Sweating palms, racing heart rate, weak at the knees and butterflies in the stomach rate…If you think that we are talking about signs of falling in love, then you are WRONG. These phrases, often used to describe bodily reaction when one has a crush on someone, are also used to describe physiological response when one is under tremendous stress.

Biological response to stress

Stress is any uncomfortable "emotional experience accompanied by predictable biochemical, physiological and behavioral changes" (Baum, 1990). When the body is under stress, the homeostasis of the body is disrupted. In reaction to this, the Autonomic Nervous System (ANS) will generate an immediate response during stress. This is done through its sympathetic and parasympathetic systems. The sympathetic nervous system is responsible for producing a response to the stress stimuli, whereas the parasympathetic nervous system counteracts the response, thus controlling the duration of the response (McCorry, 2007).

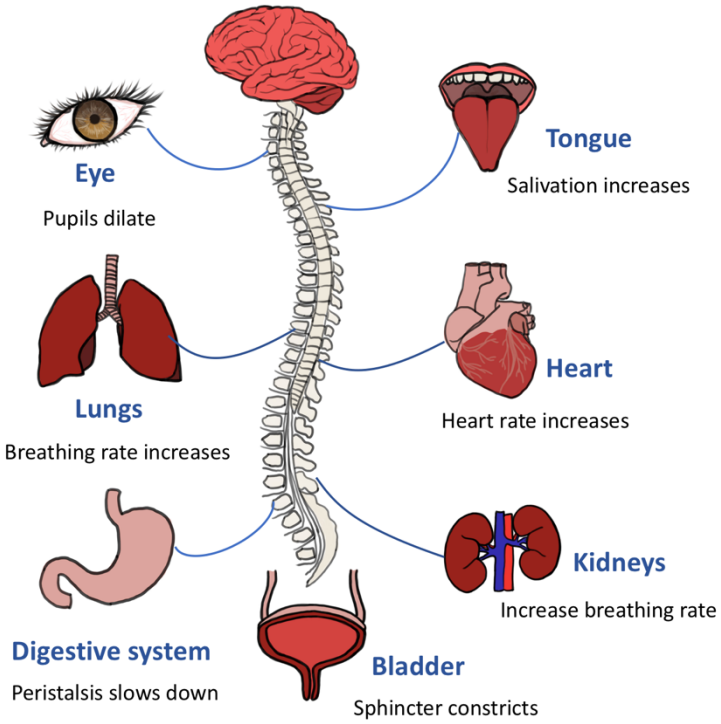

Figure 1. Diagram of effects of ANS during stress[1]

Stress stimuli come in mainly two forms, psychogenic[2] and systemic[3]. Both forms of stimuli are processed in several forebrain structures (Figure 1.), such as amygdala, the hippocampus and the hypothalamus. These structures receive inputs from subcortical and cortical regions of the brain, that are involved in higher-order sensory processing and memory. They also receive chemical signals from other structures

[1] Figure 1 was drawn by Tong Meng from Anglo-Chinese Junior College.

[2] Psychogenic stress stimuli are also known as emotional stress. Examples include anxiety and nervousness.

[3] Systemic stress stimuli are also known as physical stress. Examples include blood loss and inflammation.

involved in arousal and attention. The signals from these limbic structures are channeled downwards, allowing the downstream processing of limbic information. These limbic regions work together to stimulate the activation of the hypothalamic-pituitary-adrenocortical (HPA) axis (Ulrich-Lai & Herman, 2009).

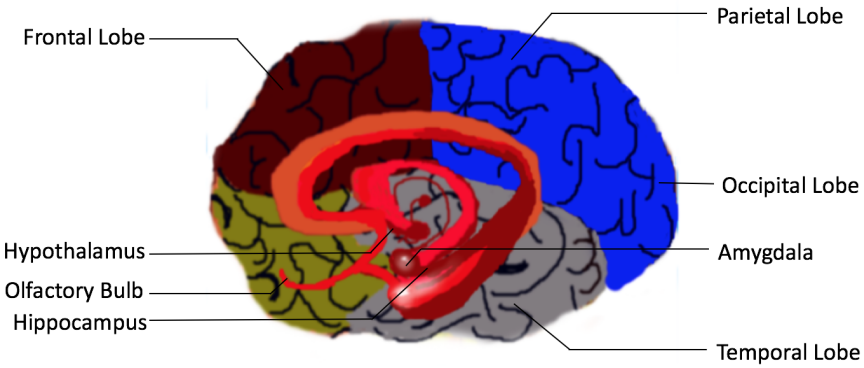

Figure 2. The Limbic System[4]

The HPA axis is the main system responsible for establishing homeostasis during stress (Stephens & Wand, 2012). In response to a stressor, the HPA axis and sympathetic nervous systems are activated. Activation of the sympathetic nervous system results in the release of adrenaline and noradrenaline from the adrenal medulla into the bloodstream. This results in an increase in a person's blood pressure, heart rate and energy mobilization. This sympathetic activation results in the commonly known 'fight or flight' response, which was first coined by Walter Cannon (1871-1945) in the early twentieth century. Hence, the 'fight or flight' is associated with feelings of adrenaline rush levels, heart pounding, nervousness, increased reaction time and alertness.

