Understanding Stress- A Different Approach

BSE398A (Undergraduate Project) - END TERM REPORT

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STRESS AND ITS IMPACT ON OUR LIVES

Stress is a state of physical, mental, and emotional tension. It is a defense mechanism of the body against dangerous situations, built into us by the transfer of genetic material from our hunter-gatherer ancestors. Common stressors for our ancestors included things like the sudden appearance of a predator in front of them. In such situations, the body puts on top priority- escape from the current dangerous situation, and other trivial functions are temporally put on low priority. This reaction is beneficial for the species in the long run, and thus evolution has selected it.

However, in the past few centuries, our lifestyle has changed so drastically that evolution wasn't able to cope with it, and we have ended up in a very bad spot healthwise on our species' timeline. The modern-day stressors are very different from ancient ones and thus need a different response mechanism. However, we still have a response mechanism meant for the ancient stressors, and this causes a lot of problems. Our current lifestyle has left us in a state of constant tension and anxiety. Stress was never meant to be chronic, but now it is, in most of our lives. Chronic stress is a major contributor to many mental problems and lifestyle diseases including heart diseases. Given that the most common cause of death today worldwide is heart-related diseases [1], we can not ignore stress any longer in our lives.

NEURAL CORRELATES OF STRESS

Cortisol and DHEA

Cortisol and DHEA (Dehydroepiandrosterone) are two important neuromodulators associated with stress. They are co-regulated compounds and show a delayed reaction to stressors. Upon activation of the HPA (Hypothalamus Pituitary Adrenal) axis due to stressor, the hypothalamus secretes CRH (Corticotropin-Releasing Hormone), which upon reaching the pituitary gland, induces the release of ACTH (Adrenocorticotropic Hormone) into the bloodstream. This ACTH reaches the adrenal glands above the kidneys and causes the release of both cortisol and DHEA. Research has shown that long-term high levels of cortisol affect the immune, cognitive and metabolic machinery of the body in a negative way. In many cases, DHEA has been found to regulate the body's response to stressors by opposing cortisol action. [2]

Epinephrine and Norepinephrine

Epinephrine and Norepinephrine are catecholamines (monoamine neurotransmitters). They are the molecules that cause a quick reaction of the body against stressors. They are the molecules behind the fright or flight response of the body against an acute stressor. Norepinephrine is released by the adrenal glands into the bloodstream as a hormone. It is also released by noradrenergic neurons in the sympathetic and central nervous systems. Epinephrine is produced mainly by the adrenal glands.

Macroscopic Circuits

Neurocognitive Systems, which are sets of parts of the brain that have a similar function and act together. They include the SN (Salience Network) and ECN (Executive Control Network). The Salience Network is the network responsible for reflex and habitual activities, and regulation of various systems. It is the system, which requires less manual attention, but is faster. It consists of the amygdala, thalamus, hypothalamus, and midbrain. The Executive Control Network is the network responsible for higher cognitive tasks, memory functions, and attention. It is the system, responsible for cautious, manual decisions, and is functionally slow. It consists of the dorsolateral and dorsomedial prefrontal cortex, frontal eye fields, etc.

Upon action of the stressor, catecholaminergic responses are the first ones to act. Salience Network takes control at this stage. They are followed by non-genomic corticosteroid effects. ECN begins coming up with SN at this stage. Then, the genomic corticosteroid effects follow, which last till late after the stressor has been overcome. Now, again ECN control has taken over. [3]

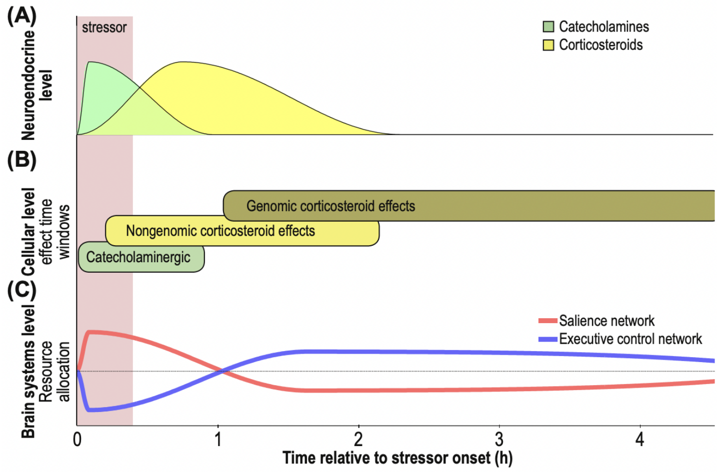

Fig 1: Time dependence of different stress responses of the body [3].

