CHAPTER 14

A conceptual framework for studying emotions–cognitions–performance linkage under conditions that vary in perceived pressure

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Abstract: A unified conceptual framework, which integrates the structural components of human performance, such as emotional processes (i.e., feelings, mood), cognitive processes and structures (e.g., knowledge architecture, long-term working memory), motor processes (coordination, endurance), and the neurophysiologic basis of these structural components (i.e., activation of cortical areas) is introduced. Recent developments in the cognitive, neurological, expertise, and emotion sciences provide a sound evidence for this conceptualization. The unified conceptual framework enables a better understanding of human performance, and allows generating applications, which share scientific validity.

Keywords: mental representation; emotions; brain activity; cognitive processes; action

Introduction

Many performers exhibit high-level performance in practice, but sometimes struggle under stressful/competitive conditions (see Beilock and Gray, 2007 for extensive review). Though motor skills and mental representations of these skills are inherited and learned, the performer’s use of them alters under emotional/mental and temporal pressure. How does the emotional–cognitive–motor linkage change under pressure? What are the underlying mechanisms that permit or prevent an efficient course of action? Questions such as these cannot be answered with confidence at this stage. Though sound theories and extensive research have been devoted to explore this linkage, almost all efforts have not taken an integrative approach to answer these questions. In this chapter, a conceptual framework is provided offering an integrative approach to study mental and motor operations under emotion-invoking pressure conditions.

There is a substantial interest in exploring a framework of human performance. Yet, foundations for the experimental analysis of the structure

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and functioning of human capabilities to perform have only been established in recent years as new methods in cognitive neuroscience and movement science have developed. Our aim in this chapter is to compile results from various fields, such as intelligence, problem solving, emotions and emotion regulation, action and the motor system, and expertise, and to make comprehensive claims regarding the underlying mechanisms of human performance. Once these mechanisms are uncovered, ecologic applications can be made to enhance performance. So far, the structural components of human performance, such as emotional processes (i.e., feelings, mood), cognitive processes and structures (e.g., knowledge architecture, long-term working memory), motor processes (coordination, endurance), and the neurophysiologic basis of these structural components (i.e., activation of cortical areas) have been studied independently. We integrate current understandings into a unified theoretical framework to enable a better understanding of human performance.

Basic assumptions and concepts

Every conscious action made by humans is a consequence of response selection, whether intentional or unintentional. By definition, response selection indicates adaptive behavior based upon the capacity to solve problems. This “behavioral effectiveness” is directed by cognitive processes and mental operation. The effectiveness of these processes consists of the richness and variety of perceptions processed at a given time; that is, the system capacity to encode (store and represent) and access (retrieve) information relevant to the task being performed (Tenenbaum, 2003). From an information-processing perspective, motor behaviors consist of encoding relevant environmental cues through the utilization of attentional strategies, processing the information through an ongoing interaction between working memory and long-term memory, making an action-related decision, and executing the action while leaving room for refinements and modifications. Under pressure, changes in each of these components are seen. These changes are sequential in nature (i.e., begin with the perceptual components, continue with the cognitive components, and end with the motor system). Taking a complimentary perspective, the cognitive construction of human actions consists of four levels, each with a designated function (Schack, 2004a, b; see Table 1). The function of the mental control level (level IV) is sketched for voluntary movement regulation, and the coding or the anticipated outcome of movement. The mental representations level (level III) predominantly forms a cognitive benchmark for the mental control level (i.e., level IV). It is organized conceptually, and is responsible for transferring the anticipated action outcome into a model of the movement structure it requires. Because an action is “no chain of details, but a structure subdivided into details” (Bernstein, 1988, p. 27, translated), movement organization must have a working model of this structure at its disposal. The corresponding abilities for using movement representations have been acquired stepwise during technical preparation. These movement representations hold the knowledge that relates directly to performance. However, the model also clearly reveals that these representations are functionally embedded in further levels and components of action organization. Therefore, the functioning of the lower levels (levels I and II) is sketched as well. The level of sensorimotor control is linked directly to the

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environment. In contrast to the level of mental control (level IV), which is induced intentionally, the level of sensorimotor control (level I) is induced perceptually.

For the stability of practical performance, all four levels are of significance. Yet, if excellent performance is shown under neutral conditions but collapses under pressure, one should assume that though cognitive and motor systems are established, the performer's access to these systems under pressure is impaired. It is furthermore plausible that there is another system besides the predominantly cognitive motor system, which, among other things, is accountable for the control of emotional processes (i.e., self-regulation and mental control). For working purposes, reliance on three independent, but inter-related systems is made:

- Cognitive structure components and processes (cognitive appraisal)
- Emotional system
- Self-regulation structure (e.g., various strategies are applied here: emotional control, motivation control, attention control, etc.).

When performance is satisfactory under neutral (nonpressure) conditions, all levels (see Table 1) function harmoniously and optimally.

**Current state of the art on the emotions–cognitions–performance linkage**

**Affect, emotions, and links to cognition**

According to Rosenberg (1998), affective traits are stable predispositions, which determine emotional responses, and reflect individual differences in emotional reactivity. Similar to affective traits, moods determine the threshold of occurrence of a given emotion. The classification of emotions as “positive” (e.g., pride, pleasure) or “negative” (e.g., anxiety, anger) is frequently based on hedonic tone (i.e., pleasant vs. unpleasant). Therefore, positive emotions are mistakenly thought to be good or desirable, while negative emotions are thought to be bad or undesirable (Plutchik, 2003). However, such categorization does not have a functional basis. Emotions motivate, organize, and guide perception, thought processes, and mobilize action towards a behavioral purpose. Positive or pleasant emotions are believed to have a role of enlarging the behavioral and thought repertoire to face a given situation (Fredrickson, 1998). A wider repertoire allows the individuals to create and develop new solutions, and enhance personal resources. Such an enhancement is associated with several processes: (1) expansion of attention focus, (2) expansion of cognitive processes, (3) expansion of action possibilities, by inducing unusual and diverse responses that add to subjects' personal resources, (4) expansion of intellectual resources, and (5) expansion of social resources (Fredrickson, 1998). The effects of positive emotions are also relevant for performers who operate under stressful conditions as they may increase the spectrum of relevant information attended to, encourage the utilization of novel and unpredictable strategies and actions, prompt the development of mastery, and enhance team interactions. These factors increase the likelihood of successful performance. By verifying the broader functions of emotions, it is possible to generate their positive effects while reducing their negative potential (Damašio, 1994).