Responses to stress are reduced by the parasympathetic nervous system. In the parasympathetic system, post ganglionic nuclei located in or near the end organs that they innervate are activated. As parasympathetic actions are generally opposite to those of the sympathetic system, hence the signal will diminish, and the response is short-lived (Stratakis & Chrousos, 1995).

Hence, in response to stress, the sympathetic nervous system will be activated, resulting in the response of heart rate rising, breath quicken and butterflies in the stomach.

Relationship between emotion and physiological changes

The word "emotion" assimilates *ex* (out) and *movere* (to move). Referring to "strong feeling" when it first appeared in 1650s, it now encompasses any feeling. The subjective and private nature of emotions renders studying of physiological changes

[4] Figure 2. was drawn by Xiong Rui.

in the body during emotional experience the only possible way to indirectly deepen our understanding of emotions. The intricate relationship between emotions and physiological changes has been fascinating psychologists for centuries: they have been wondering emotions are the result or the cause of various physiological changes.

In the 19th century, psychologists William James (1842-1910) and Carl Lange (1834-1900) independently proposed that emotions are the result of physiological response to stimuli in the environment. This is known as James-Lange Theory of Emotions. Under this theory, when one sees a fierce bear, the adrenaline released by adrenal gland causes increase in heart rate and blood pressure, and the brain detects these physiological changes and interprets them as “fear”.

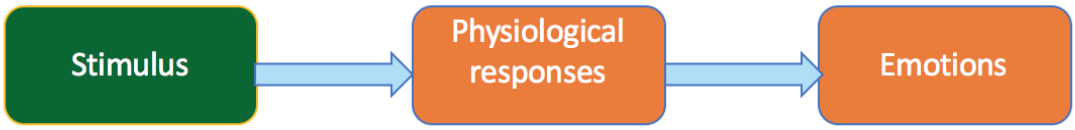

Figure 3. Illustration of James-Lange Theory of Emotions

If we agree with James-Lange theory, the problem is that sometimes we feel terrified because our heart rate increases, but other times, after intense exercise for example, our heart rate also increases but we do not feel terrified. How to explain the uniformity of the physiological responses in different emotions?

One century later, Stanley Schacter (1922-1997) and Jerome E. Singer (1934-2010) revised the James-Lange Theory of Emotions and proposed the Two-factor Theory of Emotions. According to the new theory, both physiological arousal and cognitive label are required to generate emotions, and the physiological arousal is labeled by interpretation of specific context. For example, when one sees a fierce bear, some regions in the brain, for example the thalamus, will send two signals: one to the cortex to give rise to emotions, the other to the automatic nervous system to arouse physiological response. The physiological arousal will be processed based on the person’s understanding of current situation (perhaps based on past experience) and be given a label as fear. If the reason for certain physiological arousal is unknown, the person would tend to seek cues in the environment. This is how misattribution of arousal occurs. Since our physiological response to stress and love is similar, could love be a misattribution?

