes (Glover, 2004). Quick processing of the control representation can therefore yield fast online adjustments. How does emotional input affect such control processes? In an attempt to answer this question, Coombes et al. (2008) required participants to sustain force at 10% of maximum voluntary contraction using visual feedback to produce accurate performance. Following 5 s of visual feedback, feedback was occluded by emotional images for 6 s, and participants were required to maintain force output to the target level as accurately as possible. They sought to determine whether the force decay typically evidenced (e.g., Davis, 2007) would be modulated by emotion valence or emotional arousal.

Accuracy remained high during the control condition, in which feedback remained visible. Notably, however, relative to neutral conditions, less root mean squared error was evidenced

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during pleasant and unpleasant emotional states, indicating an arousal-driven increase in force production. Hence, when one sustains force using a movement (the pinch grip) that is not directed toward or away from the body, pleasant and unpleasant emotional states similarly excite the motor system, suggesting that emotional modulation of nondirectional force at moderate force levels varies as a function of emotional arousal, not emotional valence.

In sum, emotional states robustly alter motor output, and the arousal and valence components of emotional experience differentially affect motor control and execution, respectively. Recent work has shown that the manner in which the emotion system alters the motor system is complex. The specific emotional state (Coombes et al., 2007a), the distance and direction of the movement required (Lavender & Hommel, 2007), and individual differences in proclivity to adopt different attentional control mechanisms (Coombes et al., 2009) influence the characteristics of the movement executed. Isolating and integrating each of these factors systematically and precisely is critical if we are to better understand and predict human motor performance in emotionally evocative performance settings.

Implications for HF

There has been a history of interest in factors affecting human movement within this journal. The ISI Web of Science database reveals that this journal contains 51 articles with titles containing derivates of the terms *motor* and/or *movement* as they relate to manual control and human movement and featuring an empirical study. However, there has been little consideration for how emotions affect these factors. A review of the 51 studies identified revealed only 2 related to this topic (Biersner, 1976; Worchel, Shebilske, Jordan, & Prislin, 1997). A review was also undertaken of the 3 emotion-and-affect articles published within this journal to identify empirical studies of this topic, with one result (Biersner, McHugh, & Bennett, 1977). A similar review of the 7 psychological-states articles and the 12 Shaver articles revealed no relevant studies. Finally, the 40 stress articles were reviewed, revealing 6 such studies (Bell, 1978; Berkun, 1964; Galinsky et al., 1993; Gildea et al., 2007; Matthews et al., 1998; Van Orden, Benoit, & Osga, 1996).

It is notable that of the nine studies identified from these reviews, stress is the emotion-related concept of primary interest in six of these. Of these six, three studies involve investigations of the effects of physical stressors on the performance of a task involving a substantial motor component: Bell (1978) showed that performance on a pursuit rotor task was unaffected by hot room temperatures, Biersner (1976) presented evidence that divers' ability to hang rings on pegs underwater was negatively affected by cold water temperatures, and Van Orden et al. (1996) showed that participants in a simulated military task requiring use of a trackball input device fired more liberally during hostilities in the presence of loud noise.

Of the three remaining studies concerned with stress, the study by Berkun (1964) revealed that soldiers' attempts to repair a broken telephone were negatively affected by fear of harm but less so for more experienced soldiers. Research by Gildea et al. (2007) provided evidence that learning on the Space Fortress video game, requiring operation of a joystick input device, could be predicted by participants' stress appraisals in relation to the task prior to beginning their training. Last, motor restlessness was used as an index of stress during a vigilance task studied by Galinksy et al. (1993) and increased with the length of the vigilance interval.

Thus, in only three of the nine studies identified from the review is there a consideration of emotion-related concepts other than stress. Biersner et al. (1977) attempted to predict the outcome of sports games from pregame self-reported happiness and depression and found that depression rose significantly prior to lost games for skilled players but not for unskilled players.