Negative emotions, such as anxiety, should be understood not only as having an undermining effect on performance, but also as a process of adaptation to specific events or a motivating factor for a particular action. A performer’s anxiety in a particular moment of an action can reinforce his/her sensitivity to dangerous situations, prompting adoption of defensive strategies, and engaging in more realistic decision making. Carver and Scheier’s (1988) control process model of anxiety and performance holds that anxiety can have both facilitative and debilitative effects on performance depending on subjects’ expectancy of being able to cope with anxiety and complete the action. Support for this contention in sport comes from the work of Jones and colleagues, where highly skilled swimmers (Jones et al., 1994) and cricketers (Jones and Swain, 1995) interpreted both cognitive and somatic anxiety symptoms as more facilitative to performance. Swimmers who had positive expectancies...
of goal attainment interpreted anxiety as more facilitative than swimmers who had negative expectations of goal attainment (Jones and Hanton, 1996). Thus, cognitive anxiety can improve motivation and facilitate appropriate attention focus (Jones et al., 1993).

When movements were performed following exposure to emotional stimuli, active defensive circuitry resulted in faster, but more variable, voluntary movements. In the study of Coombes et al. (2006), exposure to unpleasant images led to an increase in mean force production of a sustained voluntary movement more than exposure to pleasant stimuli, as well as acceleration of central processing times. Furthermore, the length of exposure to affective stimuli mediated speed and accuracy of motor performance; compared to pleasant stimuli, unpleasant stimuli led to either increased error or increased speed. According to biphasic theory of emotion (Lang et al., 1997), the wide array of emotion can be classified by two dimensions; valence (i.e., appetitive or defensive), and arousal intensity. When performing a task, the two affective dimensions are activated by the functional brain, priming physiologic adaptations and mental representations, which correspond with the environmental context. Thus, the nature of the task, the context, and the emotion eliciting stimuli all mediate the production of movement (Coombes et al., 2006).

The relationship between emotion and cognition from an action-oriented perspective is depicted in Fig. 1. The appraisal of events, action effects, or stimuli in the environment is the first cognitive process in action organization in the model. The result of appraisal is not only stored in memory, but is of central meaning for evoking emotions. The stimuli and appraisal-dependent emotions are stored in memory as specific elements of cognitive event profiles. Furthermore, emotions are functionally linked with the beginning and maintaining of motivation. One stimulus may produce not only one, but several types of motivation.

At this stage, the level of mental control comes into play. Processing at this level starts with the decision about a relevant action. The result of this decision-making process is the intention to reach specific action effects. Based on this intention an action plan is created and the mental control processing runs to a module, which is responsible for action-execution. This module is linked to the level of sensorimotor control (see Table 1), and includes all motor components necessary for production of goal-directed action effects. The kind and quality of action effects are important information for the action system. But if the action effects are not congruent to the intended outcomes, or not valid to cope with the actual situation, the appraisal system will read an insufficient action, and will evoke negative emotions. In case of problems in action realization (e.g., the real situation in competition is much more difficult than the expected one), mental control processing must run through another path. Now, the performer must use action strategies such as control of attention, control of emotion, or motivational control. Such strategies are supported by inner speech, and are used to stabilize action realization. Thus, if the performer lacks such strategies, he/she has no tools to control the action in a befitting manner. If the performer lacks mental control, he/she will not realize his/her intentions and will lack intended action effects. This kind of information is negatively valued by the appraisal system, and influences the development of emotions dramatically. Thus, one important link between emotion and information storage is caused by the representation of emotionally induced action effects in long-term memory. From this point of view, emotions are a part of information storage in general.

Emotions can be viewed as memory units (Bower, 1981). They are components linked to the memory system that facilitate access to mental representations associated with targets of judgment (Forgas, 1991). Due to prior associations, innate and learned environmental situations activate particular emotion nodes stored in memory. This activation spreads throughout neuronal circuits to mental representations of events associated with that emotion influencing encoding and retrieval of material, as well as the valence of judgments of people, events, objects, and behaviors (Bower, 1991). Emotions are activated by experiencing the emotions again, or by activation of any
of their links (Barry et al., 2004). The stronger the activation of particular emotional nodes is, the greater the mood-congruent effect. When emotions are strongly activated emotion-congruent constructs (e.g., concepts, words, themes, and rules of inference) become primed and available for use bringing into readiness certain perceptual categories, themes, or ways of interpreting the world congruent with current emotional states. In affect-priming terms, an emotion node spreads activation throughout the memories to which it is connected, increasing the chance that those memories will be retrieved (Bower, 1981).

Emotions are stored in memory as functional elements of event files. Changes of emotional states trigger the related event files (see Fig. 1), and activates related structures of mental representation. This is important for capturing human performance because perception and action are based on the same representation structures (see coding theory; Prinz, 2005). Such an emotion-based activation of representation affects the perception of the actual situation, and the focus of attention. Therefore, there is the risk that a vicious circle (i.e., a no-win situation) between threatening stimuli, and negative emotional states, which activates event files, representation structures, and focuses attention on threatening stimuli, with performance decrement as a probable result.

The model proposed in Fig. 1 enhances capturing the complex interaction between emotion, judgment, and decision making. After perceiving a situation or a stimulus-configuration, appraisal processes play an important role for the formation of emotions. The appraisal of a particular situation is based on different memory traces. In case of positive experience and a high congruence
between intended and actual action, positive-oriented memory sources become the reference point for appraisal. The result of such an appraisal process could be in the form of a positive mood. The positive mood affects the generation of motivation in this situation, and influences the process of decision making (see Fig. 1).