DECISION-MAKING TASKS AND THEIR IMPORTANCE

Decision Making is a process in which you have to take different inputs from the surroundings, weigh the available choices, and choose the correct one out of them. For example, a simple decision like what to wear can also involve complex computations, taking in various types of inputs/information (such as what is the event, how is the weather, etc.), weighing the available choices (the available clothes), and making the decision. Decision Making Tasks are designed with the purpose of getting a better understanding of the individual's brain by analyzing the choices he makes in a given task.
Most of our day-to-day actions/thoughts fall in the category of decision making, and thus, Decision Making Tasks are more directly linked to our behavior, compared to other, say Memory Tasks. Thus, they are important tools for getting insight into the brain and its functioning. A few Examples of Decision Making tasks are- BART (Balloon Analog Risk Taking), Foraging Task, 2/4 armed bandit task.

FORAGING TASK

The foraging task is a simple task in which a person has to maximize his fruit output, by making a choice between exploration and exploitation, as the output of the current bush diminishes with time. Being too explorative implies that the person is not utilizing a given bush optimally, and wasting more time looking for other bushes, whereas being too exploitative means the person is spending more time on a bush than optimal, and thus, obtaining lesser outputs.
Our ancestors were hunter-gatherers for a long time and faced exploration-exploitation dilemmas frequently. They had to decide on when to leave a given foraging area and seek other new ones. The correctness of this decision was crucial for their survival. We are their descendants and hence have similar behavioral traits hardwired in us. Thus, the ancestral importance of foraging is an advantage of it against other similar tasks.
There is evidence that higher stress levels are associated with over-exploitative behavior in foraging [4]. It is theorized that this could be due to the person having a pessimistic opinion about the unknowns (Bushes out of view in case of foraging). This negative opinion makes the person stay on a given bush for longer than optimal. This also enforces a vicious cycle in which due to the person exploring less, he gets lesser opportunity to correct his opinion of the surroundings.
Now that we know what decision-making tasks are, and an example in particular- foraging, we can look into a technique of measuring brain activity, and its relation with decision-making tasks.

ELECTROENCEPHALOGRAPHY

Electroencephalography (EEG) is a simple, easy, and safe way to detect brain activity. It includes the placement of multiple electrodes on the scalp of the individual, which detects the voltages due to the neuronal currents in the brain. EEG offers excellent temporal resolution, of the order of milliseconds, which is extremely useful when measuring brain activity while performing a task such as foraging. [5] [6]
The excellent temporal resolution of EEG allows for breaking it into various components on the time axis, such as the P300 (positive deflection in 300ms-500ms time range post-stimulus) and N200 (negative deflection in 200ms-350ms time range post-stimulus). In the BART task, exploratory behavior is associated with higher amplitude in the P300 component of the EEG [7]. This link between EEG and decision-making can be better understood by understanding the LC-NE (Locus Coeruleus-Norepinephrine) system.

THE LC-NE SYSTEM

LC (Locus Coeruleus) is a part of the brain stem, crucial for the body's arousal, attention and stress response. It is a major source of Norepinephrine for the brain and thus, understanding the LC-NE system is crucial for understanding stress. The LC-NE system works in either of two modes- phasic, or tonic (phasic release of NE or tonic release of NE). Phasic release of NE is associated with a high concentration on a given task (Yerkes-Dodson Curve) [8], whereas tonic release is associated with more distractibility. Thus, phasic activity is helpful when a person needs to focus on just one task, such as giving an exam. Tonic activity is helpful when the person needs to be aware of the surroundings in general, such as hunting in a forest.

CONCLUSION

We have established a link between decision making and stress - more stress leads to over-exploitative behavior (person has got a confident pessimistic opinion of unknowns), and between EEG and decision making - more

P300 amplitude is linked with more exploratory behavior. This helps us establish a connection between EEG and stress - that the post-stimulus P300 component of EEG of stressed individuals will be on average less in amplitude compared with unstressed individuals.
It is important to note here, that exploratory behavior means recomputing the weights of the available choices using the information available, rather than straightaway choosing the option of exploring the unknown.

The LC-NE system is the reason behind the link of Decision Making with EEG, as the phasic activity of LC-NE (which is responsible for more focus on the given task) is related directly to the P300 component of EEG. The over-exploitative nature of stressed people in decision-making tasks denotes their pessimistic opinion of the unknown and thus gives insight into how stressed individuals respond to such tasks.

Overall, my aim was to learn about stress and the bodily mechanisms behind it, but I also got to learn about Decision Making Tasks and EEG along with it, and also the relation between the three. This connection was necessary to understand different nuances of stress, which would be difficult to understand alone.

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