The study by Matthews et al. (1998) was concerned primarily with driver stress but involved a multidimensional conceptualization of the construct, developed by Gulian, Matthews, Glendon, Davies, and Debney (1989), comprising multiple emotions. According to Gulian et al., driver stress involves three main factors: driving aggression, which concerns irritation, impatience, and behavioral aggression; dislike of

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driving, which concerns anxiety, unhappiness, and lack of confidence; and driving alertness, which concerns active monitoring of potential hazards. These factors are measured by the Driving Behavior Inventory (Gulian et al., 1989), which Matthews et al. used in an attempt to predict vehicle control in a driving simulator. These authors found that individuals reporting high dislike of driving had reduced driving control skills, and those reporting high driving aggression were more frequent and error prone in their overtaking.

Although Worchel et al. (1997) did not attempt to measure any type of emotion, their results were explained with reference to an emotional mechanism. These authors studied the effect of competition in the learning of Space Fortress, a video game discussed earlier. Competition was shown to aid task performance for participants with greater aptitude for the task, measured as self-reported aptitude for using computers and via baseline testing on the task, but negatively affected performance for those with lower task aptitude. These results were interpreted with reference to an expanded view of social facilitation theory (Zajonc, 1965), in which competition is thought to increase arousal levels, which promotes dominant responses. This is useful for higher-aptitude performers, in whom appropriate task responses are relatively dominant, but is detrimental for lower-aptitude performers, in whom inappropriate task responses are relatively dominant.

Also notable about the nine studies identified here is that their focus is not on any particular aspect of movement but is instead on variables related to overall task performance (e.g., time taken to repair a telephone; Berkun, 1964). This finding is not surprising, given that HF is an applied field and overall task performance is of clear practical importance. Nonetheless, a prerequisite to improving performance on tasks involving movements, through either changes in training or alterations in interface design, is to understand the factors, including emotion, that affect the production and control of the movements involved in completing the task.

Therefore, we recommend that HF researchers consider carefully how different emotions, such as happiness, sadness, fear, and joy, affect the planning and control of movements in interaction with machine systems. Insights into these effects would inform the development of interfaces and input devices of interest to HF researchers (e.g., Rogers, Fisk, McLaughlin, & Pak, 2005). To inform the design process, we propose that HF researchers strive toward establishing *principles of emotional compatibility* based on the identification of natural relationships between emotion and movement. For example, research in HF might converge on the findings by sport psychologists that threat appraisals expedite extension movements (described earlier). If so, then a basis would be provided for an emotionally compatible design principle that states that systems should be designed so that in conditions eliciting threat appraisals, the appropriate response within the interface involves a movement away from the body.

Future research might also attempt to identify maladaptive alterations to movement planning and control arising from particular emotions, as these must underlie critical human errors that compromise overt behavior, leading to fatigue, injury, performance failure, and death. Research of this type would allow input devices to be designed to better accommodate these problems. We hope that this article will help stimulate such research.

SUMMARY AND CONCLUSION

In the current article, we showed that the field of HF, as it is represented within this journal, has paid little attention historically to emotion-related concepts, with the exception of stress. The import of this shortcoming is made clear when it is considered that *Homo sapiens* is often regarded as *the* "emotional animal"; its actions, and the decision making leading to them, are shaped markedly by dynamic emotional processes (Stephan, 2009). If this is indeed the case and, as HF researchers have recently argued, humans remain a vital component within work systems despite marked advances in technology and automation (Parasuraman & Wickens, 2008), then researchers and designers of work systems cannot afford to continue to be "affect blind" (Whang et al., 2003, p. 623).