In turn, emotions influence the judgments about situations both directly and indirectly. The direct influence is based on the development of different types of motivation, which result in appraisal-based emotions. The question in this stage of action processing is, how much and what type of motivation is generated in a situation? The indirect influence has to do with the informational quality of emotions, and is a reference point for decision making and judgments. Thus, one may decide more holistically, or nonanalytically, in case of positive mood. From this point of view, the direct influence of emotions has to do with the content of decision making, especially the number and quality of motivation, while the indirect influence of emotions is defined by the type of decision making (holistic vs. analytic mode of decision making). This emotion-based influence on mental control modes is valid for action organization, because the formation of emotions is grounded on memory-based appraisal processes (see Fig. 1). To conclude, emotions are important information sources for individuals’ decision making and mental control. For instance, concerning a special situation, positive mood is an indicator for successful coping, and an effective action organization in the past. This information reduces the probability of errors in action, or the probability for threat and danger.

As can be noted in the model (see Table 1), processes of mental regulations are required for a high capacity of information processing and mental control. They take place at the lower sensorimotor levels, and have to do with the use of basic routines and sensorimotor representation structures. At the level of mental control it is important to generate valid plans and to control attention and emotions in case of unexpected external events in the action organization. Basic regulation must generate and implement such tools like routines at the lower level, and implement control strategies at the mental control level. If such steps are taken, the action system contains sufficient capacity for the regulation of the actual action.

Affect can also be used as input for cognitive processing and behavior. Positive affective states inform subjects that the environment is safe, and no specific action is required (Schwarz and Bless, 1991). According to Schwarz and Bless, people experiencing positive affects also benefit from greater cognitive flexibility, being able to establish more word associations, and find more relationships or differences between concepts than controls. Subjects in negative moods are constrained by the identified problematic situation, thus access to and application of diverse knowledge structures are less flexible, and performance decline is more probable. Thus, emotions can be seen as preceding or resulting from an action as well as “accompanying” it, and creating a coping style, which must be considered when performing an action, particularly under pressure conditions.

The model shows a functional relationship between the level of mental control and emotions (Fig. 1). From this point of view, the development of emotions is functionally related to the actual generated action effects. Of importance for the formation of emotions is the difference between intended and actual effects, and the appraisal of a difference. For this reason, the model is in accordance with specific emotion theories. Mandler (1979; 1985) assumes that the abort of a planned action can be seen as a central reason for anxiety development. Based on Mandler’s approach, task-relevant stimuli are perceived through the increased interruption of the action. In turn, these stimuli demand their own attention resources, and therefore disturb action performance. Thus, anxiety could not only be the reason of a performance interruption, but also stringently seen as its consequence. The models (see Table 1 and Fig. 1) consists of the assumption that the interruption of activated performance plans and the increasing inability to subordinate the action performance to an action program are attributed both emotionally and negatively. Particularly, through the collapse of solid connections within the system of mental control, the inner speech loses
the function of an instrument of action control (see Schack, 1997). The result is a functional damage of mental control; a mental control deficit. One can deduce three reasons for the development of such a mental control deficit including the involved emotional reactions from the model.

The first reason is the development of an inappropriate action plan. On the basis of the former, specifically negative, experience within an action space, and therefore motivated by specific information–evaluation mechanisms in the appraisal system, a biased scheme of the internal and external action conditions is underlying the process. Subsequently, reference stimuli are selected, which match this appropriate scheme, and influence the information processing disadvantageously. Already before selecting an action, one must rely on a cognitive scheme, which was established through former experience, which suggests the recourse to stereotypical action sequences (e.g., avoidance, dysfunctional internal dialogue, etc.). The second reason of the mental control deficit issue is directly related to the first reason, and refers to the deficient availability of action control strategies. A shortcoming of aim-oriented control of the action performance (e.g., failure of coping or motivation control), can lead to termination of the initiated action and the collapse of the mental control.

The third reason of such an action control deficit is related to a collapse of the control anticipation. With decreases of the anticipatory system to perform and control an action, and cope with incidental difficulties when performing an action, the effect of negative emotions increases within the process of action argumentation and action performance (Bandura, 1991; Carver and Scheier, 1991). Finally, affective reactions can inhibit an organized course of the interaction of cognitive processes during the action construction, and prevent the building of solid connections of mental control (Schack, 1997).

The notion of appraisal and coping

People make decisions based on an evaluation or appraisal process through which the transaction is judged to be essential in maintaining, enhancing, or hindering well-being (Lazarus, 1999). When encountering a stressful condition, people appraise the resources they can use to cope with the situational demands. Primary appraisal consists of judgments concerning the relevance of what is happening in the transaction to one’s values, goal commitments, beliefs about self and the world, and situational intentions. Secondary appraisal, which may precede primary appraisal in some cases, refers to a cognitive–evaluative process that is focused on what can be done about a stressful transaction. This type of appraisal refers to subjects’ evaluation of such factors as agency, future expectancies, and coping options. Positive emotions arise in the presence of favorable conditions, but negative emotions follow under unfavorable ones.

Generally, as it is assumed in the model, the triggering of emotional states is bound to appraisal processes, whereupon the necessary information evaluation results from the evaluation criteria. Phylogenetically predispositioned (i.e., subcortical) evaluation mechanisms are related to an immediate appraisal system, whereas experience-dependent (ontogenetically experienced) evaluation mechanisms are assigned to a (cortically attached) memory-dependent appraisal system. The former mechanisms are connected to parts of the limbic system, and therefore can generate emotional reactions virtually concurrently when getting information, which is liable to a primary (subcortical) evaluation. If information relies on an individual memory inventory, which can only be evaluated through experience-based representations, then the triggering of emotional reactions takes place after the cognitive processing. Here, both the experience the performers have gathered in certain situations, and the coping strategies they have at their disposal are of vital importance to the quality of action generation and control.