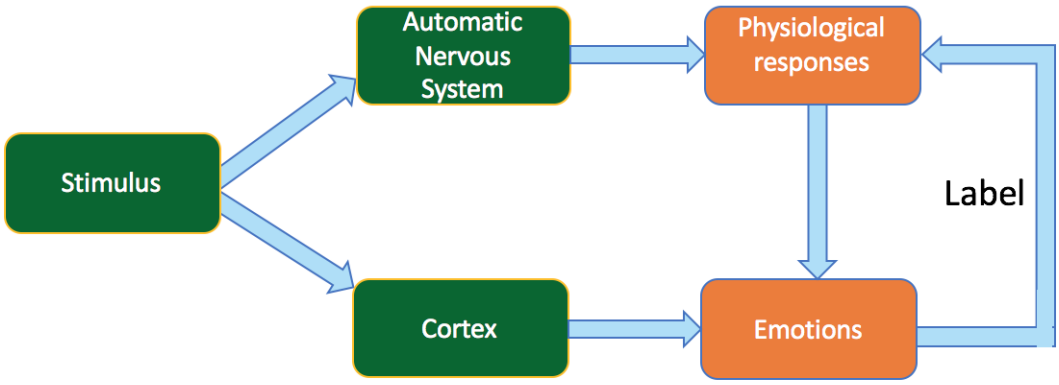

Figure 4. Illustration of Schacter and Singer's Two Factor Theory of Emotions

Arousal and Attraction

Donald Dutton and Arthur Aron (1974) conducted one of the most notable experiments to confirm that physical responses could cause an illusion of falling in love. The experiment showed that being in fight-and-flight state makes another individual seem more attractive to a person. An attractive female confederate approached male passersby on a shaky suspension bridge (the experimental group) and a sturdy bridge (the control group) respectively. Those who walked on the shaky bridge would have been forced into a fight and flight mode due to the fear of falling, while those walked on the sturdy bridge would not experience a change in mental state, i.e. would not experience arousal. After the male passersby walked across either bridge, the female confederate asked them to complete questionnaires and gave them her contact number. As it turned out, the sexual imagery score for the experimental group was higher than that for the control group. In addition, a higher ratio of participants in the experimental group called back. These results showed that the lady seemed more attractive to those who walked on the shaky bridge. Such phenomenon of misattribution of arousal is later referred to as "suspension bridge effect", named after the above experiment.

There are many other experiments that showed the same result, one of which is the roller coaster experiment. Researchers approached individuals (165 males and 135 females) who were either waiting to enter or just got off from a roller coaster ride, and showed them a photograph of an average looking, opposite-gendered individual. Participants were asked to rate the attractiveness of the person featured in the photograph. The study found that those who just got off from the ride and were sitting with a non-romantic partner found the person in the photograph more attractive, as compared to those who were waiting to begin their roller coaster ride. This phenomenon can be easily explained by the theory of misattribution: those who just exited from the roller coaster still had the residual nervous system arousal due to excitement from the ride, and they misattribute the arousal to be caused by having a crush on the individual in the picture, hence they found the person more attractive.

Towards a Scientific Understanding of Love

What the above studies and many others demonstrate is that arousal can be a basis for liking. In situation where there is a strong stimulus, our bodies react with a series of physiological responses. Emotion is an outcome of our cognitive label of these bodily responses. When we cannot recognize the source, we might misattribute such arousal as attraction towards someone. Hence, it is not surprising that love accompanied by arousal (sexual or otherwise) is stronger love than love with a lower level of arousal. That is probably why we see frequently in Shakespeare's literary works such expressions as 'love is blind and lovers cannot see', or 'love is madness'.

"Lovers and madmen have such seething brains
such shaping fantasies, that apprehend
more than cool reason ever comprehends.
The lunatic, the lover, and the poet
Are of imagination all compact."
A Midsummer Night's Dream 5:1:4-8

By unveiling the science behind love, it is hoped that we are more aware of how our emotions and relationships are formed. Knowledge of love and affect can have many real-life applications.

Online Dating

There have been many apps and websites in the business of love, including Singapore's homegrown company, LunchClick, which have local user figures that range in the high six figures. Since online dating relies highly on 'love at first sight', there are some risks of misattributing physiological responses as 'love', or attraction towards another user. The misattribution theory can improve the effectiveness of online matchmaking algorithms by monitoring and analysing users' physiological responses. Chances of success can be increased by intelligent advice on who is more likely to be the Mr/Ms Right.

Affective Computing

Looking even further, a better understanding of emotions and attractions can be applied in Affective Computing. Affective Computing proposes that we give computers the ability to recognise, express, and in some cases, 'have' emotions. The emotion models explained in the previous sections can inspire important breakthroughs in the field. With the developments in wearable technologies, it is possible to invent personal devices that can detect physiological response (arousal) when people interact with others. It may enhance self-awareness of affective state and potentially lead to more stable and healthy relationships, improving social welfare in the long run.

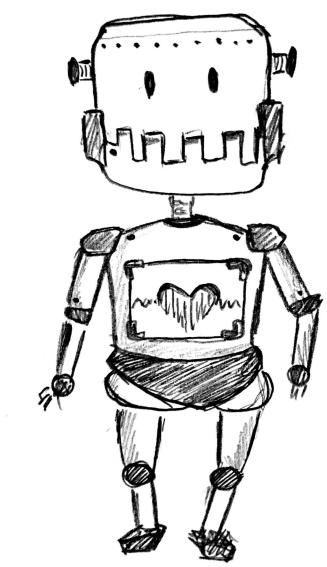

Figure 5. A robot with a heart[5]

Practical Tips

Now that you understand the theory of falling in love, you must be an expert in this field. Here are just some practical tips that might further your 'research' (yes, just for research!)

1. Think twice. Is it love, or fear? Fear is a one of the strong arousal that you might misattribute as attraction, and even love. Next time before you jump into the conclusion that you have fallen in love, consider it again, *scientifically*.

2. Places that are surprisingly 'love-inductive': gyms, jungles, roller coaster, haunted house… You may fall love more easily when physiological arousal is intense, because you mistakenly attribute your body's responses to the attraction by that someone.

3. Watch horror movies with your crush to increase your chances. While he/she is screaming with racing heartbeat, you know your moment has come. Rihanna has it right, 'We found love in a hopeless place.'

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