The central mission of the article was to show how research on emotion in sport psychology

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TABLE 2: Future Research Goals for the Field of Human Factors in Three Areas of Research on Emotion

Future Research Goals
Emotional preparation for performance
Identify psychological skills used by (skilled) operators to self-regulate emotional states
Explore how any identified skills were developed and use the results to inform training in the skills
Investigate the efficacy of training novice operators in the use of such skills
Explore how systems can be designed to sense the onset of emotional states shown to negatively affect task performance
Explore how systems can be designed to support the operator's use of psychological skills shown to be effective in reducing emotional states that negatively affect task performance and promote those that positively affect such performance
Emotional traits
Examine how operators' use of work systems is affected by emotional traits and their interaction with emotional states
Derive principles for system design on the basis of these findings
Test the efficacy of interfaces and work systems designed on the basis of these principles
Explore the efficacy of selection on the basis of individual differences in emotional traits
Explore the efficacy of tailoring training according to individual differences in emotional traits
Emotion and motor functioning
Identify the effects of individual emotions on simple movements involved in operation of work systems
Derive principles of emotional compatibility for input devices on the basis of these findings
Test the efficacy of input devices designed on the basis of these principles
Identify maladaptive alterations to movement planning and control arising from particular emotions

might help change this situation. To this end, three areas of research on emotion within sport psychology were showcased, and the theories, methods, and applications associated with this research were described. The implications of each area for HF were then discussed, and future research directions for the field were proposed.

The first area involved a review of skilled athletes' use of emotional self-regulatory skills to achieve psychological states optimal for performance in both practice and competition. The review showed that although HF researchers have investigated task-related factors (e.g., operator time on task) and environment-related factors (e.g., type of display) affecting system performance, they have all but ignored the role of the human operator in this regard. In reaction to this situation, it was proposed that the potential development of emotional self-regulatory skills by proficient operators might be an important human factor contributing to effective systems performance and should be targeted in future research.

The second area involved a review of recent research indicating that an emotional trait could explain risk-taking behavior in dangerous domains. The review highlighted how individual differences research in HF has essentially overlooked emotional traits in favor of perceptual and cognitive constructs but how initiating research in HF on emotional traits might add significant value to key areas in the field, such as selection, training, and system design.

The third area concerned research on the link between emotion and motor behavior. It was shown that the historical interest with movement within HF has not included a consideration for how emotions affect movements—a surprising situation, given the interest in the field in identifying best principles for the design of input devices. Proposed was that research on the effects of emotions on movements might lead to the development of principles of emotional compatibility for the design of input devices and work systems more generally. The suggestions made for future research in these sections are summarized in Table 2 as future research goals. It is anticipated that these goals will stimulate research on emotion within HF.

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We hope that this article will not only inform HF about research on emotion in sport psychology and its implications for the HF field but also stimulate HF researchers and sport psychologists to consider how to move forward together to solve problems related to emotion that are common to both fields (cf. Fiore, Hoffman, & Salas, 2008). Salzinger (2003) claimed that "the way in which our universities have divided up the sciences does not reflect the way in which nature has divided up its problems" (p. 3). This appears to be true in relation to some key natural problems being tackled by the sciences of sport psychology and HF, including how best to address and accommodate negative effects of human emotion within the environments typifying these domains.

In conclusion, we believe that HF researchers and designers must begin to consider the effects of human emotion in the workplace if they expect to continue to enhance workplace productivity, safety, and health. Hopefully, by highlighting research efforts by sports psychologists in the area of emotion, we have been able to inject some much needed emotion into the field of HF. It is now up to the research community in the field to consider the extent to which the theories, methods, and applications outlined here can usefully inform future research on emotion in HF and ultimately lead to more accurate principles and guidelines, and tools and interventions, for the design of man-machine systems.

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KEY POINTS

- Although there is some acknowledgment within human factors that emotion is a "critical" human factor absent from the field, this topic remains largely underresearched within the field.
- Research on emotion within human factors will benefit from a consideration of theory and research on this topic within the field of sport psychology.
- As sport psychology and human factors are essentially applied fields concerned with enhancing performance in complex, real-world domains, continued cross-talk about research on emotion and related topics will advance both fields.

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