Coping

Coping refers to “constantly changing cognitive and behavioral efforts to manage specific external and/or internal demands that are appraised as taxing or exceeding the resources of the person”
Lazarus and Folkman, 1984, p. 141). Thus, coping is an ongoing process that takes into account the “fit between what one does, the requirements of the conditions being faced, and one’s individual needs” (Lazarus, 1999, p. 80). Lazarus considers that good coping consists not only of choosing the most adequate strategy, but also being flexible about abandoning an effective strategy for another, even more effective one. Coping helps subjects to deal with aspects of a problem (i.e., problem focused), and with the emotions associated with it (i.e., emotion focused). Endler and Parker (1990) added avoidance-coping as another dimension.

Appraisals and coping are considered to be associated with emotions (Lazarus, 1999). In order for a coping response to be executed, one has to evaluate what is at stake (i.e., primary appraisal), and whether one can cope with the situation (i.e., secondary appraisal). In contrast, efficient coping processes also influence and change appraisals and the nature of the transaction. As a threatening person–environment relationship is reappraised, a new relational meaning of the stressful encounter is constructed (Folkman and Lazarus, 1990), and different emotions arise.

The conceptual framework presented here extends Lazarus’s (1999) concept, as it is more suitable to the motor domain. It assumes that two basic forms of performance regulation are necessary to secure smooth performance: a process regulation and a basic regulation. While the latter regulates emotional–motivational basic processes, the former accounts for the precise execution of the action goals. Process regulation builds on basic regulation; basic regulation creates the necessary conditions for process regulation. As known from many situations in sport, some athletes falter in competition despite being able to perform well under training conditions. It is argued here that these athletes show good process regulation under low pressure, but they fail to do likewise under high pressure. In such cases, it is possible to diagnose difficulties in basic regulation. Basic regulation stabilizes the action system under different pressure conditions. Thus, the goal of basic regulation is to stabilize the emotional and motivational processes in every situation of action organization. Therefore, basis regulation uses different tools at every level of action organization.

At the level of sensorimotor control, routines are helpful to operate an optimal fit among anticipation of perceptual action effects, perceptual input, and behavior units for stabilizing emotions. Routines provide an athlete with a consistent set of behaviors that can be specifically activated in moments of intense pressure and in those situations when it is difficult to become motivated. Routines give performers a sense of security and the confidence that they can rise up to meet the challenge. At the level of mental control, well-functioning performers are using a toolbox of strategies to control emotion and motivation. These strategies are based on inner speech (i.e., self-instructions), and are considered important psychological tools for coping with adversity (Schack, 1997).

In contrast to basic regulation, the process regulation is a procedure responsible for controlling the actual action organization. Process regulation activates and focuses modules like, for instance, attention and motor decisions making for reaching goal-directed action effects. Basic regulation and process regulation are not separated in reality. Furthermore, they contribute in a separate and specific manner to the same action and to the same performance. But if performers fail to reach the anticipated effects, and do not perform well, it is necessary to look closer to the covert regulation processes, to distinguish between deficits in basic regulation and deficits in process regulation. In some cases, one may suffer deficits in both regulation types. To improve process regulation one must use training procedures in general (e.g., imagery training), which are determined at the level of mental representation (see Fig. 1). To improve basic regulation one must use specific self-regulation trainings (e.g., stress-regulation trainings), which are working at the level of mental control. Here, one must develop strategies to control emotions in an appropriate manner.
Physiological and cognitive consequences of emotions on performance

Rooted on the premise that negative emotions have very specific autonomic changes, and positive emotions are characterized by a relative lack of autonomic reactivity, Fredrickson et al. (2000) described positive emotion action tendencies as nonspecific. Based on the different action tendencies of both types of emotions, it was hypothesized that positive emotions undo the cardiovascular after-effects of negative emotions. Because negative emotions narrow individuals’ thought-action repertoires while positive emotions broaden them (Fredrickson, 1998), the latter might serve to correct the effects of the former. Therefore, if negative emotions increase cardiovascular activity, preparing the body for quick and vigorous action, positive emotions facilitate recovery of cardiovascular function. Indeed, Fredrickson et al. (2000) found that after anxiety-induced cardiovascular reactivity, contentment- and amusement-eliciting films produced faster cardiovascular recovery than neutral or sad films. When these films were viewed after an emotionally neutral film, positive emotional states were not significantly different than neutral states in maintaining the physiological activation. That is, the reduced autonomic reactivity occurred only after initial heightened physiological activation due to negative emotions. In addition, cardiovascular activation after negative emotions was found to last longer than after positive emotions, regardless of reactivity (i.e., initial activation). The prolonged activation observed after negative emotions was speculated to be the product of ruminative thoughts (Brosschot and Thayer, 2003).

The findings of prolonged activation and faster recovery of cardiovascular activity associated with positive emotions (Fredrickson et al., 2000) have relevant implications as they support the need for intervening, in clinical contexts, with both types of emotions. When excessive activation is associated with an unpleasant hedonic tone, cognitive restructuring may facilitate positive emotions and rapid recovery. This has a significant impact on performance, not only because excessive arousal may reduce information processing (Easterbrook, 1959), but also because athletes may use this physiologic activation as a cue to build their self-efficacy (Bandura, 1997).

Arousal is thought to have a curvilinear relationship with performance (Easterbrook, 1959). Experienced at an optimal level, arousal maintains an optimal attention focus that consists of allocation of sufficient attention resources to task-relevant cues, while filtering or ignoring task-irrelevant cues. Departures from those optimal states results in performance impairment by altering performer’s attention focus, resulting in the inability to pay attention to relevant cues (i.e., overarousal induces excessive narrowing of attention focus) or inability to ignore irrelevant cues (i.e., underarousal induces an excessively broad attention focus).

In a dual-task autoracing simulation, drivers who were highly anxious experienced an altered ability to acquire peripheral information at the perceptual level (Janelle et al., 1999). At higher levels of anxiety, the identification of peripheral lights became slower and less accurate, and significant performance decrements occurred in central and peripheral tasks. A variety of negative and positive emotions are also associated with increased activation; making it unclear whether it is the arousal or the valence of the emotions responsible for alterations on information processing. It is likely that arousal may interfere differently with cognitive processes, and consequently with motor performance when associated with different hedonic tones.

