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Review

A neuroscience approach to optimizing brain resources for human performance in extreme environments☆

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ABSTRACT

Extreme environments requiring optimal cognitive and behavioral performance occur in a wide variety of situations ranging from complex combat operations to elite athletic competitions. Although a large literature characterizes psychological and other aspects of individual differences in performances in extreme environments, virtually nothing is known about the underlying neural basis for these differences. This review summarizes the cognitive, emotional, and behavioral consequences of exposure to extreme environments, discusses predictors of performance, and builds a case for the use of neuroscience approaches to quantify and understand optimal cognitive and behavioral performance.

Extreme environments are defined as an external context that exposes individuals to demanding psychological and/or physical conditions, and which may have profound effects on cognitive and behavioral performance. Examples of these types of environments include combat situations, Olympic-level competition, and expeditions in extreme cold, at high altitudes, or in space. Optimal performance is defined as the degree to which individuals achieve a desired outcome when completing goal-oriented tasks. It is hypothesized that individual variability with respect to optimal performance in extreme environments depends on a well "contextualized" internal body state that is associated with an appropriate potential to act. This hypothesis can be translated into an experimental approach that may be useful for quantifying the degree to which individuals are particularly suited to performing optimally in demanding environments.

Contents

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1. Introduction

Extreme environments are characterized as those situations which place a high demand on the physiological, affective, cognitive, and/or social processing resources of the individual. Extreme environments strongly perturb the body and mind, which in turn initiate complex cognitive and affective response strategies. Performance in different types of extreme environments may share some optimal characteristics, but specific environments can also have unique demand characteristics. For example, exposure to the cold and isolated environment of an Antarctic expedition may result in extreme social and sensory deprivation, whereas exposure to military combat operations may entail extreme sensory overload. It is clear that there are many different types of extreme environments or situations, but it is less clear that an individual's cognitive and affective responses are as varied as the variation in different types of extreme environments (Fig. 1).

There is substantial evidence from studies of expedition members, military operators, and elite and extreme athletes that exposure to extreme situations, i.e. conditions that impose a significant cognitive, emotional, and/or physical stress on the individual, has profound effects on performance. Optimal performance can be defined as the degree to which individuals achieve a desired outcome when completing goal-oriented tasks. It is important to note that in an environment that does not impose significant physical or psychological stresses, a task may not be considered demanding and can be performed adequately by individuals with average abilities. In contrast, an individual may have great difficult in performing the same task in an extreme environment. For example, an individual may be quite a good marksman at a practice shooting range, yet not be able to optimally perform as a marksman in combat. Another individual may be excellent at performing an athletic task in practice, but not able to perform to a similar degree in an international competition. An extreme environment may make the completion of specific tasks much more challenging, and thus fewer individuals may be capable of optimally performing the specific tasks. Here we aim to (1) summarize our current understanding of the effects of exposure

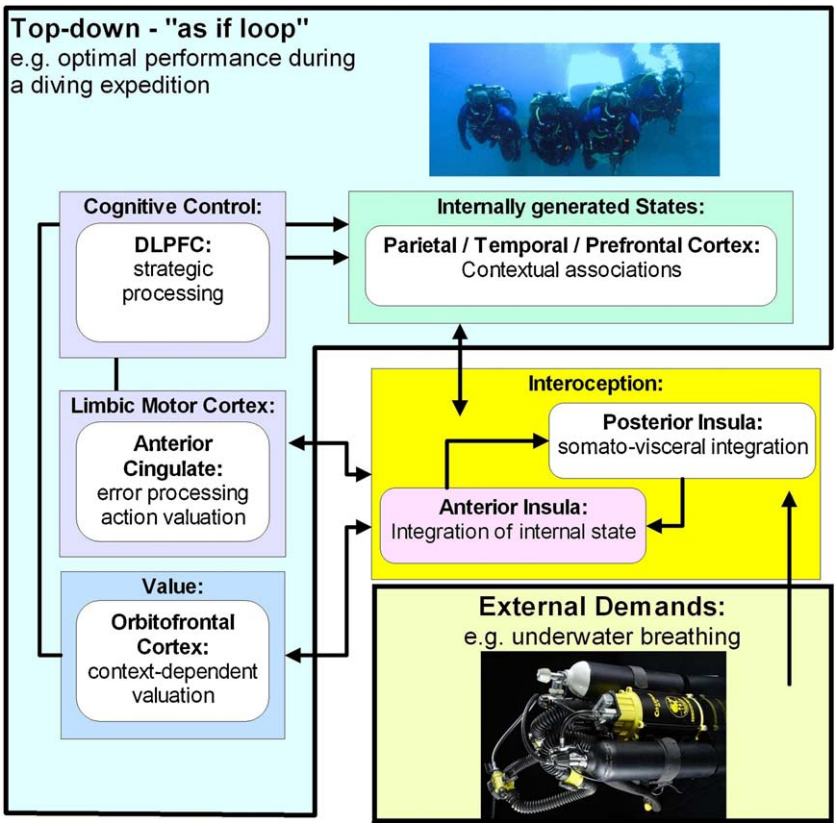

Fig. 1. The extended limbic circuitry and the top-down control circuitry involved in optimal performance in extreme environments. The individual is thought to maintain a homeostatic steady state in the presence of top-down performance demands and bottom up physiological challenges to the body. The anterior insula is critical for the integration of an internal state, which, in turn, is the association of affect to a stimulus. Optimal performance is hypothesized to occur if the peripheral challenges are optimally contextualized by top-down modulatory areas, i.e. when there is minimal discrepancy between what the top-down system is predicting the body should feels like and what the peripheral afferents signal that the body is feeling.