Variation of psychological and physiologic activation due to the stress response has an effect on the width of attention field, level of distractibility, amount of investment in controlled processing, and efficiency of attention processing (Janelle, 2002). These processes depend largely on the emotional experience (Mellalieu, 2003). In line with the research on specific psychological and physiologic appraisal responses (e.g., Tomaka et al., 1997), it would be important to determine how the cognitive changes are influenced by different appraisals of the stressful situation (i.e., threatening vs. challenging situation).
Extensive research studying marksmen has focused on the impact of arousal on sustained attention and performance; mainly distinguishing arousal, a nonspecific concept, from vigilance, a “preparatory attention state associated with anticipated cognitive/perceptual or behavioral activity independent of arousal” (Tremayne and Barry, 2001). Vigilance has a marked behavioral connotation involving “sustained readiness to detect and respond to environmental changes: it is an active, performance-related process involving perception of stimuli and information processing” (Collet et al., 1996, p. 954).

An increased activation level, measured by electrodermal activity, has been found to limit performance in sharp (rifle) shooters (Caterini et al., 1995). Caterini et al. described good shooting performances as characterized by low amplitude and increased duration of response of physiologic adaptations representing better mastery of emotional reactivity and greater concentration time, respectively. In contrast, systematic decrease in activation prior to the shot did not discriminate between best and worst shots (Tremayne and Barry, 2001). However, experts developed a marked state of attention focusing in the 10–15 s prior to shot initiation. If this state is enhanced and extended to the shot, better performance occurs. Worse shots take place when there is less vigilance, and when shot-initiation is delayed until reduced maximum vigilance occurs.

Tremayne and Barry (2001) compared physiological patterns of best versus worst shots. In expert pistol shooters, lower pre-shot electrodermal levels and longer and more systematic pre-shot cardiac deceleration characterized best shots compared with worst shots. Comparing with novices, experts underwent a slow reduction in skin conductance and heart rate levels before the shot, and “rebound” increase immediately after the shot, which were not observed in novices.

The concept presented in Table 1 and Fig. 1 allows studying the cognitive patterns related to different tasks, stress sources (pressure information), and related emotions. The patterns concerning the “pressure” information representation and the relationship between “pressure” information and emotions are the reference point for appraisal in real situations. These links allow predicting emotional states, and modifying the reference points (i.e., benchmarks) of the appraisal systems, and measure the link between the representation of threatening situations and the representation of action organization in these situations. The goal is to strengthen the productive links between the representation of the situation and the representation of the action (Nitsch, 2004; Schack and Hackfort, 2007). In the motor performance domain, one must capture the mental representations of situational components, such as the representation of the team structure, or the representation of the environmental conditions of a specific competition. Furthermore, one must know what type of activities performers have represented to cope with situations that vary in many respects. Finally, it is essential to measure the types of event-representations and action representations, and look for the fit between these two representation types. A misfit between these representations may lead to emotions of stress and anxiety. From this perspective, looking at the emotional process itself is insufficient, without measuring the cognitive benchmarks (especially event and action representations) of the appraisal process, which constitutes the development of emotions in action (see Fig. 1).

Cerebral cortical activity during skilled visuo-motor performance — a model to assess the impact of emotions during performance

The superior performer shows relaxation in non-essential areas of the brain and minimizes communication between the thinking and the motor regions — in essence, they become instinctive and efficient. Figure 2 illustrates brain electrical activity maps that reveal higher cortical activity (i.e., electroencephalogram (EEG) gamma power) in novice shooters compared to expert shooters. The gamma power is positively related to cerebral cortical activation and the higher levels exhibited by the novices implies a “noisy” or less stable platform from which to initiate motor commands to the skeletal muscles. Such a state would result in greater performance variability and diminished
accuracy, which is typically the case with the novice. The lower levels of gamma power in the expert reduces such neuromotor noise, thus enabling greater consistency of performance, which is a hallmark of expert performance. In addition, the appearance of such cortical "noise" in the expert under conditions of psychological stress can result in a reversion of performance level to that of the novice (see Hatfield et al., 2004 for extensive review).

As such, the "busy" or noisy mind of the novices is associated with increased variability of the aiming trajectory as compared to that of the experts. More specifically, EEG studies of expert marksmen have revealed less activation in the left temporal region (T3), relative to that observed in the right homologous region, during the aiming period leading up to the trigger pull (Hatfield et al., 1984) implying an adaptive state of regional relaxation whereby potential interference from left-hemispheric verbal–analytic activity with automated motor processes is effectively managed. This finding has particular significance relative to earlier discussion in this paper in which negative moods were posited to elicit analytic step-by-step strategies. Accordingly, such strategic thinking is associated with the left hemisphere, and the study results imply both a lack of such an analytical cognitive approach, as well as a diminution of negative affect, during expert motor performance. Similarly, Haufler et al. (2000) observed less activation in the frontal, central, temporal, parietal, and occipital regions in expert shooters relative to novices. The skill difference was of greatest magnitude in the left temporal region, and revealed a similar pattern of temporal asymmetry in the experts to that observed earlier by Hatfield et al. (1984). The experts accomplished the task in a more efficient manner as indicated by the EEG. No differences in cortical activation were noted between the groups when they performed cognitive tasks with which the participants were equally familiar, suggesting that the task-specific EEG differences were obtained as a result of practice and skill level. It could be theorized that those who perform best under
pressure are able to maintain cortical relaxation during challenge, while those who fail to maintain such a state are more likely to “choke.”

The relationship between expertise, cortical activation, and order formation in long-term memory is considered a major challenge. To learn more about these interactions and networks, one must combine the neurophysiological methods, like EEG-coherence measures (Deeny et al., 2003), and methods for measuring the structure of mental representation (Schack, 1999). In order to learn more about such relationships, a pilot study was conducted by Schack (2003). Twelve experts and 12 novices performing rotational movements in the field of gymnastics were examined on representations of somersault flights. To examine cortical activity for these movement representations, a special measurement of the neuronal activity in the brain was employed. The assumption was that information recall in the memory is accompanied by space and time defined changes in excitability in neuronal network structures; this is the basis of the neurophysiologic measurement. The EEG-coherence method (Schack, 1999) was used for this purpose. Here activity of cortical areas is revealed by a sequence of coherence maps, which remain stable over time.

The analysis of the structural dimension analysis of motor memory (SDA-M) data pointed to differences between the mental representations according to the level of expertise. It was shown that the cognitive structure of experts is close to the biomechanical structure of the actual movement. The representations of experts were highly differentiated, and were more strongly function oriented than the novices’ representations using a special invariance measure. The simultaneous neurophysiologic findings indicated that experts’ cognitive activation of movement representations is accompanied by activation of several cortical areas. These patterns of activation provide a glimpse of the network of neurophysiologic areas with a high mental economy and a high stability. It seems that there are two different functions of activation concerning the time-related steering of movements and concerning space-oriented aspects of movement representations. A failure to obtain a stable activation of separate areas in movement representation was evident.

Another interesting question has to do with a systematic study of differences in cortical activation in perception of object and action concepts. Some studies were carried out to measure the cortical activation in perception of object concepts (Krause, 2000). Findings revealed the same kind of activation in the brain while performing and imagining actions (Jeannerod, 2004). Most of these studies were conducted through simple hand or finger movements. It would be challenging to measure the corresponding cortical activation in the brain using basic action concepts (BACS; e.g., the task-related elements, which constitute together the mental representations structure) of complex actions in experimental settings, and to find out about possible differences concerning the involved areas in object and action concepts.

Although evidence consisted of stationary self-paced target shooting, Kerick et al. (2004) recently extended the study of brain processes during skilled marksmanship to reactive shooting scenarios in which soldiers and marines had to react quickly to “pop-up” targets and discriminate between friend and foe stimuli. That is, they had to suppress firing on the friendly targets, and engage the enemy targets in an attempt to more closely approximate the kinds of challenges faced by soldiers in the field. The study attempted to achieve a degree of ecological validity for warfare conditions and, importantly, revealed the classic left temporal relaxation effect during the aiming period in the highly skilled group of participants. In addition, the investigators noted a decrease in alpha power as they progressively challenged the study participants with cognitive load (i.e., challenged them with increasing attention demands and decision making during shooting). Such a negative relationship between demand and alpha power provides a form of concurrent validation for the notion reported above that higher alpha levels are associated with cortical relaxation. However, studies on the relationship between physiological arousal, emotions, stages of brain activity, mental representations, and performance quality must be designed to investigate how
mental frame tools can affect or alter performance systematically in case of physiological activation. Additional studies must focus on the question of how mental frames influence the quality of emotions, and to what extent the quality of emotions on performance (see Fig. 1). There is a need for experimental research to find out how strong performance is influenced by the type and quality of emotions, and to learn about the functional granularity of cognition–emotion units in the production of performance.

**Management of brain processes to enhance performance**

**Affective neuroscience — brain processes during emotion.** Based on fundamental neuroscience concepts provided by Bear et al. (2001), Hatfield et al. (2004) recently articulated a model with which they speculated on the neural structures involved in a system or circuit, which mediate the psychological and physiological responses to stress and its impact on motor performance. Generally, the stress response is orchestrated by the limbic system, but the central components of this functional circuit are the amygdalae, small almond-shaped structures located bilaterally, and anterior to the hippocampi on the inferior and medial aspect of the temporal lobes. Multiple sensory pathways converge in the basal lateral nuclei of the amygdalae so that environmental events are immediately processed (Pare et al., 2004). Depending on the valence of the stimuli, the lateral nuclei then communicate with the central nucleus in each amygdala and subsequent connections travel to critical forebrain, brainstem, autonomic, and endocrine structures that mediate the expression of emotion. Specifically, there are interconnections from the central nuclei to the: (1) hypothalamus, which results in sympathetic arousal and stimulation of stress hormones via the hypothalamic–pituitary–adrenal (HPA) axis; (2) the periaqueductal gray, which results in motor responses; and (3) the cingulate cortex, which results in additional cortico-cortical communication with neocortical association regions such as the temporo-parietal regions. Additionally, interconnections to pontine nuclei in the reticular formation result in an increase in overall arousal. In this manner orchestrated sequelae occur in response to a stressful environment, which collectively, can change the performer’s mental and physical state in a profound manner. For example, heart rate and cortisol levels rise, as does muscle tension, and the performer may concomitantly experience excessive self-talk and “too much thinking” such that his/her attention is compromised and the execution of normally automated psychomotor skills, such as marksmanship, become explicitly managed—timings and coordination are then altered and likely reduced in quality while attention shrinks. In support of the “overthinking” hypothesis, Hung et al. (2005) provided psychophysiological evidence of increased networking between the left temporal region and the motor planning regions of the brain, by assessment of T3-Fz alpha EEG coherence levels, when study participants were asked to perform a dart-throwing task under the pressure of social evaluation. Relative to a nonstress control condition the increased “traffic” in the brain was accompanied by heightened reports of state anxiety and reductions in self-reported confidence levels. As expected, accuracy of performance or visuo-motor coordination was also reduced. However, how these changes were associated with mental representational changes was not studied, but can now add to bridging the understanding of covert and overt behaviors.

In light of the mental and physical change alterations that accrue, the activation of the amygdalae serves as a pivotal event in the manifestation of stress, and the control of activity in the amygdalae would exact a powerful influence on the performer’s mental and physical state. Beyond the structures and processes outlined by Bear et al. (2001), Hatfield et al. (2006) also argued that a critical component of the circuitry underlying the neurobiology of fear is the executive control over limbic function and subcortical emotional circuits, which is housed anatomically in the frontal regions of the forebrain. Importantly, the anterior cortical regions have extensive anatomical connections with several subcortical limbic structures implicated in emotional behavior, particularly the amygdala (Davidson, 2002, 2004).
Davidson and colleagues have generated a significant body of literature that clearly shows a positive association between left frontal activation and positive affect while relative right activation is associated with negative affect (Tomarken et al., 1992; Davidson, 1998). Although the lateralization of frontal activation is robustly related to the valence of emotion, recent evidence points to a more fundamental association such that left frontal activation mediates approach-oriented behavior while right frontal activation is associated with avoidance or withdrawal-oriented behavior (Davidson, 2004).

For example, left frontal activation is manifested during hostile behavior, which is certainly not a positive affective state, but most definitely involves approach toward an intended target. Whether positive in nature, approach-oriented, or a combination of the two dimensions, it would appear that such a neurobiological state would be highly adaptive for the performer who must control his/her emotional level while actively engaged with challenging tasks while under great pressure. Because EEG alpha power is inversely related to activation (i.e., relaxation), R minus L alpha power (i.e., Log right frontal alpha power — Log left frontal alpha power), when positive, implies greater relaxation in the right region or, in other words, a state of left frontal activation. Hence, positive numbers for this metric imply left activation and executive control over emotion structures and processes. This state involves a coherent utilization of mental representations presented in Table 1 (level III), which correspond perfectly to self-regulation (level IV), and allows smooth motor coordination, information processing, decision making, and awareness to cues, which trigger changes in both cognitive and motor systems. Conversely, a negative value implies greater relaxation in the left region and a lack of executive control over limbic circuits, thus resulting in collapse in both III and IV levels (see Table 1), and probably also in level II and I. Therefore, this EEG metric provides an opportune target for neurofeedback training to enable a heightened level of executive control over emotional response and task engagement during stressful and challenging tasks.

Importantly, there is evidence that this circuit (as quantified by this metric) can be controlled through augmented feedback training involving learned control over the activation of the frontal region of the brain. The key to control this disruptive chain of events, which would be especially important for those prone to anxiety, is to attain command of the frontal-limbic circuit and maintain appropriate mental representation functioning. Recent neurofeedback studies (Allen et al., 2001) provide strong evidence that frontal control over responsivity to fear-eliciting stimuli can be learned with neurofeedback training. Fortunately, a convenient frontal asymmetry metric can index relative frontal activation such that positive scores indicate relative left activation while negative scores indicate relative right activation. Such a metric offers a pivotal candidate or powerful target for neurofeedback training to achieve control over a full cascade of mental and physical events during intense emotional challenge. The goal of such an intervention would be for the performer to acquire systematic control over the emotional brain circuit, and to elicit it automatically so as to facilitate learning and maintain performance under the stress of competition.

Finally, the principle of specificity mandates that there is a need to assess the efficacy of neurofeedback within the context of military/dynamic challenge settings. That is, training must be similar to field maneuvers. Thus, how can we get expert shooters to progress faster? We can improve the essence of attention and emotion regulation by learning control over critical brain processes.

Pressure-induced performance failure

According to the conceptual framework presented here, the mental representational schema must be distorted in a way that task-irrelevant cues will be associated with relevant cues, and interfere with motor control. This interference can be detected by both distorted mental representations and “noisy” activation of the cortical system — allowing us to understand the underlying mechanism of choking under pressure.
For highly motoric tasks, according to explicit monitoring theory, the mechanisms underlying pressure-induced performance failure result from pressure shifting attention to the details of skill execution (Baumeister, 1984). This attention-to-skill execution disrupts the automaticity of well-learned skills, resulting in performance failure. Such explicit monitoring may be associated with excessive or unnecessary cortico-cortical communication, thus introducing “noise” into the motor planning regions of the brain resulting in degraded quality of performance. The foundations for the explicit monitoring theory are anchored in both self-awareness and skill-acquisition literature (Hardy et al., 1996; Lewis and Linder, 1997). The self-awareness literature (e.g., Baumeister and Showers, 1986) supports the notion that situational factors such as audience presence, ego-relevance, competition, and reward/punishment contingency can induce inward shifts of attentional focus. The argument linking pressure to self-focus draws on the idea that under pressure, the importance of the task becomes more salient. In order to ensure correctness of execution, more attention is given to monitoring the processes of performance (Baumeister, 1984; Lewis and Linder, 1997). It is this monitoring of skill execution that ultimately leads to performance failure in well-learned skills. Baumeister (1984) suggested that the increased self-focus caused by pressure leads to a disruption in the automatic nature of skill execution resulting in performance breakdown. A number of studies have found support indicating that increased attention to the details of a well-learned movement leads to performance breakdown (e.g., Beilock and Carr, 2001; Beilock et al., 2002, 2004). However, taking into consideration performers’ skill level, and measuring cortical activity with mental representation simultaneously will allow one to conclude whether performance changes or maintenance (in some cases facilitation) is due to shifting attention inwards and onto task details or to external interfering emotional–cognitive elements.

The specific mechanism underlying breakdown in automaticity is offered by Masters’ (1992) reinvestment hypothesis. Masters hypothesized that under stress, increased self-focus causes expert performers to reinvest declarative or explicit knowledge learned during earlier stages of skill acquisition (Gray, 2004; Mullen et al., 2005). This reinvestment of explicit knowledge leads to the automatic control structures that normally run uninterrupted to be dechunked, resulting in smaller sequences of independent units, which must be run and activated separately (Beilock and Carr, 2001). Once the control structure has been broken down, the process of activating and running each independent unit not only slows the performance, but also increases the likelihood of errors at each transition between the units (Beilock and Carr, 2001; Beilock and Gray, 2007). The breakdown in the automatic control structure results in the return to novice control strategies seen early in skill acquisition. If this is the underlying process that accounts for coordination breakdown, then mental representations must show it in the form of structure change. The new method (see Fig. 1 and Table 1; Schack, 2004a, b; Schack and Mechsner, 2006) must be implemented to show how mental representations change under pressure in relation to skill level and task characteristics; evidence that does not exist today.

**Summary**

A conceptual framework, which offers an integrative approach to study the underlying mechanisms of mental, emotional, and motor operations under neutral and pressure condition was developed. The structural components of human performance, such as emotional processes, cognitive processes and structures, motor processes, and the neurophysiological basis of these structural components (i.e., activation of cortical areas) have been integrated into a holistic framework that enables a better understanding of human performance, and allows generating applications that share scientific validity.

The conceptual framework consists of four levels, each with a designated function of mental control, mental representations, sensorimotor representations, and sensorimotor control. Once performance suffers under pressure, all structures
remain stable, but the mental control level alters as it cannot meet the environmental or inner requirements of the task’s demands. Mental control (self-regulation) breaks down because the performer lacks the sufficient strategies required for coping under external and/or stressful factors. Within this conceptual framework, motions are functionally adaptive and direct behavior. Positive and negative emotions can have a facilitative or debilitative effect on cognitive performance, depending on the nature of the task.

The model places an important role to the process of situational appraisal and evoking emotions. At this stage decision making and intention to reach specific action and action plans are created, and mental-control processing runs to a module, which is responsible for action execution. This module is linked to the level of sensorimotor control (see Fig. 1), and includes all motor components, which are necessary for production of goal-directed action effects. Once the action effects are not congruent to the intended action effects, the appraisal system “reads” an insufficient action, and evokes negative emotions. In some cases the control must consist of action strategies, such as control of attention, control of emotion, or motivational control in order to stabilize the motor action. Once the performer lacks such strategies, he/she may choke. Thus, one important link between emotion and information storage is caused by the representation of emotionally induced action effects in long-term memory. From this point of view emotions are a part of information storage in general.

The stronger the activation of particular emotional nodes are, the greater the mood-congruent effects. When emotions are strongly activated, emotion-congruent constructs (e.g., concepts, words, themes, rules of inference) become primed and available for use bringing into readiness certain perceptual categories, themes, or ways of interpreting the world congruent with current emotional states. Consequently, when athletes imagine positive (performance supporting) emotions while preparing for competition, they activate relevant knowledge that lead to emotion-directed forms of imagery, which focus their attention. Failing to perform well under pressure may be linked to both emotion state and the failure to utilize appropriate coping strategies.

Emotions operate as somatic markers by helping to consider or eliminate certain options, and increasing the accuracy of decision making. The model proposed in Fig. 1 illustrates the interaction between emotion, judgment, and decision making. The appraisal of a particular situation is based on different memory traces. In turn, emotions influence the judgments about situations both directly and indirectly. The direct influence is based on the development of different types of motivation, which result in appraisal-based emotions. The indirect influence has to do with the informational quality of emotions, and is a reference point for decision making and judgments. Thus, one may decide more holistically, or nonanalytically, in case of positive mood. From this point of view, the direct influence of emotions has to do with the content of decision making, especially the number and quality of motivation, while the indirect influence of emotions is defined by the type of decision making (holistic vs. analytic mode of decision making). Positive mood initiates a holistic mode of decision making, while negative mood triggers a more analytic mode in decision making and mental control.

As one can notice in the model (see Table 1), basic regulations are required to process information and for action control. They take place at the lower sensorimotor levels, and have to do with the use of basic routines and sensorimotor representation structures. At the level of mental control, one generates valid plans and controls attention and emotions in case of unexpected external events in the action organization. Basic regulation must generate and implement such tools like routines at the lower level, and implement mental control strategies at the mental control level.

The model consists of the assumption that the interruption of activated performance plans and the increasing inability to subordinate the action performance to an action program are emotionally negatively attributed. Particularly, through the collapse of solid connections within the system of mental control the inner speech loses the function of an instrument of action control (see Schack, 1997). The result is a functional damage
of mental control: a mental control deficit due to inappropriate action plan, the deficient availability of action control strategies or a collapse of the control anticipation.

The concept presented in Fig. 1 allows studying the cognitive patterns related to different tasks, stress sources (pressure-information), and related emotions. The patterns concerning the “pressure” information representation and the relationship between “pressure” information and emotions are the reference point for appraisal in real situations. These links allow predicting emotional states, and modifying the reference points (i.e., benchmarks) of the appraisal systems, and measure the link between the representation of threatening situations and the representation of action organization in these situations. The goal is to strengthen the productive links between the representation of the situation and the representation of the action (Nitsch, 2004; Schack and Hackfort, 2007). In the sport domain, one must capture the mental representations of situational components, such as the representation of the team structure, or the representation of the environmental conditions of a specific competition. Furthermore, one must know what type of activities athletes have represented to cope with situations that vary in many respects. Finally, it is essential to measure the types of event representations and action representations, and look for the fit between these two representation types. A misfit between these representations may lead to emotions of stress and anxiety. From this perspective, looking at the emotional process itself is insufficient, without measuring the cognitive benchmarks (especially event and action representations) of the appraisal process, which constitutes the development of emotions in action.

For understanding the components of performance and their interaction, it is necessary to find out the relationship between skill level, cortical activation, and order formation in long-term memory. To learn more about these interactions and networks, one must combine the neurophysiological methods, like EEG-coherence measures (Schack, 1999; Deeny et al., 2003), and methods for measuring the structure of mental representation. The mental representations of experts were highly differentiated from those of novices, and were more strongly function oriented than the novices’ representations. The simultaneous neurophysiological findings indicated that experts’ cognitive activation of movement representations is accompanied by activation of several cortical areas. These patterns of activation provide a glimpse of the network of neurophysiological areas with a high mental economy and a high stability. It seems that there are two different functions of activation concerning the time-related steering of movements and concerning space-oriented aspects of movement representations. A failure to obtain a stable activation of separate areas in movement representation was evident. According to the conceptual framework presented here, the mental representational schema must be distorted in a way that task-irrelevant cues will be associated with relevant cues, and interfere with motor control. This interference can be detected by both distorted mental representations and “noisy” activation of the cortical system allowing the detection of the underlying mechanism of choking under pressure. The implementation of a research agenda, which takes into account all the overt and covert behaviors simultaneously, can clarify the functionality of the model presented here.

References


